

<div>(21) Application No:2316182.1</div> <div>(22) Date of Filing:23.10.2023</div> <div>(30) Priority Data:<div>(31) 2022170052(32) 24.10.2022(33) JP</div></div>	<div>(51) INT CL:<div>G02B 15/14 (2006.01)G02B 15/16 (2006.01)G02B 15/20 (2006.01)</div></div> <div>(56) Documents Cited:<div>EP 3945357 A1JP 2015138178 A US 20210278642 A1US 20170192212 A1</div></div> <div>(58) Field of Search:<div>INT CL G02B Other: SEARCH - PATENT</div></div>
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(54) Title of the Invention: **Zoom lens and imaging apparatus including the same**
Abstract Title: **A zoom lens and an imaging apparatus with the zoom lens which satisfy predetermined inequalities of lens surface distances and a sum of lens thicknesses.**

(57) A zoom lens L0 includes a first positively powered lens unit L1, a second negatively powered lens unit L2 and a rear lens group of lens unit(s) LR or L3,L4,L5,L6. The first, second and rear lens units are arranged in order from an object to an image side and intervals between adjacent lens units change during zooming. The first lens unit moves toward the object side during zooming from a wide angle to a telephoto end. The second lens unit includes three or more lenses. The zoom lens satisfies predetermined inequalities of $4.3 < TD12t / TG12 < 12.0$ and $3.6 < TD1 / TD2 < 30.0$. TD12t is a distance from a lens surface closest to the object side in the first lens unit to a lens surface closest to the image side in the second lens unit at the telephoto end. TG12 is a total sum of thickness of lenses included in the first lens unit and the second lens unit. TD1,TD2 is a distance from the lens surface closest to the object side in the respective first or second lens unit to a lens surface closest to the image side in the respective first or second lens unit. All distances and the thickness are taken along the optical axis.

FIG.1

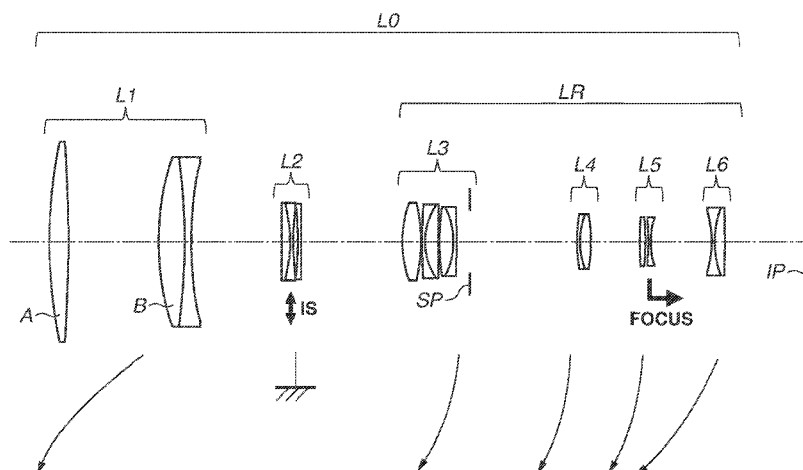


FIG.1

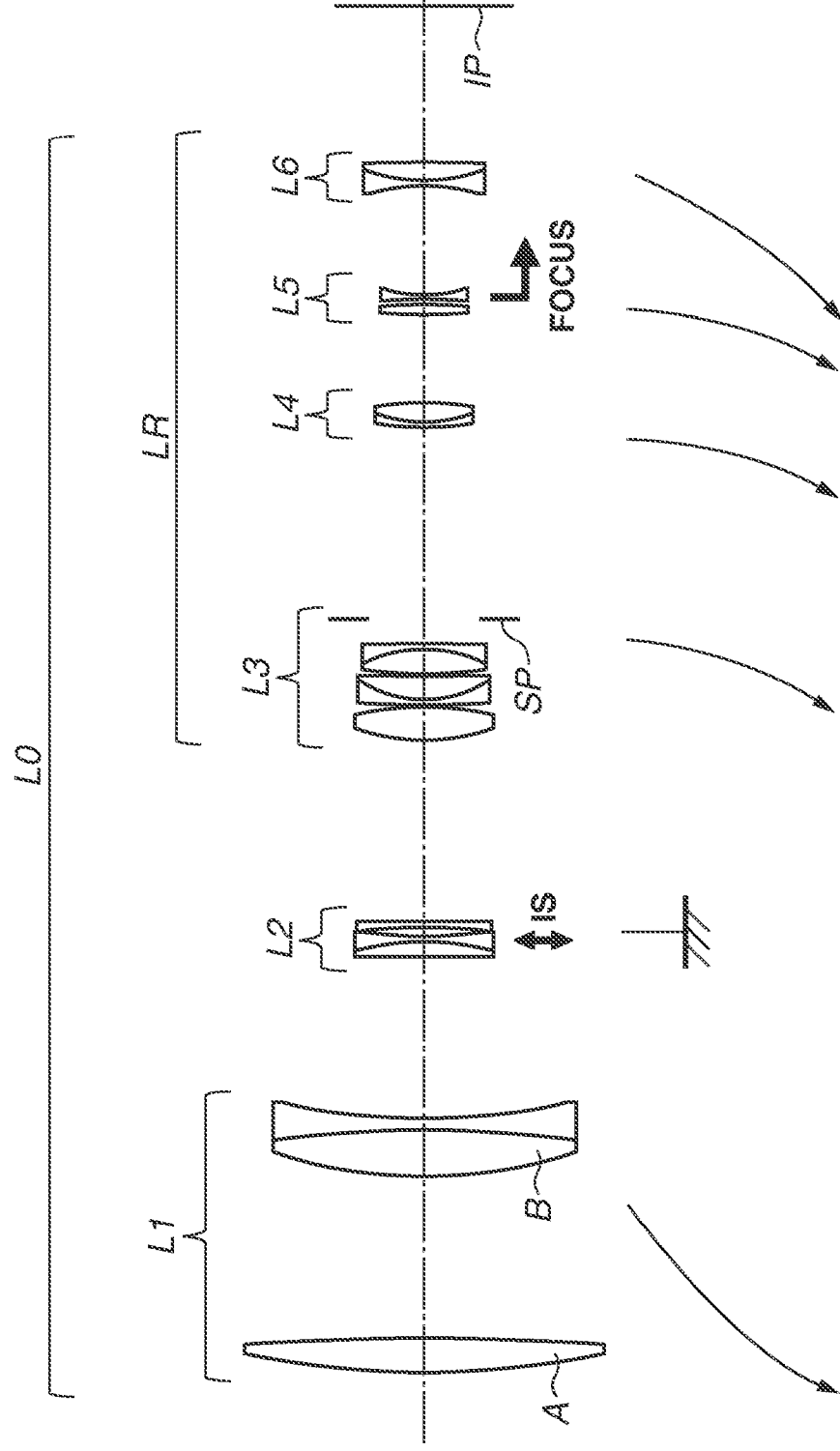


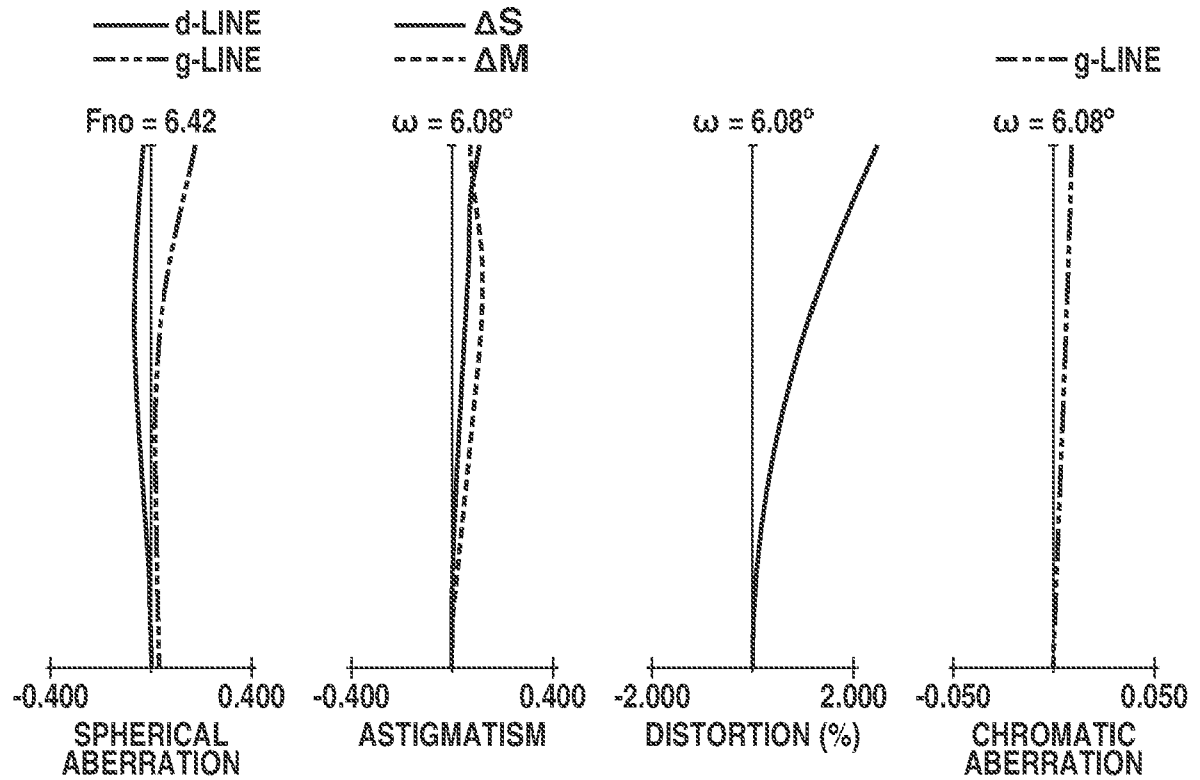
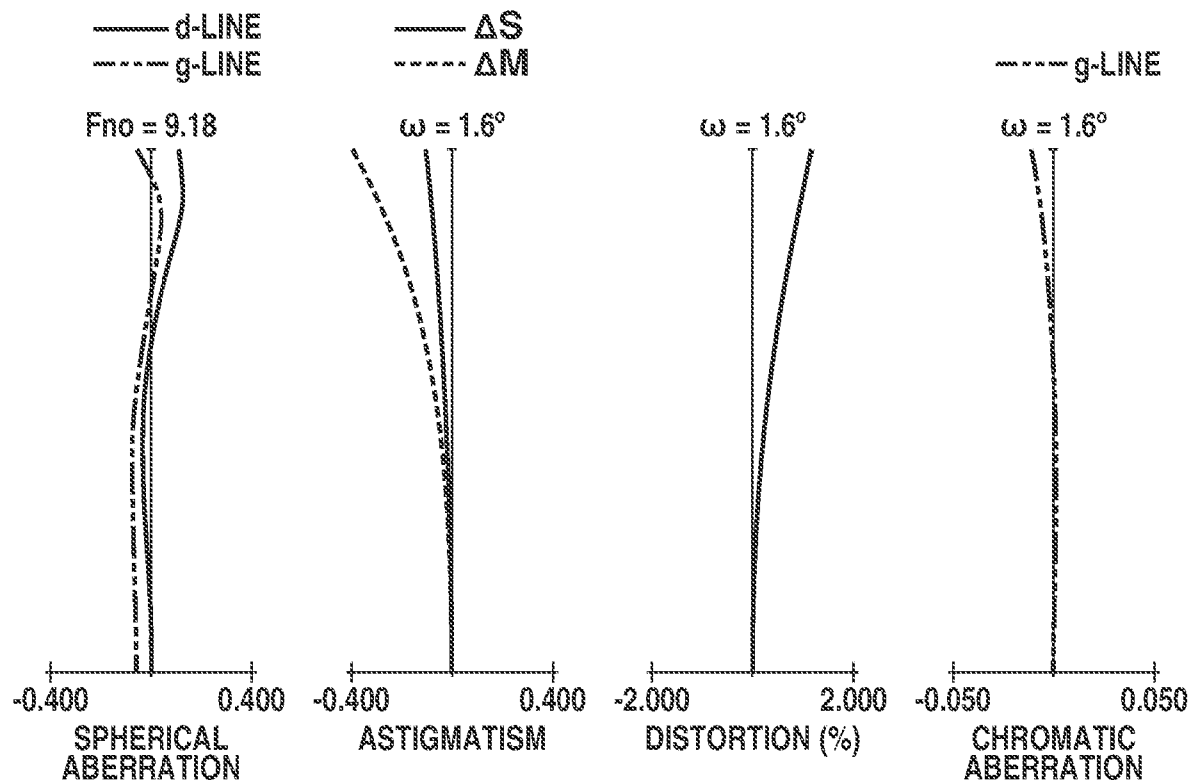
FIG.2A**FIG.2B**

FIG.3

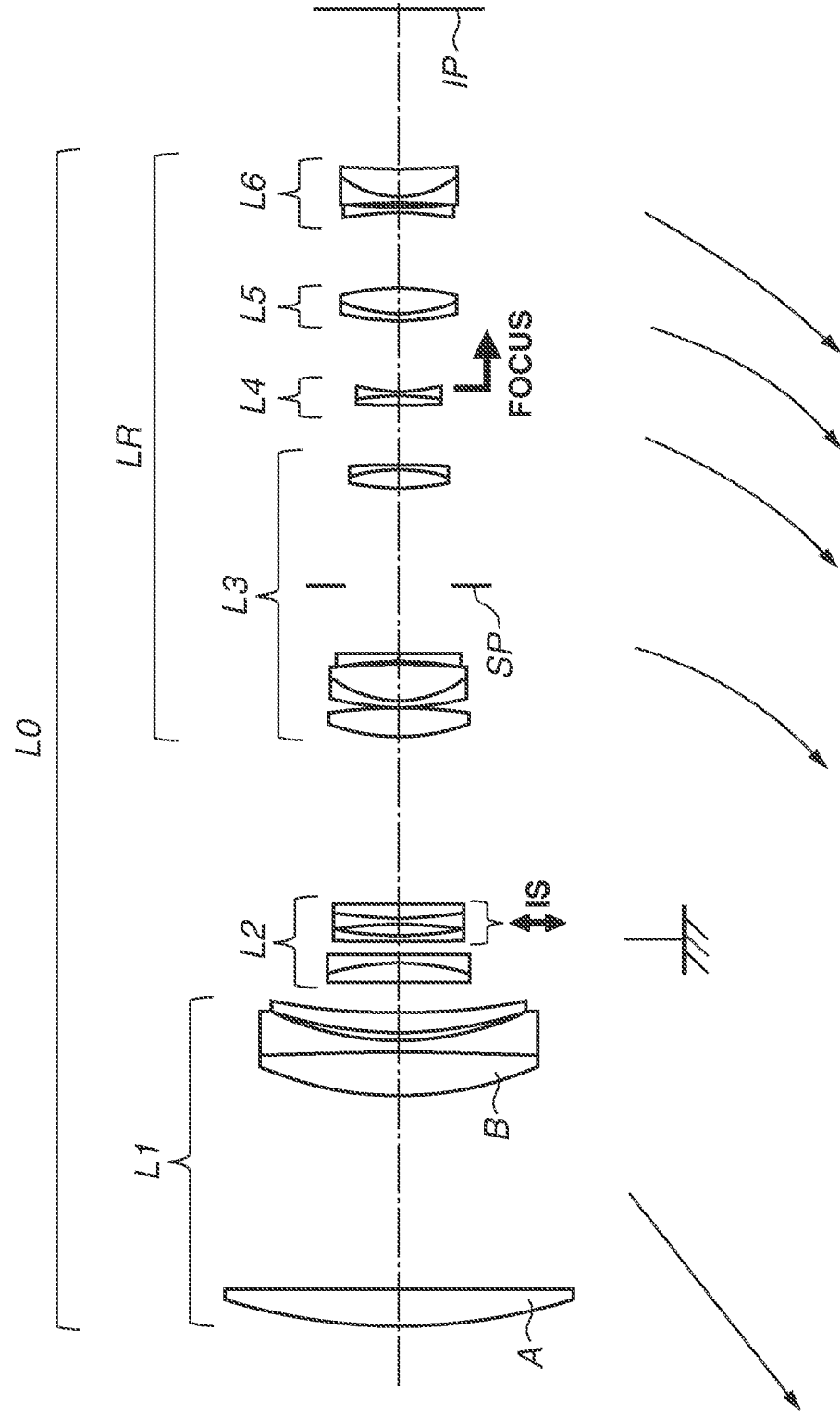


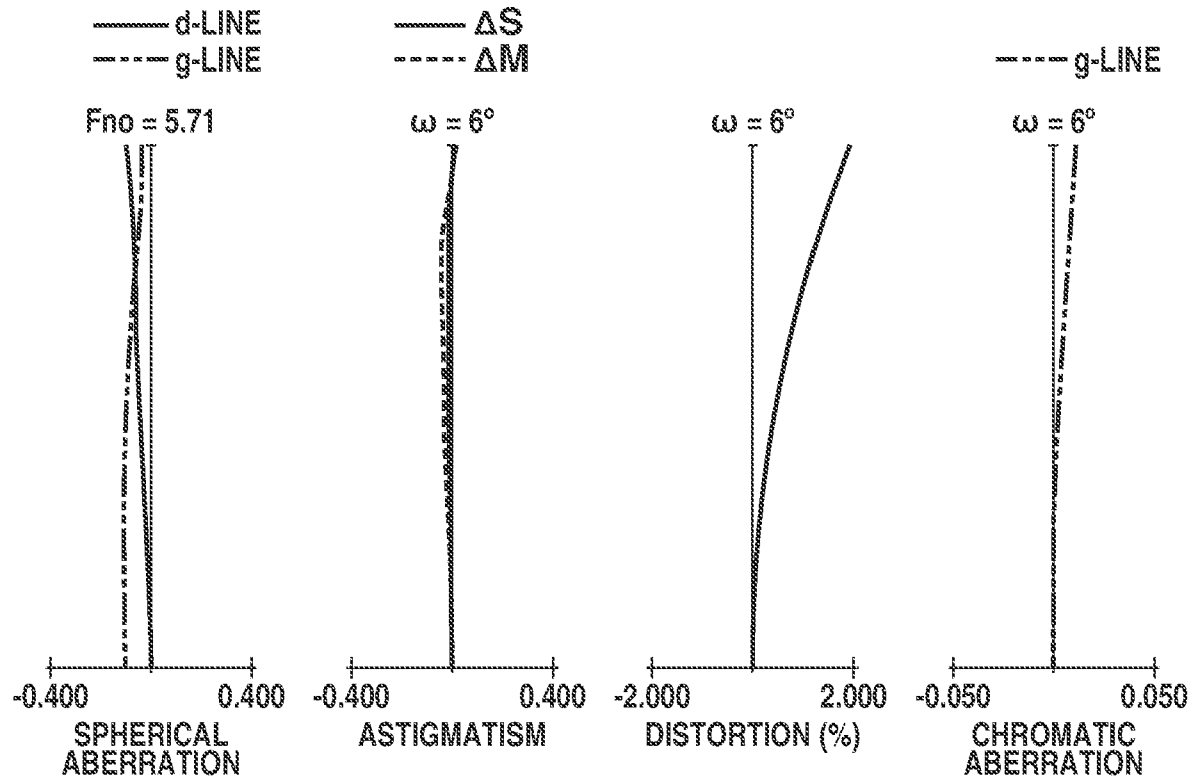
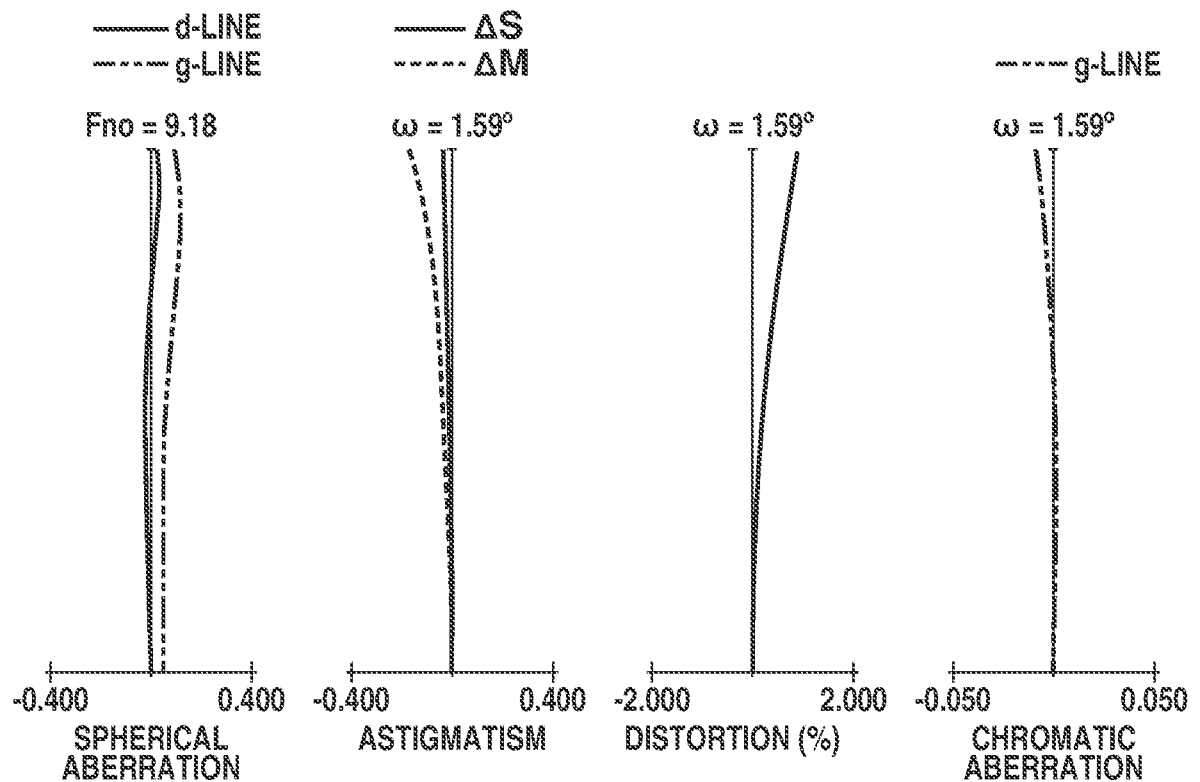
FIG.4A**FIG.4B**

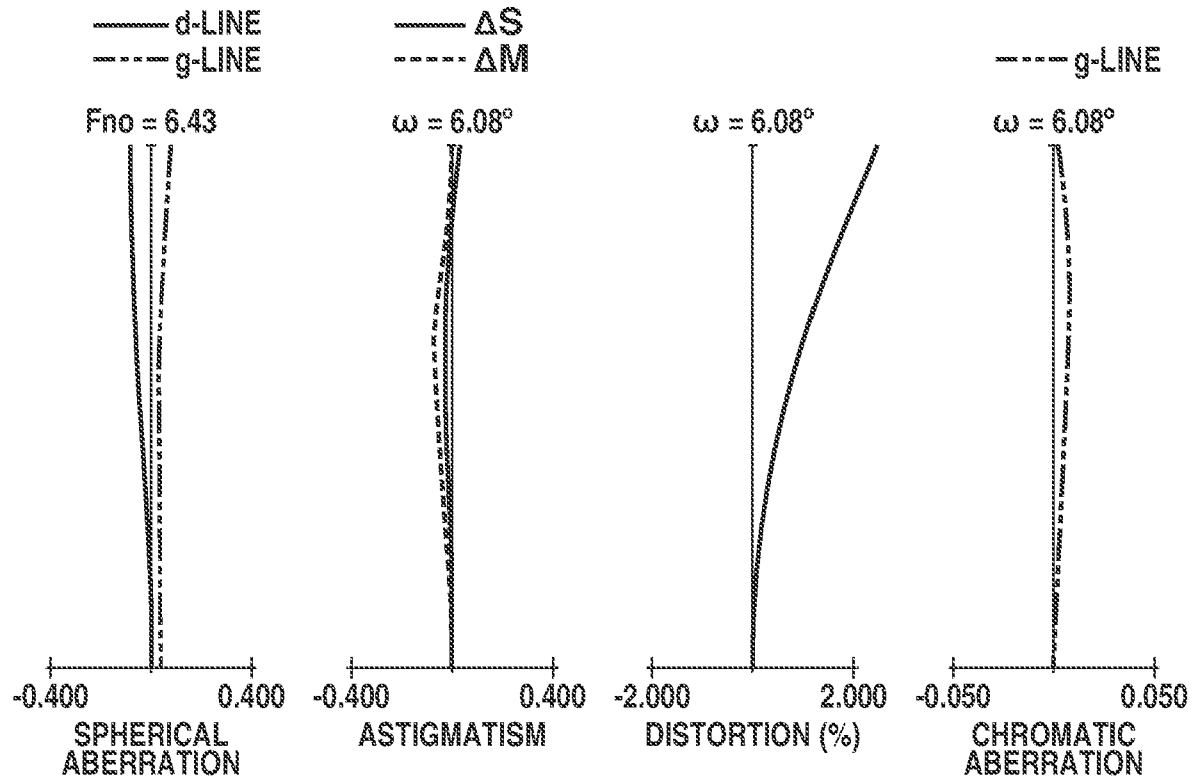
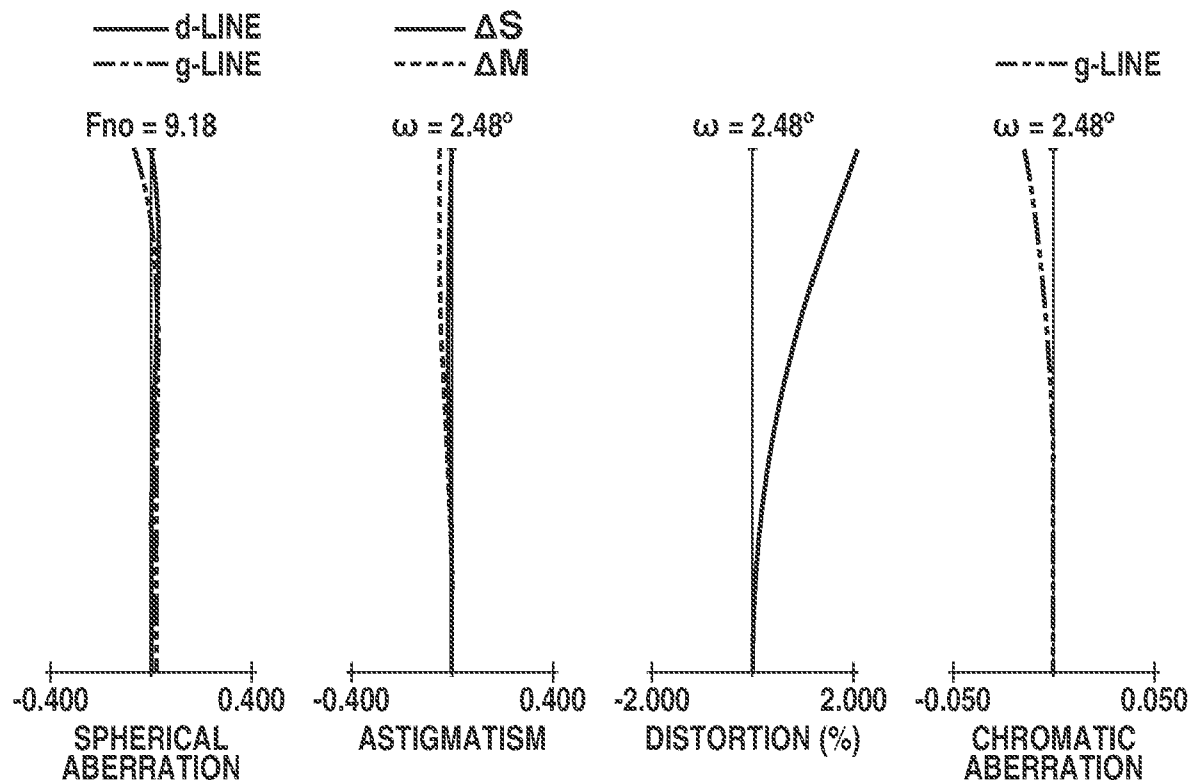
FIG.6A**FIG.6B**

FIG.7

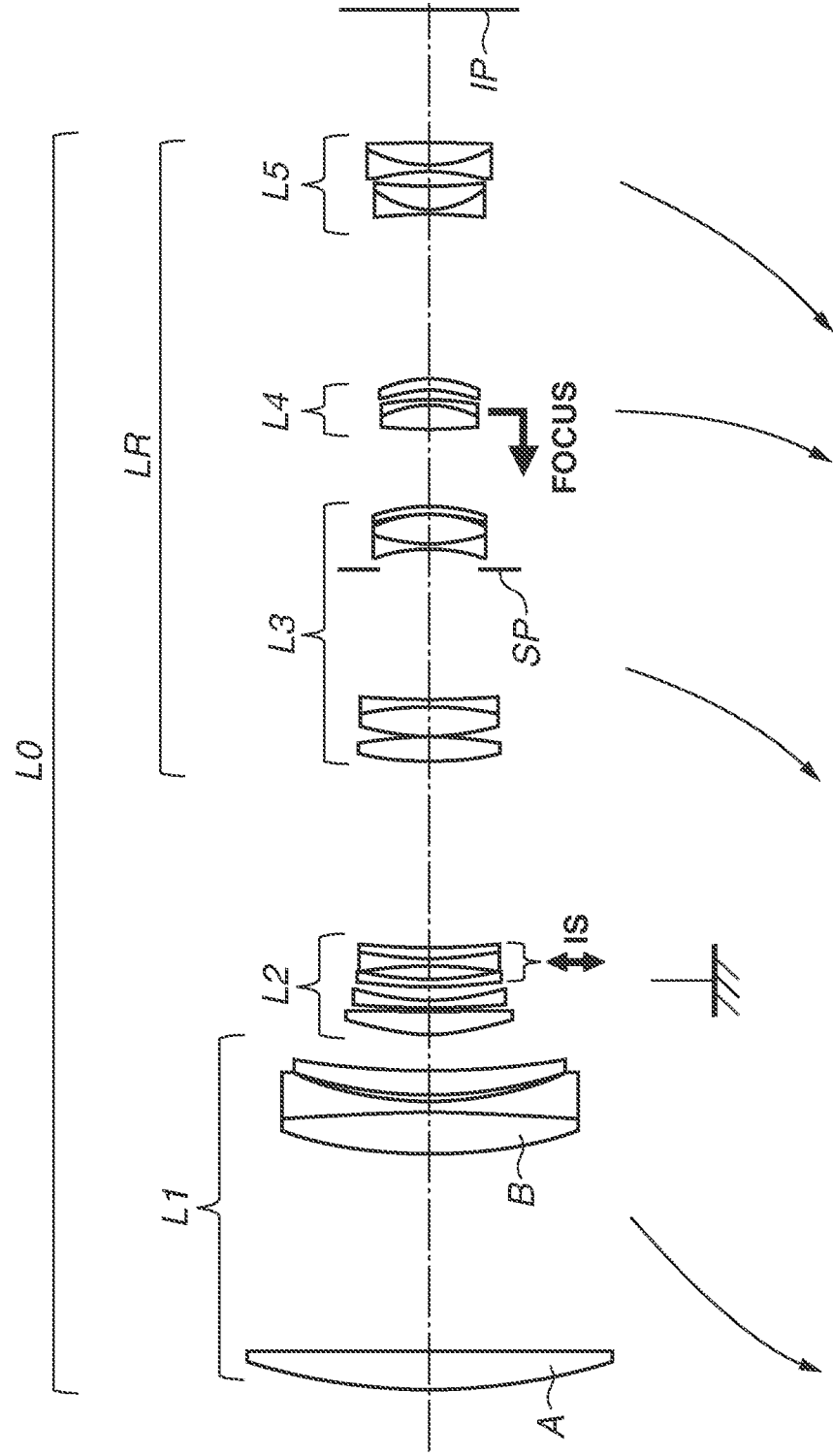


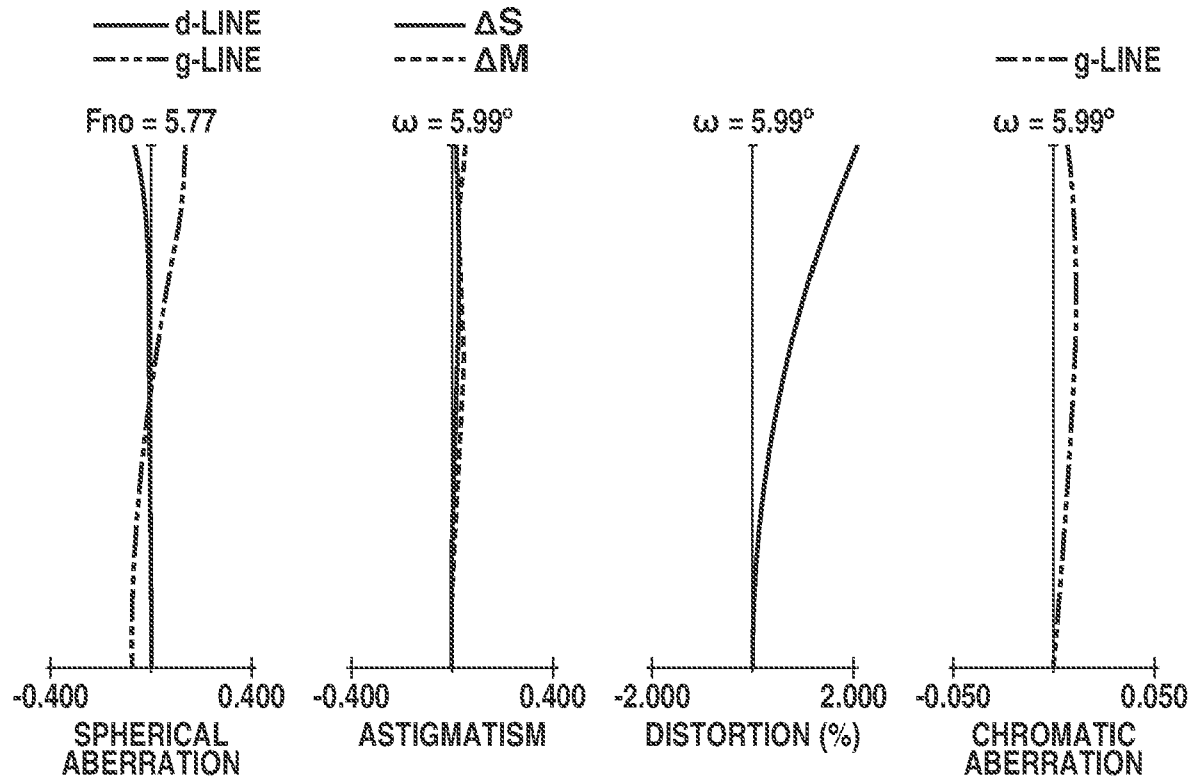
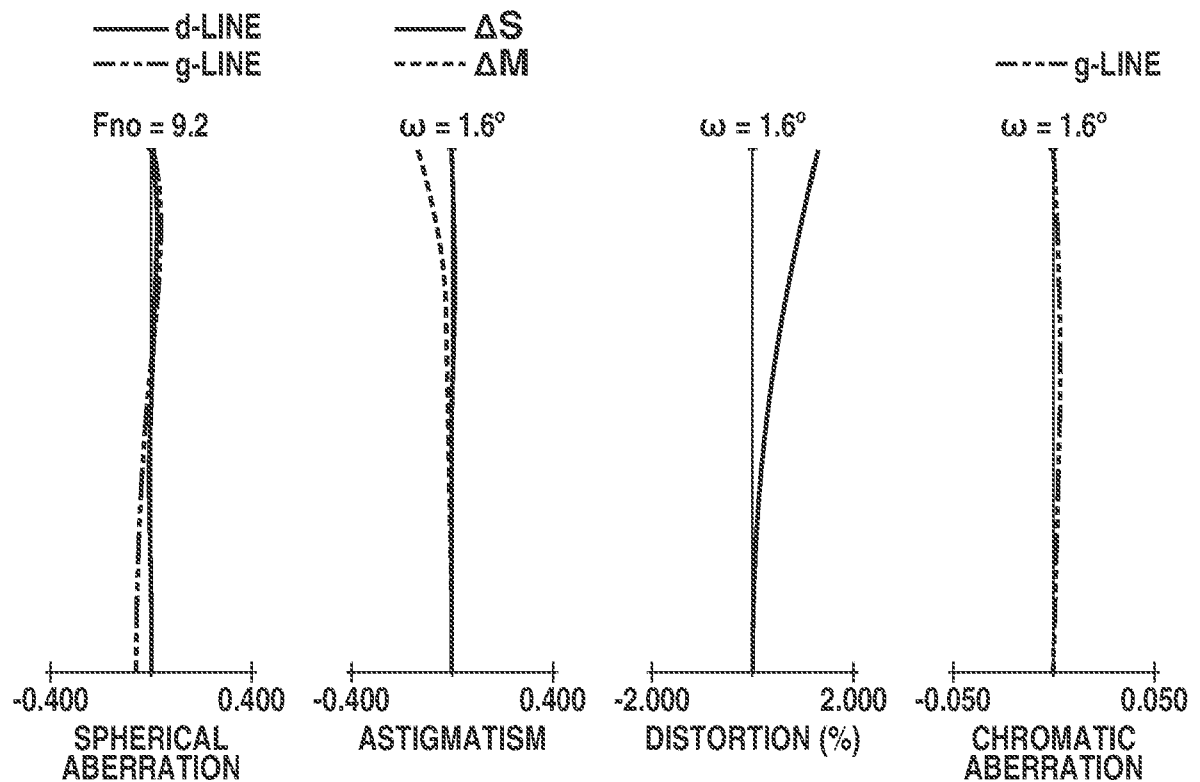
FIG.8A**FIG.8B**

FIG. 9

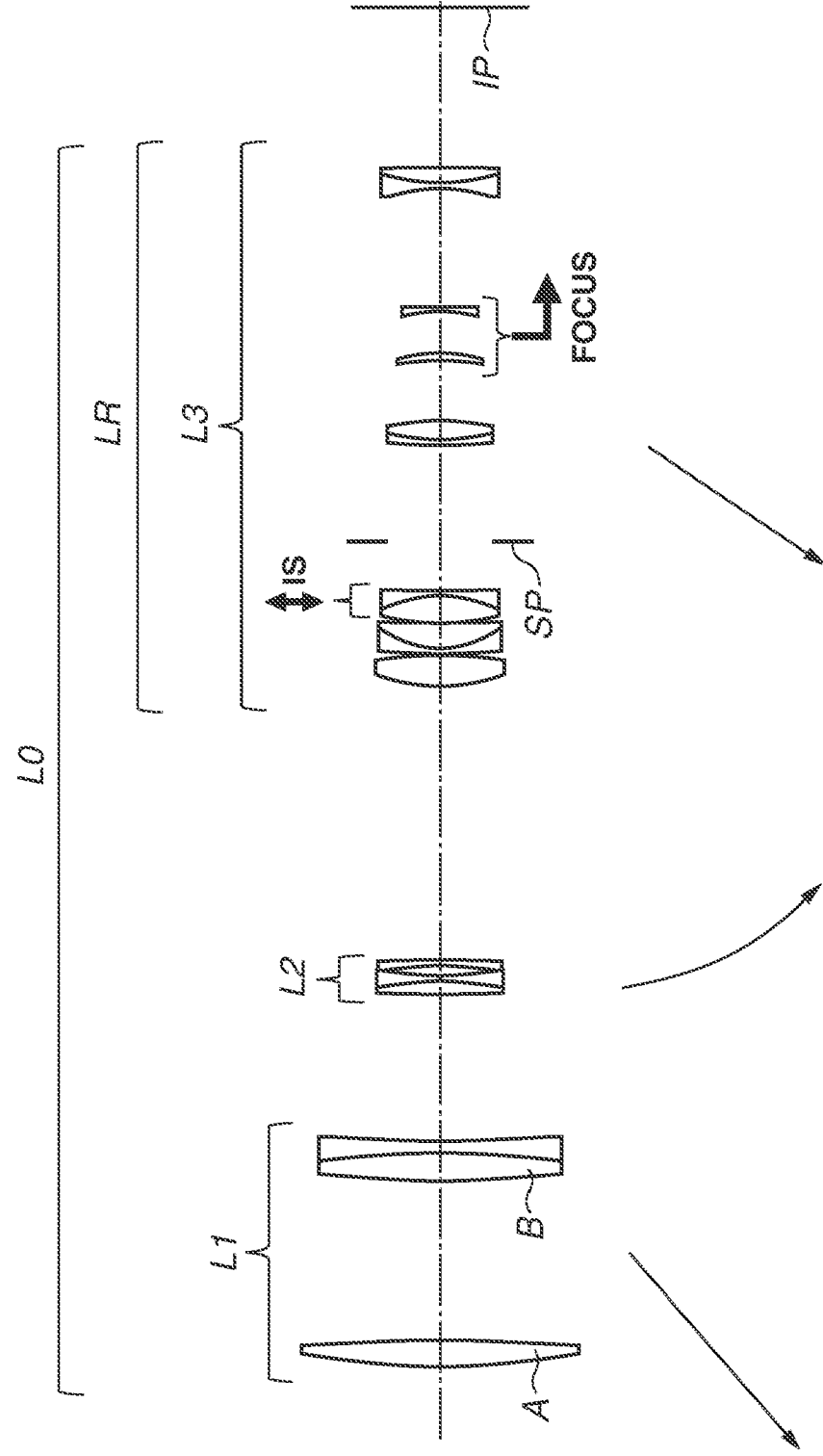


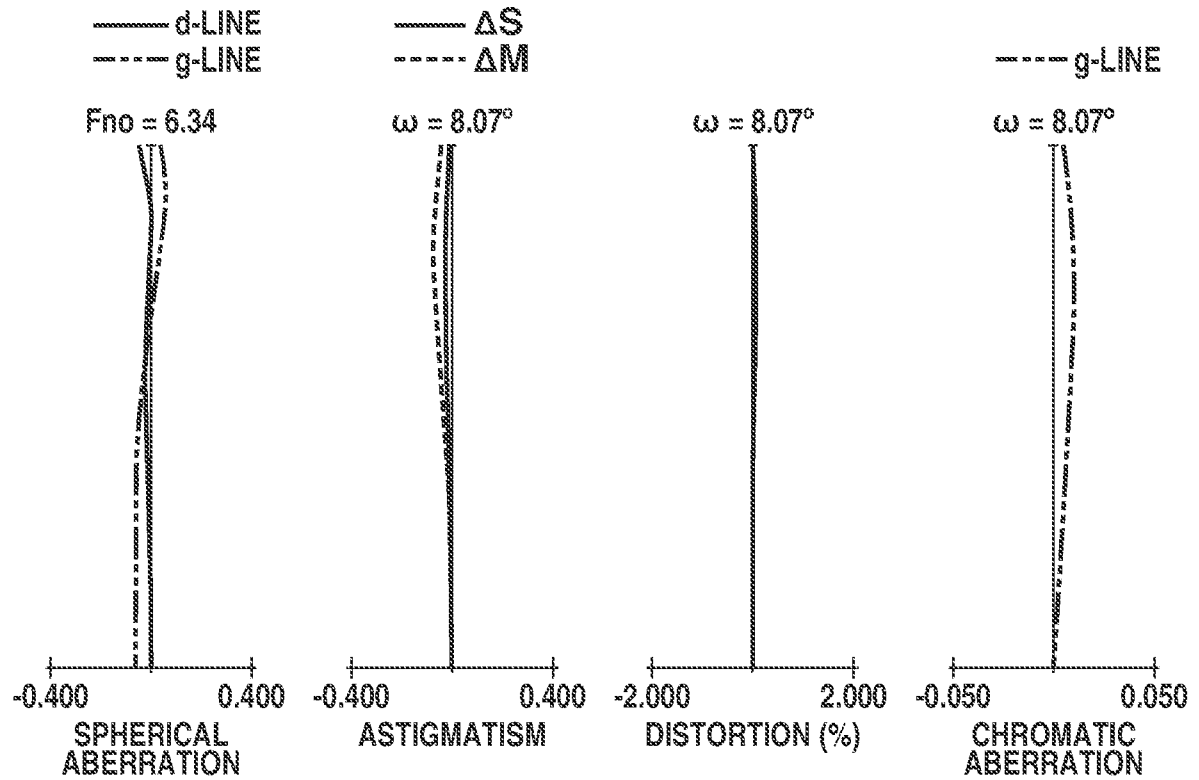
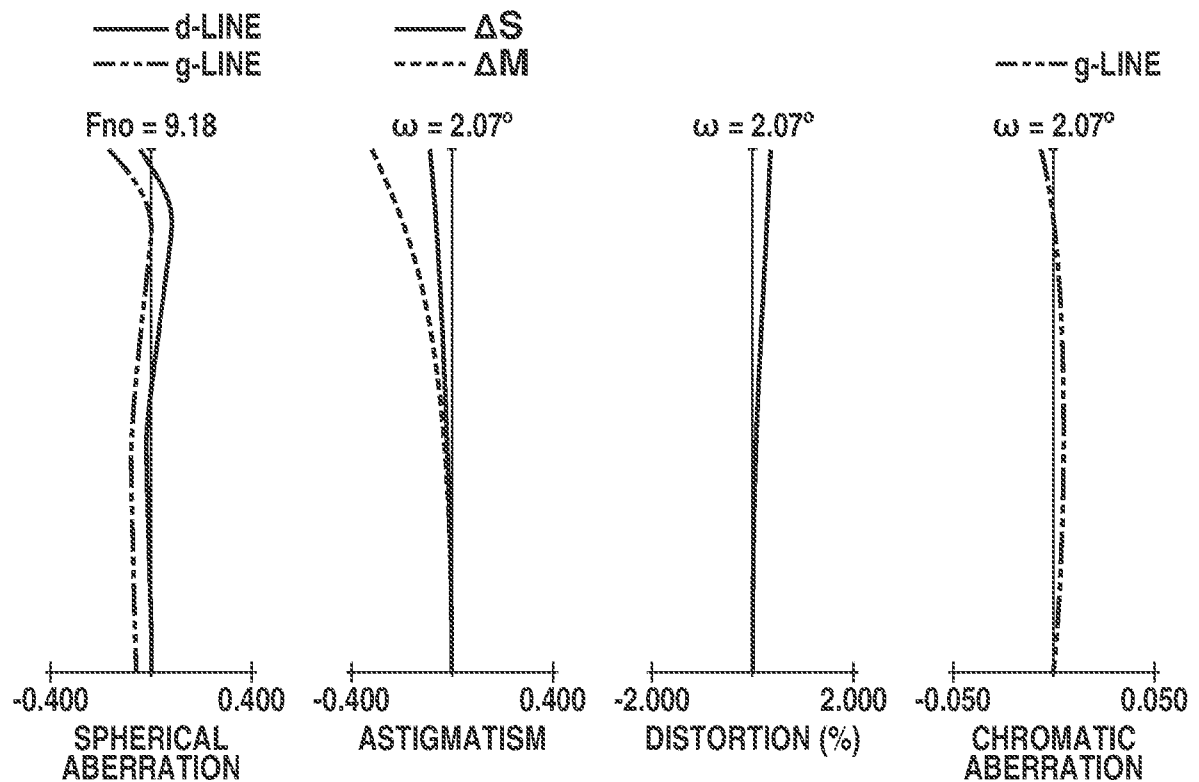
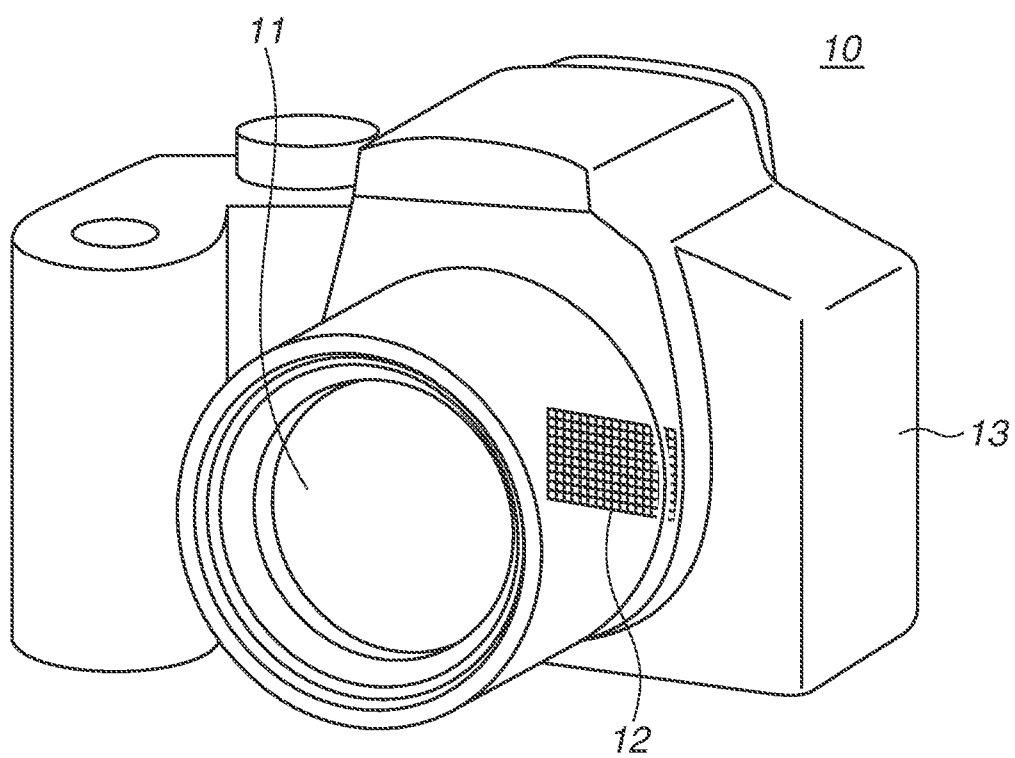
FIG.10A**FIG.10B**

FIG.11



TITLE OF THE INVENTION

ZOOM LENS AND IMAGING APPARATUS INCLUDING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a zoom lens, and is suitable for imaging apparatuses, such as a digital video camera, a digital still camera, a broadcasting camera, and a silver-halide film camera.

Description of the Related Art

[0002] In recent years, there has been a demand that a zoom lens used as an imaging optical system for an imaging apparatus is small in size and weight and offers high optical performance over an entire zoom range while achieving a long focal length at a telephoto end.

[0003] Japanese Patent Application Laid-Open No. 2009-86537 discusses a zoom lens in which a first lens unit is fixed during zooming and a second lens unit having negative refractive power is moved toward an image side during zooming from a wide angle end to a telephoto end. In this zoom lens, to achieve a long focal length at the telephoto end, it is necessary to increase an overall lens length at the wide angle end in order to secure a moving amount of the second lens unit during zooming.

SUMMARY OF THE INVENTION

[0004] According to an aspect of the present invention, a zoom lens comprises a first lens unit having positive refractive power, a second lens unit having negative refractive

power, and a rear lens group including one or more lens units, the first lens unit, the second lens unit, and the rear lens group being arranged in order from an object side to an image side. Intervals between adjacent lens units change during zooming. The first lens unit is configured to move toward the object side during zooming from a wide angle end to a telephoto end. The second lens unit includes three or more lenses. The following inequalities are satisfied:

$$4.3 < TD12t/TG12 < 12.0, \text{ and}$$

$$3.6 < TD1/TD2 < 30.0,$$

where TD12t is a distance on an optical axis from a lens surface arranged closest to the object side in the first lens unit to a lens surface arranged closest to the image side in the second lens unit at the telephoto end, TG12 is a total sum of thicknesses, on the optical axis, of lenses included in the first lens unit and the second lens unit, TD1 is a distance on the optical axis from the lens surface arranged closest to the object side in the first lens unit to a lens surface arranged closest to the image side in the first lens unit, and TD2 is a distance on the optical axis from a lens surface arranged closest to the object side in the second lens unit to the lens surface arranged closest to the image side in the second lens unit.

[0005] Further features of the present invention will become apparent from the following description of embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Fig. 1 is a cross-sectional view illustrating lenses at a wide angle end of a zoom lens according to a first embodiment.

[0007] Fig. 2A is an aberration diagram at the wide angle end of the zoom lens according to the first embodiment. Fig. 2B is an aberration diagram at a telephoto end of the zoom lens according to the first embodiment.

[0008] Fig. 3 is a cross-sectional view illustrating lenses at a wide angle end of a zoom lens according to a second embodiment.

[0009] Fig. 4A is an aberration diagram at the wide angle end of the zoom lens according to the second embodiment. Fig. 4B is an aberration diagram at a telephoto end of the zoom lens according to the second embodiment.

[0010] Fig. 5 is a cross-sectional view illustrating lenses at a wide angle end of a zoom lens according to a third embodiment.

[0011] Fig. 6A is an aberration diagram at the wide angle end of the zoom lens according to the third embodiment. Fig. 6B is an aberration diagram at a telephoto end of the zoom lens according to the third embodiment.

[0012] Fig. 7 is a cross-sectional view illustrating lenses at a wide angle end of a zoom lens according to a fourth embodiment.

[0013] Fig. 8A is an aberration diagram at the wide angle end of the zoom lens according to the fourth embodiment. Fig. 8B is an aberration diagram at a telephoto end of the zoom lens according to the fourth embodiment.

[0014] Fig. 9 is a cross-sectional view illustrating lenses at a wide angle end of a zoom lens according to a fifth embodiment.

[0015] Fig. 10A is an aberration diagram at the wide angle end of the zoom lens according to the fifth embodiment. Fig. 10B is an aberration diagram at a telephoto end of the zoom lens according to the fifth embodiment.

[0016] Fig. 11 is a schematic view of an imaging apparatus.

DESCRIPTION OF THE EMBODIMENTS

[0017] Optical systems according to embodiments of the present invention and an example of an imaging apparatus including any of the optical systems will be described below with reference to the attached drawings. Each of the embodiments of the present

invention described below can be implemented solely or as a combination of a plurality of the embodiments or features thereof where necessary or where the combination of elements or features from individual embodiments in a single embodiment is beneficial.

[0018] Figs. 1, 3, 5, 7, and 9 are cross-sectional views illustrating zoom lenses L0 according to first, second, third, fourth, and fifth embodiments, respectively. The zoom lenses L0 according to the embodiments are those used for imaging apparatuses, such as a digital video camera, a digital still camera, a broadcasting camera, a silver-halide film camera, a monitoring camera, and an on-vehicle camera.

[0019] In each of the cross-sectional views, the left side corresponds to an object side, and the right side corresponds to an image side. Each of the zoom lenses L0 according to the embodiments may also be used as a projection lens for a projector. In this case, the left side corresponds to a screen side, and the right side corresponds to a projected image side.

[0020] Each of the zoom lenses L0 according to the embodiments comprises a first lens unit L1 having positive refractive power, a second lens unit L2 having negative refractive power, and a rear lens group LR including one or more lens units. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. Intervals between the adjacent lens units change during zooming. Each of the lens units may include one lens or a plurality of lenses. Each of the lens units may also include an aperture stop.

[0021] In each of the cross-sectional views, each solid line arrow directed downward represents a moving locus of the corresponding lens unit during zooming from a wide angle end to a telephoto end. A focusing unit is moved as indicated by an arrow with the description of "FOCUS" during focusing from infinity to a close range. An image stabilizing unit is moved as indicated by a double-headed arrow with the description of "IS" during image shake correction.

[0022] Each of the cross-sectional views also illustrates an aperture stop SP and an

image plane IP. In a case where each of the zoom lenses L0 according to the embodiments is used for a digital video camera or a digital still camera, an imaging plane of a solid-state image sensor (a photoelectric conversion device), such as a charge-coupled device (CCD) sensor or a complementary metal-oxide semiconductor (CMOS) sensor, is arranged on the image plane IP. In a case where each of the zoom lenses L0 according to the embodiments is used as an imaging optical system for a silver-halide film camera, a photosensitive surface corresponding to a film surface is arranged on the image plane IP.

[0023] In Figs. 2A and 2B, 4A and 4B, 6A and 6B, 8A and 8B, and 10A and 10B are aberration diagrams in a case where a focus is achieved at an infinite object distance at the wide angle ends and telephoto ends of the zoom lenses L0 according to the first, second, third, fourth, and fifth embodiments, respectively.

[0024] In each spherical aberration chart, F_{no} represents a F-number, and spherical aberration amounts with respect to a d-line (with a wavelength of 587.6 nm) and a g-line (with a wavelength of 435.8 nm) are indicated. In each astigmatism chart, ΔS represents an aberration amount on a sagittal image plane, and ΔM represents an aberration amount on a meridional image plane. Each distortion aberration chart illustrates a distortion aberration amount with respect to the d-line. Each chromatic aberration chart illustrates a magnification chromatic aberration amount with respect to the g-line. Further, ω represents an imaging half angle of view ($^{\circ}$).

[0025] Next, a characteristic configuration of each of the zoom lenses L0 according to the embodiments will be described.

[0026] In each of the zoom lenses L0 according to the embodiments, the first lens unit L1 has positive refractive power, whereby a principal point is arranged on the object side, and an overall lens length (a distance on an optical axis from a lens surface arranged closest to the object side in the zoom lens L0 to the image plane IP) is shortened. The second lens unit L2 has negative refractive power, whereby a

magnification chromatic aberration that occurs in the first lens unit L1 especially at the wide angle end is corrected. Furthermore, the rear lens group LR including one or more lens units is arranged, whereby fluctuations of various aberrations that occur during zooming are suppressed.

[0027] The first lens unit L1 is moved toward the object side during zooming from the wide angle end to the telephoto end, whereby the overall lens length at the wide angle end is shortened.

[0028] The second lens unit L2 includes three or more lenses, whereby fluctuations of various aberrations that occur in the second lens unit L2 during zooming are suppressed.

[0029] Each of the zoom lenses L0 according to the embodiments is configured to satisfy the following inequalities (1) and (2):

$$4.3 < TD12t/TG12 < 12.0 \quad (1)$$

$$3.6 < TD1/TD2 < 30.0 \quad (2)$$

[0030] In the inequalities (1) and (2), TD12t is a distance on the optical axis from a lens surface arranged closest to the object side in the first lens unit L1 to a lens surface arranged closest to the image side in the second lens unit L2 at the telephoto end. TG12 is a total sum of thicknesses, on the optical axis, of lenses included in the first lens unit L1 and the second lens unit L2. TD1 is a distance on the optical axis from the lens surface arranged closest to the object side in the first lens unit L1 to a lens surface arranged closest to the image side in the first lens unit L1. TD2 is a distance on the optical axis from a lens surface arranged closest to the object side in the second lens unit L2 to the lens surface arranged closest to the image side in the second lens unit L2.

[0031] The inequalities (1) and (2) are to achieve correction of various aberrations, a high zoom ratio, and reduction in size and weight.

[0032] If TD12t/TG12 exceeds the upper limit of the inequality (1), the distance from the lens surface arranged closest to the object side in the first lens unit L1 to the lens surface arranged closest to the image side in the second lens unit L2 at the telephoto end

becomes longer. As a result, the overall lens length becomes longer, which is not desirable. If TD_{12t}/TG_{12} is less than the lower limit of the inequality (1), the total sum of the thicknesses, on the optical axis, of the lenses arranged in the first lens unit L1 and the second lens unit L2 increases. As a result, the weight of each lens included in the first lens unit L1 and the second lens unit L2 increases, which is not desirable.

[0033] If TD_1/TD_2 exceeds the upper limit of the inequality (2), the distance on the optical axis from the lens surface arranged closest to the object side in the first lens unit L1 to the lens surface arranged closest to the image side in the first lens unit L1 becomes longer. As a result, especially a diameter of a lens arranged closest to the object side becomes larger, which is not desirable. If TD_1/TD_2 is less than the lower limit of the inequality (2), the distance on the optical axis from the lens surface arranged closest to the object side in the second lens unit L2 to the lens surface arranged closest to the image side in the second lens unit L2 becomes longer. As a result, it is difficult to secure moving amounts of the second lens unit L2 and the rear lens group LR during zooming. This is not desirable because the overall lens length especially at the wide angle end is to be increased in order to obtain a desired zoom ratio.

[0034] The above-mentioned configuration can achieve a small, lightweight zoom lens offering high optical performance and a high zoom ratio.

[0035] At least one of the upper and lower limits of the value range of either the inequality (1) or the inequality (2) is desirably set to that of the corresponding one of the following inequalities (1a) and (2a):

$$4.5 < TD_{12t}/TG_{12} < 11.0 \quad (1a)$$

$$3.8 < TD_1/TD_2 < 20.0 \quad (2a)$$

[0036] At least one of the upper and lower limits of the value range of either the inequality (1) or the inequality (2) is more desirably set to that of the corresponding one of the following inequalities (1b) and (2b):

$$4.7 < TD_{12t}/TG_{12} < 10.5 \quad (1b)$$

$$4.0 < TD1/TD2 < 16.0 \quad (2b)$$

[0037] Next, a desirable configuration of each of the zoom lenses L0 according to the embodiments will be described.

[0038] The first lens unit L1 includes a positive lens A arranged closest to the object side and a positive lens B arranged adjacent to the positive lens A. The positive lenses A and B are desirably arranged with the largest air gap in the first lens unit L1 therebetween. The large air gap between the positive lenses A and B reduces an on-axis light flux that is incident on the positive lens B and lenses arranged closer to the image side than the positive lens B.

[0039] As a result, it is possible to reduce a diameter of the positive lens B and those of the lenses arranged closer to the image side than the positive lens B, thereby reducing the weight of the zoom lens L0.

[0040] Furthermore, in the first lens unit L1, a negative lens is desirably arranged closer to the image side than the positive lens B. The arrangement of the negative lens makes it is possible to appropriately correct aberrations, such as a spherical aberration and an on-axis chromatic aberration, especially at the telephoto end.

[0041] The second lens unit L2 is desirably fixed during zooming. This can reduce eccentricity of the second lens unit L2 that occurs during zooming, and can suppress fluctuations of various aberrations that occur in the second lens unit L2.

[0042] The aperture stop SP is desirably arranged between a lens surface arranged closest to the object side in a third lens unit L3 and a lens surface arranged closest to the image side in the third lens unit L3, or arranged closer to the image side than the third lens unit L3. Because an on-axis light flux incident on the third lens unit L3 or a lens arranged closer to the image side than the third lens unit L3 is relatively small, it is possible to reduce a diameter of the aperture stop SP.

[0043] Surfaces of all lenses included in the zoom lens L0 are desirably spherical in shape. Making the surfaces spherical in shape can suppress manufacturing variations,

and can thereby prevent degradation of optical performance.

[0044] During image shake correction, the whole or part of the second lens unit L2 is desirably moved so as to contain a component in a direction perpendicular to the optical axis. Since the second lens unit L2 has relatively high negative refractive power, it is possible to increase an absolute value of eccentricity sensitivity, and prevent an increase in a diameter of a lens that is moved during image stabilization. The eccentricity sensitivity mentioned herein is a ratio ($\Delta 2/\Delta 1$) of a moving amount $\Delta 1$ of the lens and a moving amount $\Delta 2$ of an image forming point on the image plane IP in the direction perpendicular to the optical axis.

[0045] Next, inequalities (3) to (11) that are desirably satisfied by each of the zoom lenses L0 according to the embodiments will be described.

[0046] Each of the zoom lenses L0 according to the embodiments desirably satisfies at least one or more of the following inequalities (3) to (11):

$$0.1 < m1/f1 < 0.5 \quad (3)$$

$$1.0 < f1/fw < 3.0 \quad (4)$$

$$-1.0 < f2/fw < -0.2 \quad (5)$$

$$1.0 < ft/TTDw < 3.5 \quad (6)$$

$$8.0 < ft/skw < 35.0 \quad (7)$$

$$5.0 < TTDw/skw < 20.0 \quad (8)$$

$$0.4 < D1max/TD1 < 0.9 \quad (9)$$

$$4.0 < |(1 - \beta ft^2)\beta rt^2| < 20.0 \quad (10)$$

$$2.0 < G1d < 3.0 \quad (11)$$

[0047] In the inequalities (3) and (4), $m1$ is an absolute value of a moving amount of the first lens unit L1 during zooming from the wide angle end to the telephoto end, and $f1$ is a focal length of the first lens unit L1. In the inequalities (4) and (5), fw is a focal length of the entire system at the wide angle end, and $f2$ is a focal length of the second lens unit L2. In the inequalities (6) to (8), ft is a focal length of the entire system at the

telephoto end, $TTDw$ is a distance on the optical axis from the lens surface arranged closest to the object side to the image plane IP at the wide angle end, and skw is a back focus at the wide angle end.

[0048] In the inequality (9), $D1_{max}$ is the largest air gap on the optical axis in the first lens unit L1. In the inequality (10), β_{ft} is a lateral magnification, at the telephoto end, of the focusing unit that is moved during focusing, and β_{rt} is a combined lateral magnification, at the telephoto end, of all the lens units arranged closer to the image side than the focusing unit. In the inequality (11), $G1d$ is a specific gravity of a material of a lens arranged closest to the object side in the first lens unit L1.

[0049] Next, technical meanings of the inequalities (3) to (11) will be described.

[0050] If $m1/f1$ exceeds the upper limit of the inequality (3), and the absolute value of the moving amount of the first lens unit L1 during zooming from the wide angle end to the telephoto end becomes larger, each lens arranged in the first lens unit L1 increases in effective diameter in order to secure a peripheral light quantity at the telephoto end, and increases in weight. If $m1/f1$ is less than the lower limit of the inequality (3), and the refractive power of the first lens unit L1 becomes weaker, the principal point is arranged on the image side, and the overall lens length becomes longer.

[0051] If $f1/fw$ exceeds the upper limit of the inequality (4), and the refractive power of the first lens unit L1 becomes weaker, the principal point is arranged on the image side, and the overall lens length becomes longer. If $f1/fw$ is less than the lower limit of the inequality (4), and the refractive power of the first lens unit L1 becomes stronger, various aberrations that occur in the first lens unit L1 become larger.

[0052] If $f2/fw$ exceeds the upper limit of the inequality (5), and the refractive power of the second lens unit L2 becomes stronger, fluctuations of various aberrations that occur in the second lens unit L2 during zooming become larger. If $f2/fw$ is less than the lower limit of the inequality (5), and the refractive power of the second lens unit L2 becomes weaker, the moving amount of the second lens unit L2 during zooming

becomes larger in order to obtain a desired zoom ratio. In other words, the overall lens length becomes longer in order to secure a space for the moving amount of the second lens unit L2 during zooming.

[0053] If f_t/TTD_w exceeds the upper limit of the inequality (6), and the focal length of the entire system at the telephoto end becomes longer, the refractive power of the first lens unit L1 or the like becomes stronger in order to prevent the increase of the overall lens length, which makes it difficult to correct various aberrations. If f_t/TTD_w is less than the lower limit of the inequality (6), the distance on the optical axis from the lens surface arranged closest to the object side to the image plane IP at the wide angle end becomes longer and the zoom lens L0 increases in size.

[0054] If f_t/skw exceeds the upper limit of the inequality (7), and the focal length of the entire system at the telephoto end becomes longer, the refractive power of the first lens unit L1 or the like becomes stronger in order to prevent the increase of the overall lens length, which makes it difficult to correct various aberrations. If f_t/skw is less than the lower limit of the inequality (7), the back focus at the wide angle end becomes longer. As a result, the overall lens length becomes longer.

[0055] If TTD_w/skw exceeds the upper limit of the inequality (8), the distance on the optical axis from the lens surface arranged closest to the object side to the image plane IP at the wide angle end becomes longer, and the zoom lens L0 increases in size. If TTD_w/skw is less than the lower limit of the inequality (8), and the distance on the optical axis from the lens surface arranged closest to the object side to the image plane IP at the wide angle end becomes shorter, the refractive power of the first lens unit L1 or the like becomes stronger, which makes it difficult to correct various aberrations.

[0056] If $D1_{max}/TD1$ exceeds the upper limit of the inequality (9), and the largest air gap on the optical axis in the first lens unit L1 becomes larger, the lens arranged closest to the object side increases in diameter in order to secure the peripheral light quantity, and increases in weight. If $D1_{max}/TD1$ is less than the lower limit of the inequality (9),

and the largest air gap on the optical axis in the first lens unit L1 becomes smaller, especially the refractive power of the lens arranged closest to the object side becomes stronger, which makes it difficult to correct various aberrations.

[0057] The inequality (10) indicates position sensitivity of the focusing unit at the telephoto end. The position sensitivity mentioned herein is a ratio ($\Delta L/\Delta d$) of a moving amount Δd of the focusing unit in the optical axis direction and a moving amount ΔL of the image forming position in the optical axis direction due to the movement of the focusing unit.

[0058] If $|(1 - \beta f t^2)\beta r t^2|$ exceeds the upper limit of the inequality (10), and the position sensitivity of the focusing unit at the telephoto end becomes higher, the refractive power of the focusing unit becomes stronger, and fluctuations of various aberrations that occur during movement of the focusing unit become larger. If $|(1 - \beta f t^2)\beta r t^2|$ is less than the lower limit of the inequality (10), and the position sensitivity of the focusing unit at the telephoto end becomes lower, the moving amount of the focusing unit increases during focusing. In other words, the overall lens length becomes longer in order to secure a space for the moving amount of the focusing unit during focusing.

[0059] If $G1d$ exceeds the upper limit of the inequality (11), and the specific gravity of the material of the lens arranged closest to the object side in the first lens unit L1 becomes larger, the lens increases in weight. If $G1d$ is less than the lower limit of the inequality (11) and the specific gravity of the material of the lens arranged closest to the object side in the first lens unit L1 becomes smaller, the material is relatively highly-dispersive, which makes it difficult to correct chromatic aberration.

[0060] At least one of the upper and lower limits of each of the inequalities (3) to (11) is desirably set to that of the corresponding one of the following inequalities (3a) to (11a):

$$0.2 < m1/f1 < 0.4 \quad (3a)$$

$$1.2 < f1/fw < 2.7 \quad (4a)$$

$$-0.8 < f_2/f_w < -0.25 \quad (5a)$$

$$1.2 < f_t/TTD_w < 3.0 \quad (6a)$$

$$12.0 < f_t/skw < 30.0 \quad (7a)$$

$$6.0 < TTD_w/skw < 15.0 \quad (8a)$$

$$0.5 < D_{1max}/TD_1 < 0.8 \quad (9a)$$

$$4.1 < |(1 - \beta f t^2) \times \beta r t^2| < 15.0 \quad (10a)$$

$$2.35 < G_{1d} < 2.55 \quad (11a)$$

[0061] At least one of the upper and lower limits of each of the inequalities (3) to (11) is more desirably set to that of the corresponding one of the following inequalities (3b) to (11b):

$$0.25 < m_1/f_1 < 0.35 \quad (3b)$$

$$1.4 < f_1/f_w < 2.5 \quad (4b)$$

$$-0.6 < f_2/f_w < -0.3 \quad (5b)$$

$$1.4 < f_t/TTD_w < 2.8 \quad (6b)$$

$$13.0 < f_t/skw < 25.0 \quad (7b)$$

$$8.0 < TTD_w/skw < 12.0 \quad (8b)$$

$$0.60 < D_{1max}/TD_1 < 0.75 \quad (9b)$$

$$4.2 < |(1 - \beta f t^2) \times \beta r t^2| < 13.0 \quad (10b)$$

$$2.4 < G_{1d} < 2.5 \quad (11b)$$

[0062] Next, the configuration of each of the zoom lenses L0 according to the embodiments will be described in detail.

[0063] The zoom lens L0 according to the first embodiment comprises the first lens unit L1 having positive refractive power, the second lens unit L2 having negative refractive power, and the rear lens group LR. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. The rear lens group LR comprises the third lens unit L3 having positive refractive power, a fourth lens unit L4 having positive refractive power, a fifth lens unit L5 having

negative refractive power, and a sixth lens unit L6 having negative refractive power. The third lens unit L3, the fourth lens unit L4, the fifth lens unit L5, and the sixth lens unit L6 are arranged in order from the object side to the image side. With the appropriate arrangement of the lens units having negative refractive power and the lens units having positive refractive power, various aberrations in the entire zoom range are appropriately corrected.

[0064] The second lens unit L2 is fixed during zooming, whereby the occurrence of aberrations due to the eccentricity of the second lens unit L2 is suppressed. The second lens unit L2 includes three lenses of a positive lens, a negative lens, and a negative lens, which are arranged in order from the object side to the image side. The second lens unit L2 is moved in a direction substantially perpendicular to the optical axis, whereby image shake correction is performed. The second lens unit L2 includes the three lenses, whereby an eccentric aberration during image shake correction is suppressed.

[0065] The fifth lens unit L5 is moved toward the image side during focusing from infinity to a close distance. Moving the fifth lens unit L5 having a relatively small diameter during focusing enables high-speed focusing. The aperture stop SP that determines the F-number F_{no} is arranged closest to the image side in the third lens unit L3. The aperture stop SP is arranged closest to the image side in the third lens unit L3 having a relatively small diameter, whereby a diameter of the aperture stop SP can be made smaller.

[0066] The zoom lens L0 according to the second embodiment comprises the first lens unit L1 having positive refractive power, the second lens unit L2 having negative refractive power, and the rear lens group LR. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. The rear lens group LR comprises the third lens unit L3 having positive refractive power, the fourth lens unit L4 having negative refractive power, the fifth lens unit L5 having positive refractive power, and the sixth lens unit L6 having negative refractive

power. The third lens unit L3, the fourth lens unit L4, the fifth lens unit L5, and the sixth lens unit L6 are arranged in order from the object side to the image side.

[0067] In the second embodiment, a positive lens is arranged closest to the image side in the first lens unit L1, in addition to the configuration according to the first embodiment. With the addition of the positive lens, a spherical aberration especially at the telephoto end is appropriately corrected.

[0068] The zoom lens L0 according to the third embodiment comprises the first lens unit L1 having positive refractive power, the second lens unit L2 having negative refractive power, and the rear lens group LR. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. The rear lens group LR comprises the third lens unit L3 having positive refractive power, the fourth lens unit L4 having negative refractive power, and the fifth lens unit L5 having negative refractive power. The third lens unit L3, the fourth lens unit L4, and the fifth lens unit L5 are arranged in order from the object side to the image side.

[0069] In the third embodiment, the second lens unit L2 includes two lenses, whereby the weight of the zoom lens L0 is reduced.

[0070] The zoom lens L0 according to the fourth embodiment comprises the first lens unit L1 having positive refractive power, the second lens unit L2 having negative refractive power, and the rear lens group LR. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. The rear lens group LR comprises the third lens unit L3 having positive refractive power, the fourth lens unit L4 having positive refractive power, and the fifth lens unit L5 having negative refractive power. The third lens unit L3, the fourth lens unit L4, and the fifth lens unit L5 are arranged in order from the object side to the image side.

[0071] In the fourth embodiment, the second lens unit L2 includes five lenses and the fifth lens unit L5 includes four lenses, whereby fluctuations of various aberrations that occur in the second lens unit L2 and the fifth lens unit L5 during zooming are

suppressed. The fourth lens unit L4 is moved toward the object side during focusing from infinity to a close range.

[0072] The zoom lens L0 according to the fifth embodiment comprises the first lens unit L1 having positive refractive power, the second lens unit L2 having negative refractive power, and the rear lens group LR. The first lens unit L1, the second lens unit L2, and the rear lens group LR are arranged in order from the object side to the image side. The rear lens group LR comprises the third lens unit L3 having positive refractive power.

[0073] In the fifth embodiment, the number of lens units is made smaller than that in the first embodiment, and the configuration comprising three lens units suppresses eccentricity of each lens unit that occurs during zooming and improves optical performance.

[0074] First to fifth numerical examples corresponding to the first to fifth embodiments, respectively, will be described.

[0075] In surface data of each numerical example, r represents a curvature radius of each optical surface, d (mm) represents an on-axis interval (a distance on the optical axis) between an m -th surface and an $(m + 1)$ -th surface (m is a surface number counted from a light incident side). In addition, nd represents a refractive index of each optical member with respect to the d-line, and vd represents an Abbe number of each optical member. The Abbe number vd of a material is expressed by $vd = (Nd - 1)/(NF - NC)$, where Nd , NF , and NC are refractive indices at Fraunhofer d-, F-, and C-lines (with wavelengths of 587.6 nm, 486.1 nm, and 656.3 nm), respectively.

[First Numerical Example]

[0076] Unit: mm

Surface Data

Surface Number	r	d	nd	vd
1	208.140	8.30	1.48749	70.2

2	-575.227	39.20		
3	117.400	11.35	1.49700	81.5
4	-270.733	2.70	1.61340	44.3
5	154.413	(variable)		
6	-1313.396	3.50	1.80518	25.4
7	-65.332	1.40	1.77250	49.6
8	114.681	2.08		
9	-137.293	1.40	1.83481	42.7
10	893.658	(variable)		
11	48.839	8.05	1.49700	81.5
12	-79.168	0.55		
13	301.466	1.35	1.77250	49.6
14	27.972	5.77	1.54072	47.2
15	776.993	0.48		
16	93.677	6.14	1.51823	58.9
17	-33.663	1.30	1.77250	49.6
18	-558.826	6.04		
19 (aperture)	∞	(variable)		
20	71.179	1.30	2.00069	25.5
21	35.239	4.65	1.61340	44.3
22	-67.501	(variable)		
23	112.661	2.56	1.51742	52.4
24	-88.341	1.22		
25	-100.206	0.90	1.59522	67.7
26	29.728	(variable)		
27	-43.800	1.30	1.49700	81.5
28	43.800	4.30	1.72047	34.7
29	-576.993	(variable)		
Image Plane	∞			

Various Data

Zoom ratio	3.82		
	Wide Angle	Intermediate	Telephoto
Focal Length	203.00	390.84	776.00
F-number	6.42	7.30	9.18
Half-Angle of View	6.08	3.17	1.60
Image Height	21.64	21.64	21.64
Overall Lens Length	331.63	390.98	421.61
BF	37.98	61.62	96.27
d5	39.49	98.84	129.47
d10	43.89	32.37	3.29
d19	46.32	45.47	47.31
d22	21.38	12.89	3.01
d26	26.74	23.95	26.42
d29	37.98	61.62	96.27

Zoom Lens Unit Data

Unit	Starting Surface	Focal Length
L1	1	302.68
L2	6	-71.48
L3	11	99.38
L4	20	82.71
L5	23	-66.78
L6	27	-203.48

[Second Numerical Example]

[0077] Unit: mm

Surface Data

Surface Number	r	d	nd	vd
1	144.748	9.32	1.48749	70.2
2	∞	48.43		

3	89.287	10.89	1.49700	81.6
4	-847.726	3.00	1.61340	44.3
5	74.191	1.97		
6	100.080	4.93	1.51823	58.9
7	174.640	(variable)		
8	∞	4.76	1.65412	39.7
9	-63.154	2.00	1.58913	61.1
10	767.732	3.37		
11	682.775	1.50	1.72916	54.7
12	82.889	2.86		
13	-101.488	1.50	1.69680	55.5
14	101.488	3.53	1.78472	25.7
15	∞	(variable)		
16	49.739	7.15	1.49700	81.6
17	-138.331	0.19		
18	64.996	1.70	1.72916	54.7
19	27.598	9.12	1.53775	74.7
20	-231.045	0.97		
21	-86.744	1.90	1.90525	35.0
22	1464.098	16.96		
23 (aperture)	∞	24.36		
24	64.330	4.61	1.61340	44.3
25	-43.939	1.30	1.89190	37.1
26	-157.290	(variable)		
27	271.506	2.33	1.85478	24.8
28	-74.228	1.00	1.83481	42.7
29	39.368	(variable)		
30	67.122	1.70	1.92286	20.9
31	38.251	6.33	1.65412	39.7
32	-60.563	(variable)		

33	-76.617	1.30	1.59522	67.7
34	166.663	1.15		
35	-165.426	1.50	1.59522	67.7
36	23.838	6.86	1.61340	44.3
37	181.816	(variable)		
Image Plane	∞			

Various Data

Zoom Ratio	3.7		
	Wide Angle	Intermediate	Telephoto
Focal Length	206.00	384.91	778.20
F-number	5.71	6.70	9.18
Half-Angle of View	6.00	3.22	1.59
Image Height	21.64	21.64	21.64
Overall Lens Length	330.11	387.57	420.11
BF	40.03	58.26	96.02
d7	7.95	65.40	97.95
d15	41.76	29.34	2.97
d26	15.09	8.51	3.09
d29	17.80	24.37	29.79
d32	18.99	13.18	1.79
d37	40.03	58.26	96.02

Zoom Lens Unit Data

Unit	Starting Surface	Focal Length
L1	1	298.92
L2	8	-73.88
L3	16	72.61
L4	27	-56.61
L5	30	58.15

L6

33

-55.76

[Third Numerical Example]

[0078] Unit: mm

Surface Data

Surface Number	r	d	nd	vd
1	276.825	6.18	1.48749	70.2
2	-600.775	39.20		
3	119.101	7.36	1.49700	81.5
4	-496.322	2.70	1.61340	44.3
5	164.850	(variable)		
6	-189.115	2.24	1.80518	25.4
7	-66.169	1.40	1.77250	49.6
8	121.138	(variable)		
9	51.485	7.45	1.49700	81.5
10	-90.684	1.12		
11	380.120	1.35	1.77250	49.6
12	30.296	5.13	1.54072	47.2
13	443.836	0.73		
14	110.891	5.53	1.51823	58.9
15	-37.072	1.30	1.77250	49.6
16	-296.706	9.32		
17 (aperture)	∞	41.15		
18	66.591	1.30	2.00069	25.5
19	34.650	3.94	1.61340	44.3
20	-83.966	(variable)		
21	93.250	2.61	1.51742	52.4
22	-71.258	1.88		
23	-69.994	0.90	1.59522	67.7
24	28.582	(variable)		
25	-179.806	1.30	1.49700	81.5

26	30.669	3.65	1.72047	34.7
27	75.036	(variable)		
Image Plane	∞			

Various Data

Zoom Ratio	2.46			
	Wide Angle	Intermediate	Telephoto	
Focal Length	203.01	395.08	500.04	
F-number	6.43	8.04	9.18	
Half-Angle of View	6.08	3.13	2.48	
Image Height	21.64	21.64	21.64	
Overall Lens Length	321.37	404.17	420.39	
BF	37.99	62.27	74.98	
d5	39.40	122.19	138.42	
d8	49.99	41.02	32.90	
d20	17.25	6.96	3.00	
d24	28.99	23.97	23.34	
d27	37.99	62.27	74.98	

Zoom Lens Unit Data

Unit	Starting Surface	Focal Length
L1	1	342.38
L2	6	-98.13
L3	9	76.09
L4	21	-64.30
L5	25	-200.31

[Fourth Numerical Example]

[0079] Unit: mm

Surface Data

Surface Number	r	d	nd	vd
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1	141.629	9.15	1.51823	58.9
2	7683.053	46.38		
3	114.796	9.86	1.49700	81.5
4	-395.656	2.70	1.61340	44.3
5	80.183	1.45		
6	101.475	5.71	1.49700	81.5
7	193.888	(variable)		
8	56.915	5.47	1.59270	35.3
9	2310.622	0.97		
10	245.283	1.65	1.83481	42.7
11	59.448	3.29		
12	119.146	1.65	1.71989	55.4
13	74.599	3.31		
14	-108.591	1.65	1.65394	60.9
15	89.528	2.66	1.84666	23.8
16	185.266	(variable)		
17	81.580	5.72	1.49700	81.5
18	-103.333	0.20		
19	61.959	6.95	1.49700	81.5
20	-70.310	1.80	1.90043	37.4
21	252.967	30.62		
22 (aperture)	∞	4.93		
23	-35.634	1.30	1.60311	60.6
24	44.939	6.76	1.52584	49.7
25	-32.909	0.20		
26	-43.510	1.95	1.48749	70.2
27	-37.860	(variable)		
28	155.017	5.70	1.57714	42.3
29	-23.967	1.20	1.95375	32.3
30	-60.504	2.43		

31	-31.133	2.56	1.58896	35.9
32	-26.486	(variable)		
33	-106.469	1.00	1.53775	74.7
34	19.932	5.81	1.51653	52.8
35	122.631	3.44		
36	-50.383	1.50	1.49700	81.5
37	30.867	5.46	1.51257	54.7
38	-294.673	(variable)		
Image Plane	∞			

Various Data

Zoom Ratio	3.77		
	Wide Angle	Intermediate	Telephoto
Focal Length	206.02	384.95	775.89
F-number	5.77	6.80	9.20
Half-Angle of View	5.99	3.22	1.60
Image Height	21.64	21.64	21.64
Overall Lens Length	326.81	380.44	419.36
BF	31.57	53.56	91.89
d7	8.62	62.25	101.18
d26	44.19	28.14	2.21
d27	18.16	26.33	35.76
d32	38.86	24.76	2.93
d38	31.57	53.56	91.89

Zoom Lens Unit Data

Unit	Starting Surface	Focal Length
L1	1	342.32
L2	8	-89.16
L3	17	102.74

L4	28	130.20
L5	33	-54.45

[Fifth Numerical Example]

[0080] Unit: mm

Surface Data

Surface Number	r	d	nd	vd
1	218.302	5.89	1.48749	70.2
2	-738.944	39.20		
3	251.266	6.97	1.49700	81.5
4	-222.883	2.70	1.61340	44.3
5	337.588	(variable)		
6	453.827	3.22	1.80518	25.4
7	-79.739	1.40	1.77250	49.6
8	100.533	2.43		
9	-89.220	1.40	1.83481	42.7
10	-393.480	(variable)		
11	44.461	7.61	1.49700	81.5
12	-88.855	0.55		
13	216.893	1.35	1.77250	49.6
14	25.104	5.51	1.54072	47.2
15	200.999	0.45		
16	61.022	6.50	1.51823	58.9
17	-32.801	1.30	1.77250	49.6
18	912.404	11.86		
19 (aperture)	∞	23.62		
20	134.867	1.30	2.00069	25.5
21	50.424	4.79	1.61340	44.3
22	-57.225	14.54		
23	-67.250	1.98	1.51742	52.4
24	-38.172	10.00		

25	-33.025	0.90	1.59522	67.7
26	-6071.683	29.02		
27	-40.861	1.30	1.49700	81.5
28	49.832	3.84	1.72047	34.7
29	-471.630	(variable)		
Image Plane	∞			

Various Data

Zoom Ratio	3.93			
	Wide Angle	Intermediate	Telephoto	
Focal Length	152.68	299.59	600.00	
F-number	6.34	8.05	9.18	
Half-Angle of view	8.07	4.13	2.07	
Image Height	21.64	21.64	21.64	
Overall Lens Length	331.63	386.74	427.64	
BF	39.31	65.54	82.78	
d5	35.90	93.92	153.22	
d10	66.79	37.64	2.00	
d29	39.31	65.54	82.78	

Zoom Lens Unit Data

Unit	Starting Surface	Focal Length
L1	1	379.81
L2	6	-78.52
L3	11	62.16

[0081] Table 1 indicates various kinds of values according to the above-described embodiments.

[Table 1]

	Expression	1st Embodiment	2nd Embodiment	3rd Embodiment	4th Embodiment	5th Embodiment

Inequality (1)	TD12t/TG12	6.960	4.731	9.936	4.867	10.030
Inequality (2)	TD1/TD2	7.348	4.022	15.245	3.645	6.479
Inequality (3)	m1/f1	0.297	0.301	0.289	0.270	0.253
Inequality (4)	f1/fw	1.491	1.451	1.686	1.662	2.488
Inequality (5)	f2/fw	-0.352	-0.359	-0.483	-0.433	-0.514
Inequality (6)	ft/TTDw	2.340	2.357	1.556	2.374	1.809
Inequality (7)	ft/skw	20.433	19.439	13.164	24.576	15.265
Inequality (8)	TTDw/skw	8.733	8.246	8.460	10.351	8.437
Inequality (9)	D1max/TD1	0.637	0.617	0.707	0.616	0.716
Inequality (10)	$ (1-\beta ft^2)\beta rt^2 $	10.261	10.400	7.447	4.299	6.023
Inequality (11)	G1d	2.460	2.460	2.460	2.480	2.460
	TD12t	199.399	196.009	197.496	197.065	216.434
	TG12	28.650	41.427	19.878	40.491	21.579
	TD1	61.550	78.536	55.441	75.245	54.762
	TD2	8.377	19.526	3.637	20.644	8.452
	m1	89.979	90.001	99.021	92.553	96.003
	f1	302.680	298.915	342.378	342.325	379.811
	f2	-71.481	-73.881	-98.129	-89.157	-78.520
	fw	203.002	206.000	203.012	206.021	152.679
	ft	775.996	778.200	500.042	775.890	599.999
	TTDw	331.633	330.112	321.374	326.807	331.633
	skw	37.977	40.033	37.987	31.572	39.306
	D1max	39.200	48.433	39.200	46.385	39.200
	βft	2.360	4.184	2.233	0.685	1.891
	βrt	1.498	0.794	1.367	2.845	1.529

[Imaging Apparatus]

[0082] Next, an example of a digital still camera (an imaging apparatus) using the zoom lens L0 according to any of the embodiments of the present invention as an imaging optical system will be described with reference to Fig. 11. Fig. 11 illustrates an imaging optical system 11 using any of the zoom lenses L0 described in the first to fifth embodiments. An image pickup device (a photoelectric conversion device) 12, such as a charge-coupled device (CCD) sensor or a complementary metal-oxide semiconductor (CMOS) sensor, is built into a camera body 10, receives an optical image formed by the imaging optical system 11, and photoelectrically converts the optical image. The camera body 10 may be a single-lens reflex camera including a quick turn mirror, or a mirrorless camera without the quick turn mirror.

[0083] In this manner, applying the zoom lens L0 according to any of the

embodiments of the present invention to an imaging apparatus, such as a digital still camera, enables obtaining high-resolution, wide-angle images.

[0084] While the embodiments and examples of the present invention have been described above, the present invention is not limited to these embodiments and examples, and can be combined, modified, and changed in various manners without departing from the scope of the present invention.

[0085] While the present invention has been described with reference to embodiments, it is to be understood that the invention is not limited to the disclosed 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.

WHAT IS CLAIMED IS:

1. A zoom lens comprising a first lens unit having positive refractive power, a second lens unit having negative refractive power, and a rear lens group including one or more lens units, the first lens unit, the second lens unit, and the rear lens group being arranged in order from an object side to an image side,

wherein intervals between adjacent lens units change during zooming,

wherein the first lens unit is configured to move toward the object side during zooming from a wide angle end to a telephoto end,

wherein the second lens unit includes three or more lenses, and

wherein the following inequalities are satisfied:

$$4.3 < TD_{12t}/TG_{12} < 12.0, \text{ and}$$

$$3.6 < TD_1/TD_2 < 30.0,$$

where TD_{12t} is a distance on an optical axis from a lens surface arranged closest to the object side in the first lens unit to a lens surface arranged closest to the image side in the second lens unit at the telephoto end, TG_{12} is a total sum of thicknesses, on the optical axis, of lenses included in the first lens unit and the second lens unit, TD_1 is a distance on the optical axis from the lens surface arranged closest to the object side in the first lens unit to a lens surface arranged closest to the image side in the first lens unit, and TD_2 is a distance on the optical axis from a lens surface arranged closest to the object side in the second lens unit to the lens surface arranged closest to the image side in the second lens unit.

2. The zoom lens according to claim 1, wherein the following inequality is satisfied:

$$0.1 < m_1/f_1 < 0.5,$$

where m_1 is an absolute value of a moving amount of the first lens unit during the

zooming from the wide angle end to the telephoto end, and f_1 is a focal length of the first lens unit.

3. The zoom lens according to claim 1 or 2, wherein the following inequality is satisfied:

$$1.0 < f_1/f_w < 3.0,$$

where f_1 is a focal length of the first lens unit, and f_w is a focal length of an entire system at the wide angle end.

4. The zoom lens according to any one of claims 1 to 3, wherein the following inequality is satisfied:

$$-1.0 < f_2/f_w < -0.2,$$

where f_2 is a focal length of the second lens unit, and f_w is a focal length of an entire system at the wide angle end.

5. The zoom lens according to any one of claims 1 to 4, wherein the following inequality is satisfied:

$$1.0 < f_t/TTD_w < 3.5,$$

where f_t is a focal length of an entire system at the telephoto end, and TTD_w is a distance on the optical axis from a lens surface arranged closest to the object side to an image plane at the wide angle end.

6. The zoom lens according to any one of claims 1 to 5, wherein the following inequality is satisfied:

$$8.0 < f_t/skw < 35.0,$$

where f_t is a focal length of an entire system at the telephoto end, and skw is a back focus at the wide angle end.

7. The zoom lens according to any one of claims 1 to 6, wherein the following inequality is satisfied:

$$5.0 < \text{TTDw/skw} < 20.0,$$

where TTDw is a distance on the optical axis from a lens surface arranged closest to the object side to an image plane at the wide angle end, and skw is a back focus at the wide angle end.

8. The zoom lens according to any one of claims 1 to 7, wherein the following inequality is satisfied:

$$0.4 < \text{D1max/TD1} < 0.9,$$

where D1max is a largest air gap on the optical axis in the first lens unit.

9. The zoom lens according to any one of claims 1 to 8, further comprising a focusing unit configured to move during focusing,

wherein the following inequality is satisfied:

$$4.0 < |(1 - \beta_{ft}^2) \times \beta_{rt}^2| < 20.0,$$

where β_{ft} is a lateral magnification of the focusing unit at the telephoto end, and β_{rt} is a combined lateral magnification of all the lens units arranged closer to the image side than the focusing unit at the telephoto end.

10. The zoom lens according to any one of claims 1 to 9, wherein the following inequality is satisfied:

$$2.0 < \text{G1d} < 3.0,$$

where G1d is a specific gravity of a material of a lens arranged closest to the object side in the first lens unit.

11. The zoom lens according to any one of claims 1 to 10,
wherein the first lens unit includes a positive lens A arranged closest to the object side and a positive lens B arranged adjacent to the positive lens A, and
wherein the positive lens A and the positive lens B are arranged with a largest air gap on the optical axis in the first lens unit therebetween.

12. The zoom lens according to claim 11, wherein the first lens unit includes the positive lens A, the positive lens B, and a negative lens that are arranged in the order from the object side to the image side.

13. The zoom lens according to any one of claims 1 to 12, wherein the second lens unit is fixed during zooming.

14. The zoom lens according to any one of claims 1 to 13, wherein the rear lens group comprises a third lens unit having positive refractive power, a fourth lens unit having positive refractive power, a fifth lens unit having negative refractive power, and a sixth lens unit having negative refractive power.

15. The zoom lens according to any one of claims 1 to 13, wherein the rear lens group comprises a third lens unit having positive refractive power, a fourth lens unit having negative refractive power, a fifth lens unit having positive refractive power, and a sixth lens unit having negative refractive power.

16. The zoom lens according to any one of claims 1 to 13, wherein the rear lens group comprises a third lens unit having positive refractive power, a fourth lens unit having negative refractive power, and a fifth lens unit having negative refractive power.

17. The zoom lens according to any one of claims 1 to 13, wherein the rear lens group comprises a third lens unit having positive refractive power, a fourth lens unit having positive refractive power, and a fifth lens unit having negative refractive power.

18. The zoom lens according to any one of claims 1 to 13, wherein the rear lens group comprises a third lens unit having positive refractive power.

19. The zoom lens according to any one of claims 1 to 18, further comprising an aperture stop that is arranged between a lens surface arranged closest to the object side in a third lens unit and a lens surface arranged closest to the image side in the third lens unit, or arranged closer to the image side than the third lens unit, wherein the third lens unit is included in the rear lens group.

20. The zoom lens according to any one of claims 1 to 19, wherein surfaces of all lenses included in the zoom lens are spherical in shape.

21. The zoom lens according to any one of claims 1 to 20, wherein a whole or part of the second lens unit is configured to move so as to contain a component in a direction perpendicular to the optical axis during image shake correction.

22. An imaging apparatus comprising:
the zoom lens according to any one of claims 1 to 21; and
an image sensor configured to receive an optical image formed by the zoom lens.



Application No: GB2316182.1

Examiner: Mr Steven Scott

Claims searched: 1-22

Date of search: 22 April 2024

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-22	EP3945357 A1 (CANON KK [JP]) see figures 5,15 the corresponding parts of the description and data tables and paragraph 12 especially.
X	1-8,10-22	US2021/0278642 A1 (RICOH CO LTD [JP]) see figures 8,61, the corresponding part of the description including tables 30-33 and claims 1-4 especially.
X	1-10,12-22	JP2015138178 A (CANON KK) see figure 5 for the lens diagram, the corresponding part of the description and data tables especially.
X	1-10,12,15,18-22	US2017/0192212 A1 (NIKON CORP [JP]) see figure 1 for the lens diagrams, the corresponding part of the description and data tables especially.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

G02B

The following online and other databases have been used in the preparation of this search report

SEARCH - PATENT

International Classification:

Subclass	Subgroup	Valid From
G02B	0015/14	01/01/2006
G02B	0015/16	01/01/2006
G02B	0015/20	01/01/2006