United States Patent [19]

Hayashi

[11] **Patent Number: 4,732,459**

[45] **Date of Patent: Mar. 22, 1988**

[54] **FAST TELEPHOTO LENS**

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[73] Assignee: **Nippon Kogaku K. K.**, Tokyo, Japan

[21] Appl. No.: **6,279**

[22] Filed: **Jan. 20, 1987**

Related U.S. Application Data

[63] Continuation of Ser. No. 633,297, Jul. 23, 1984, abandoned.

[30] **Foreign Application Priority Data**

Jul. 27, 1983 [JP] Japan 58-137379

[51] **Int. Cl.**[4] **G02B 9/00**

[52] **U.S. Cl.** **350/454**; 350/475

[58] **Field of Search** 350/454, 453, 457, 475

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,348,084	9/1982	Kitagishi et al.	350/454
4,518,229	5/1985	Yasukuni	350/454

Primary Examiner—John K. Corbin
Assistant Examiner—P. M. Dzierzynski
Attorney, Agent, or Firm—Shapiro and Shapiro

[57] **ABSTRACT**

A fast telephoto lens has a longer focal length of 300 to 400 mm, and an F-number of about 2.0 to 2.8, which does not utilize a floating mechanism, has a small deviation in aberration when the lens is focused on an object, and has a simple construction for shifting only one lens group. The fast telephoto lens is of internal focusing type and comprises positive, negative and positive lens groups from the object side, and only the negative (second) lens group is shifted to obtain an in-focus state.

15 Claims, 18 Drawing Figures

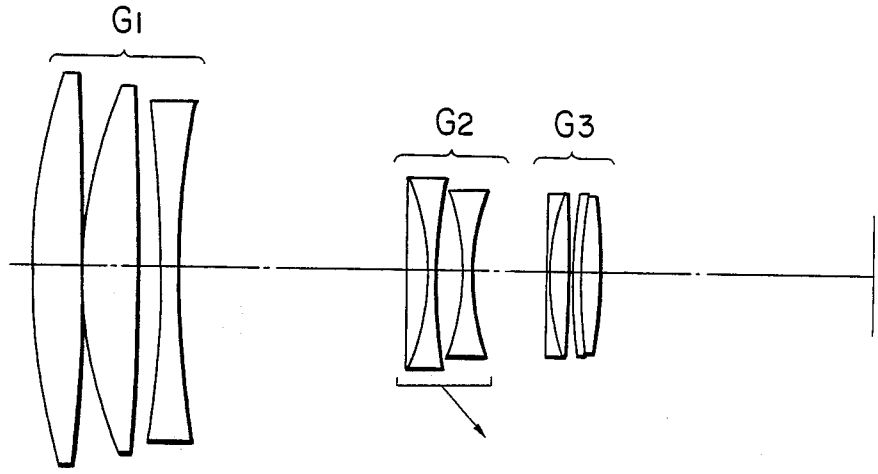


FIG. 1

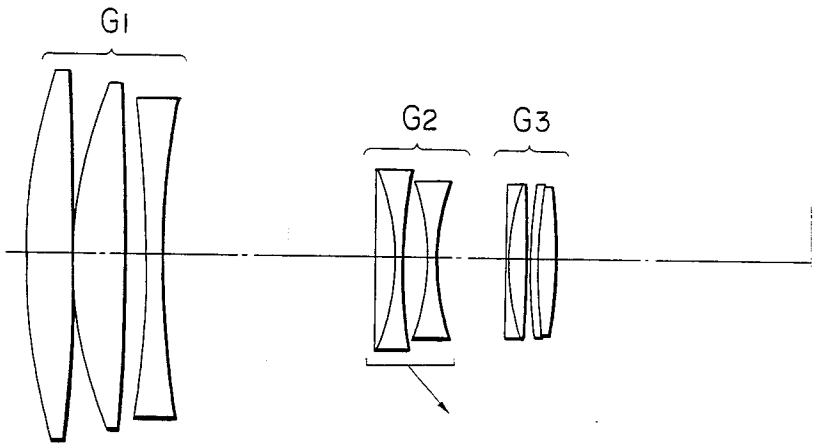


FIG. 2

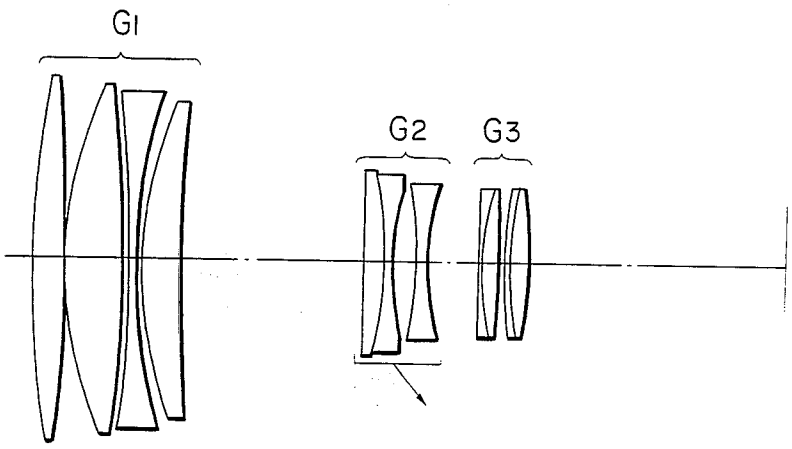


FIG. 3

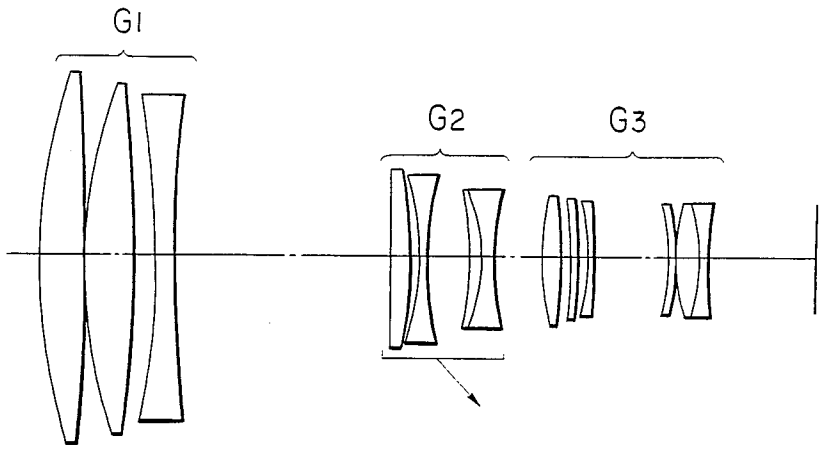


FIG. 4

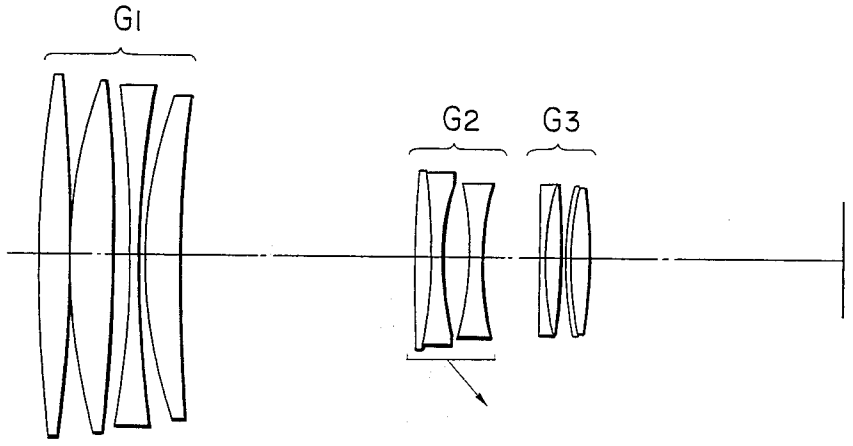


FIG. 5

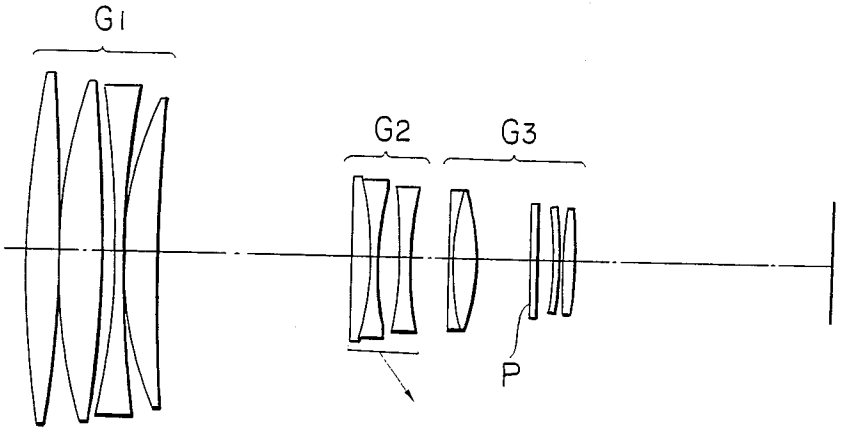


FIG. 6

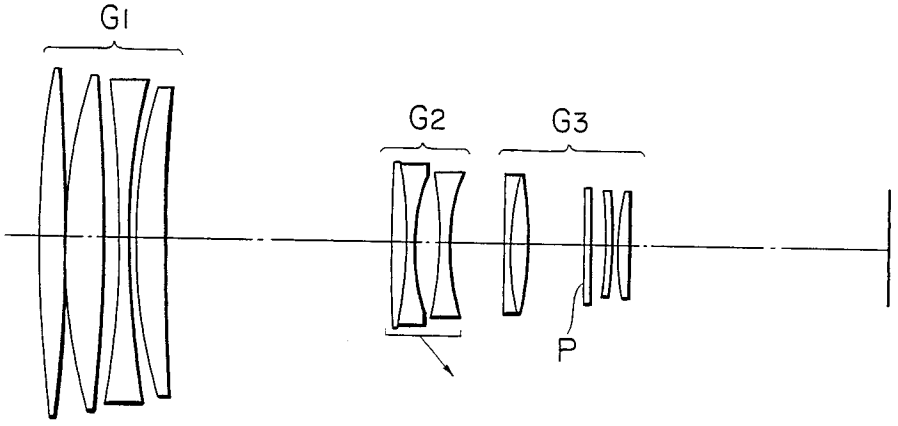
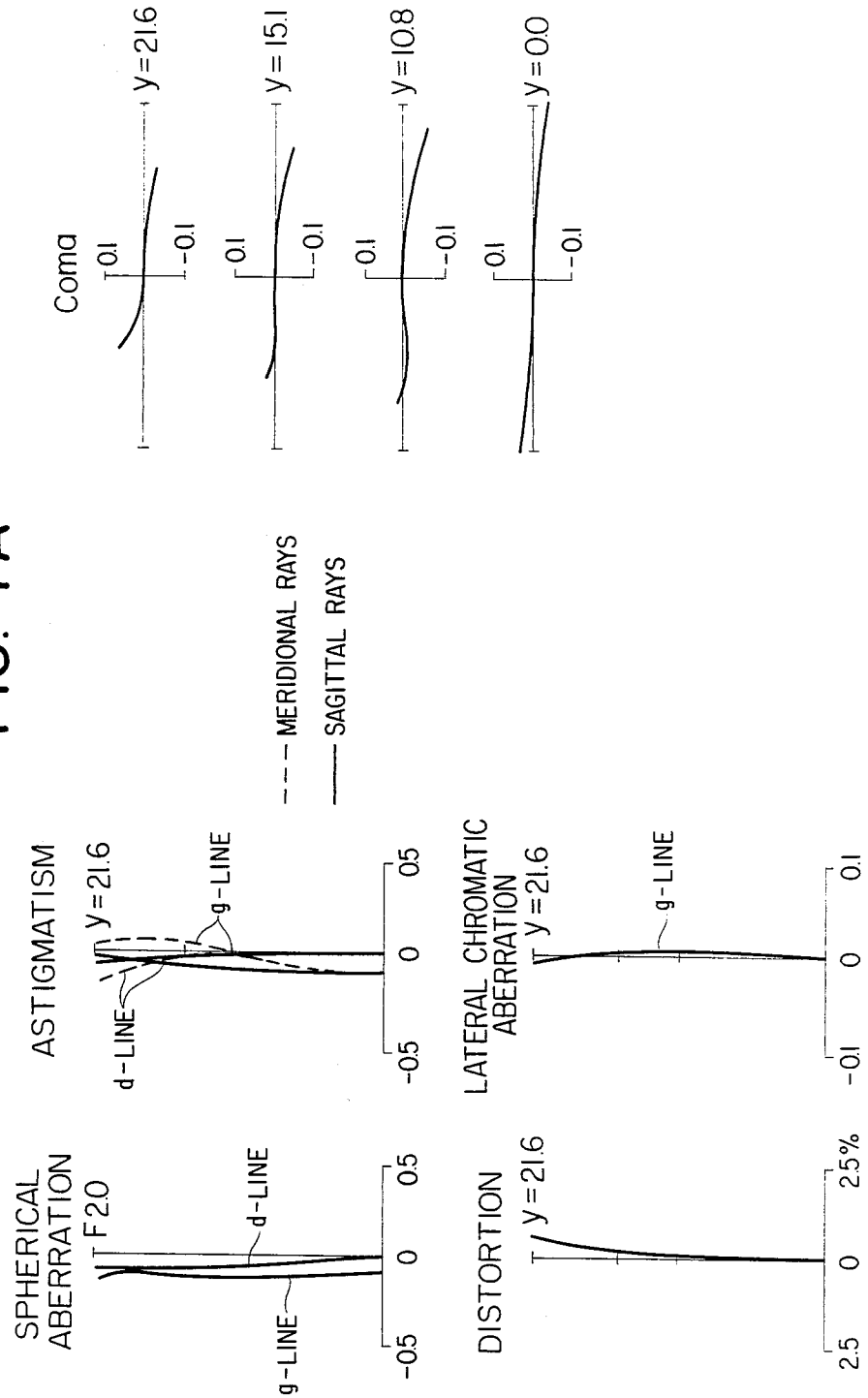


FIG. 7A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-0.1
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—— SAGITTAL RAYS
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g-LINE
0.5
0
-0.5
LATERAL CHROMATIC ABERRATION
y=21.6
g-LINE
0.1
0
-0.1
SPHERICAL ABERRATION
F 2.0
d-LINE
g-LINE
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-0.5
DISTORTION
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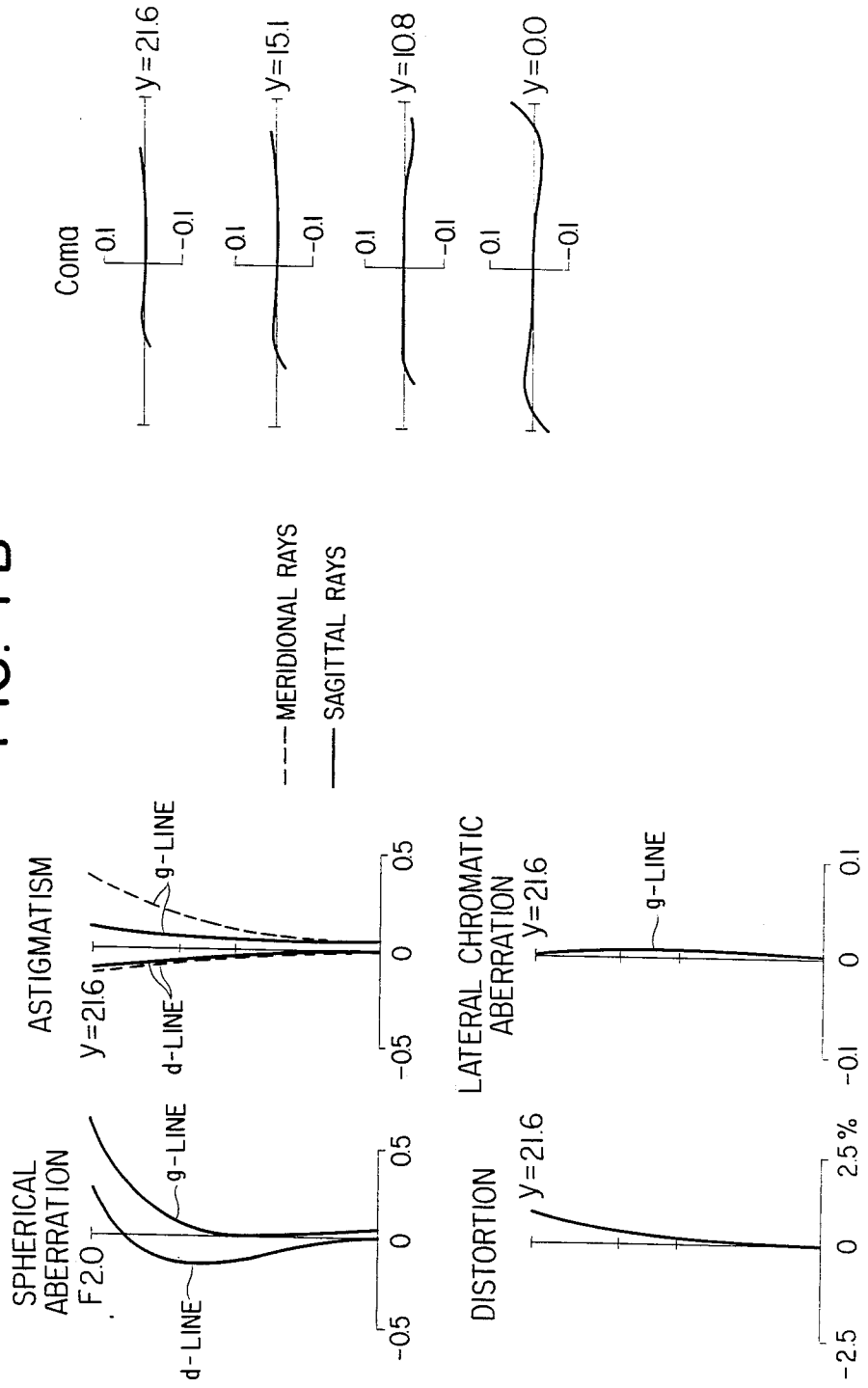
2.5

FIG. 7B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ASTIGMATISM
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g-LINE
d-LINE
SPHERICAL ABERRATION
F2.0
LATERAL CHROMATIC ABERRATION
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DISTORTION
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0.1
-0.1
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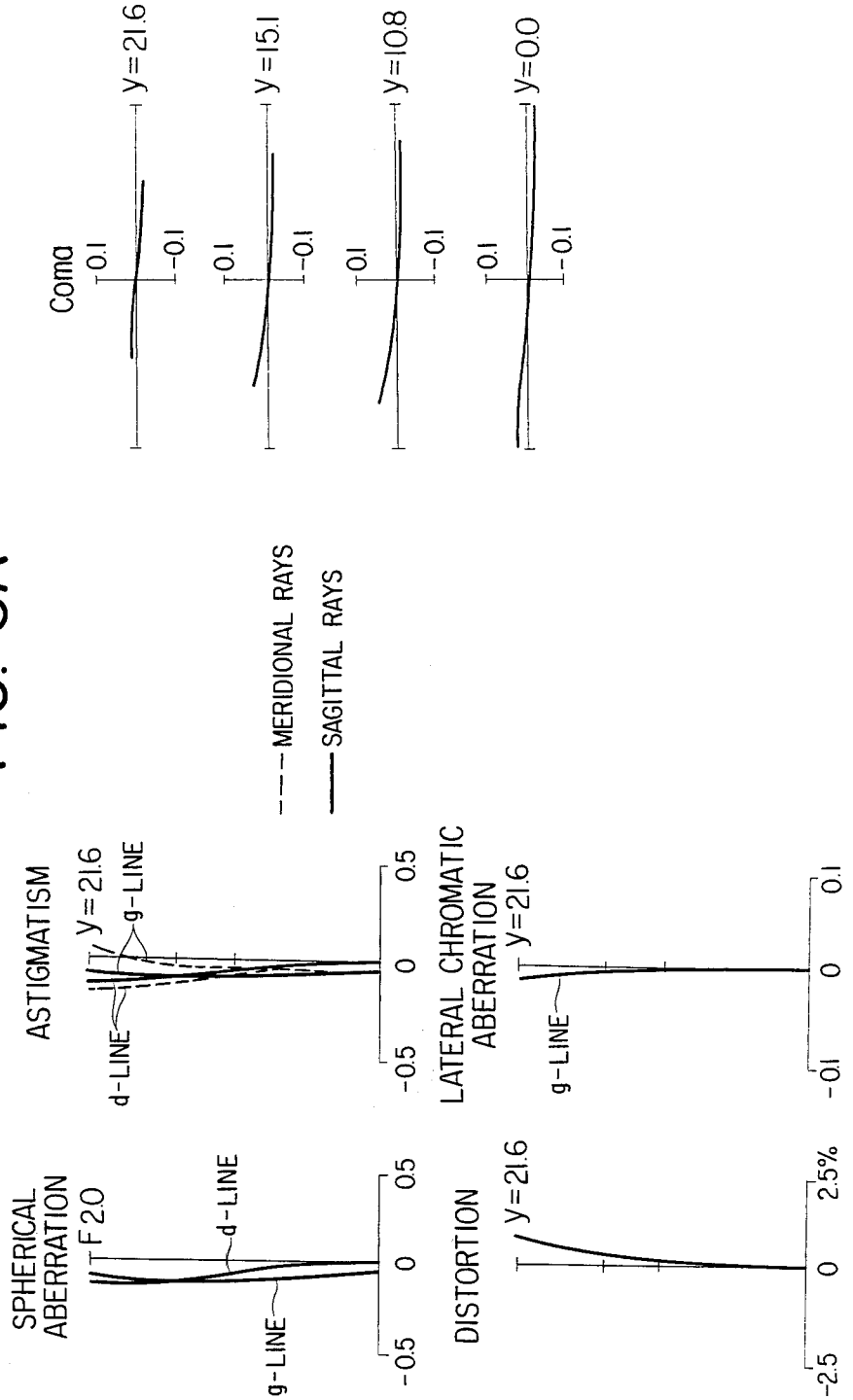
-2.5

FIG. 8A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d-LINE
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0.5
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g-LINE
-0.1
0
0.1
SPHERICAL ABERRATION
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d-LINE
g-LINE
DISTORTION
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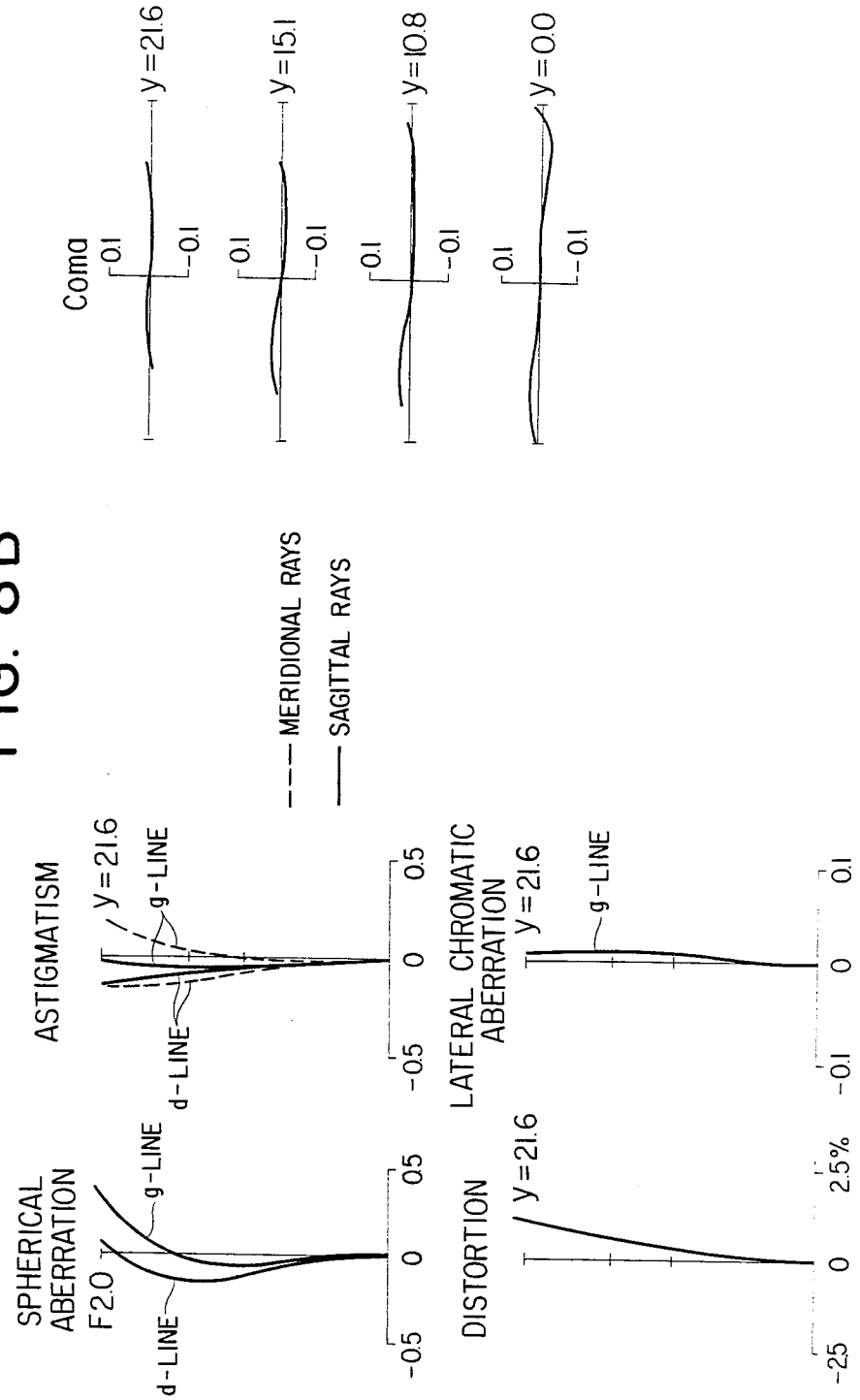
2.5%

FIG. 8B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d-LINE
SPHERICAL ABERRATION
F2.0
LATERAL CHROMATIC ABERRATION
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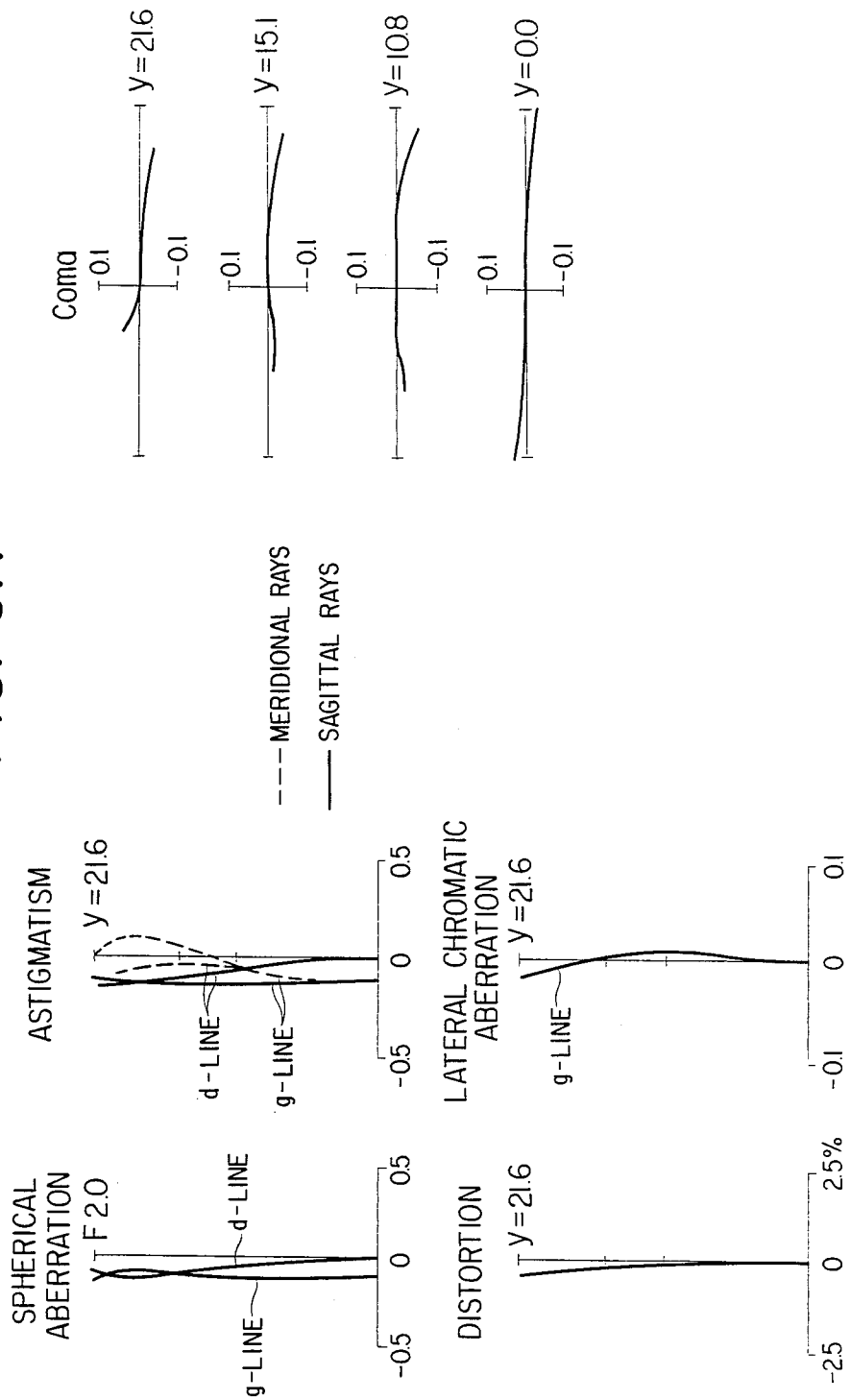
0.1

FIG. 9A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d-LINE
g-LINE
DISTORTION
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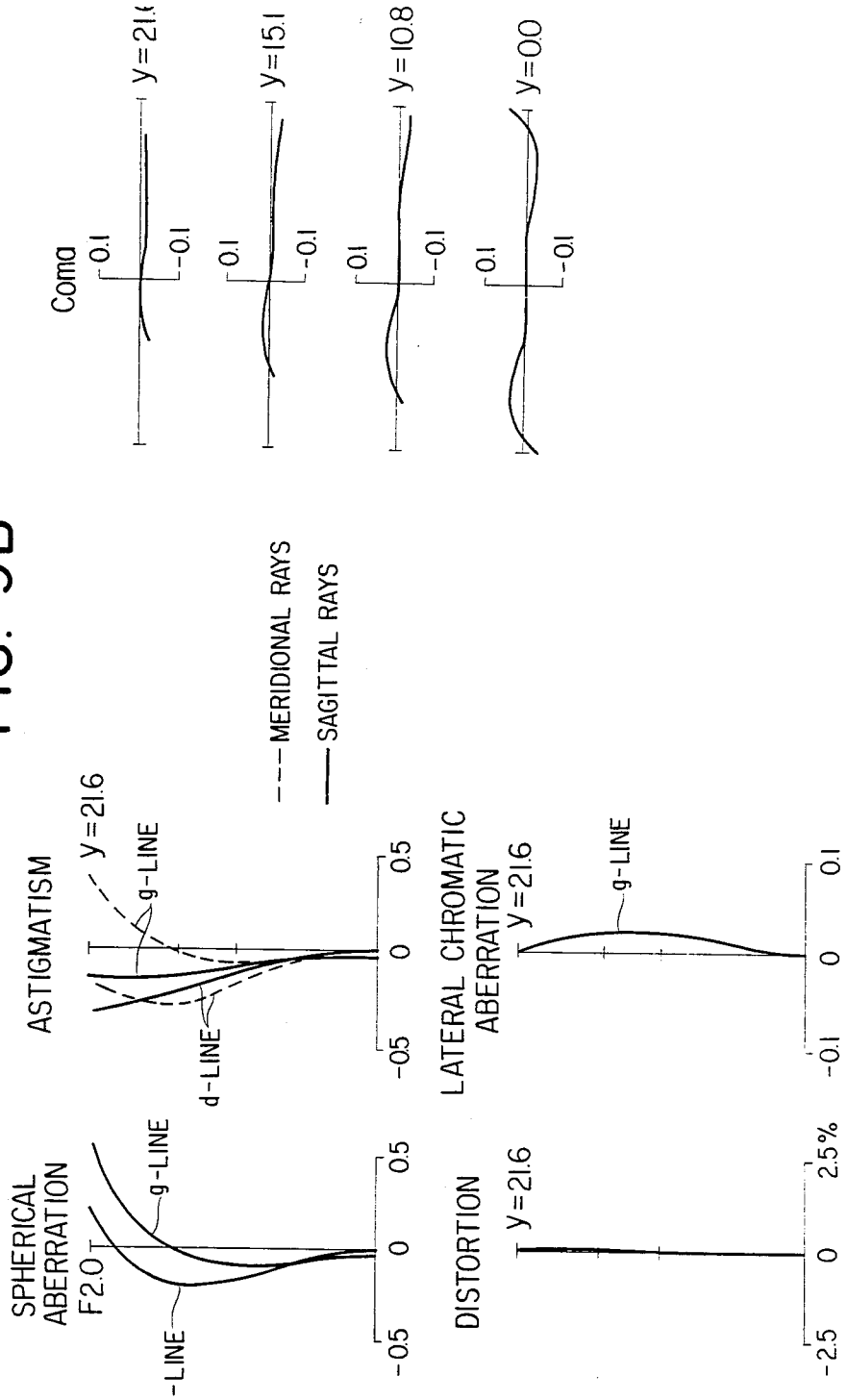
-2.5

FIG. 9B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d-LINE
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—SAGITTAL RAYS
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-0.5
LATERAL CHROMATIC ABERRATION
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g-LINE
0.1
-0.1
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F2.0
g-LINE
d-LINE
DISTORTION
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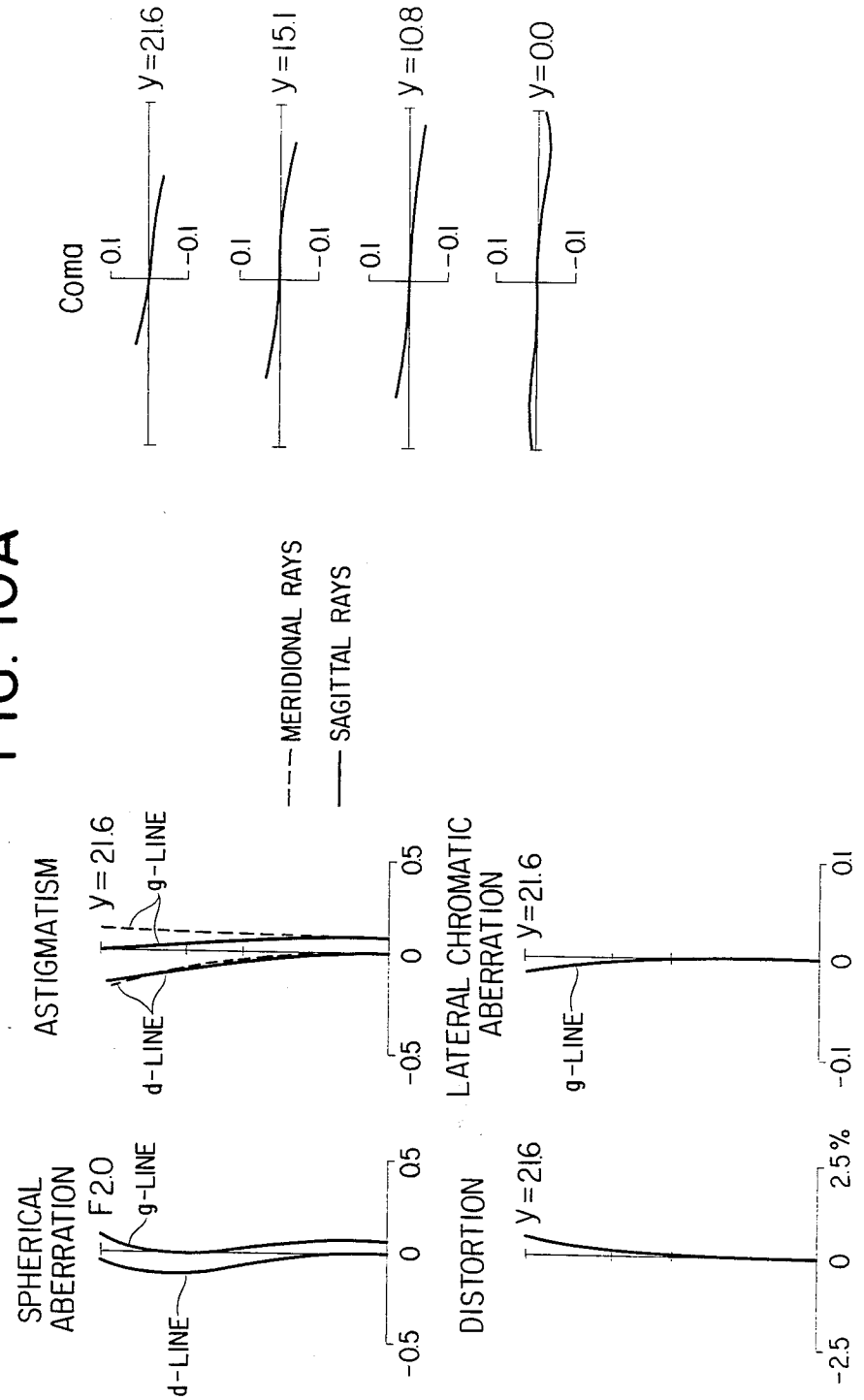
2.5%
-2.5

FIG. 10A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d-LINE
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LATERAL CHROMATIC ABERRATION
y=21.6
g-LINE
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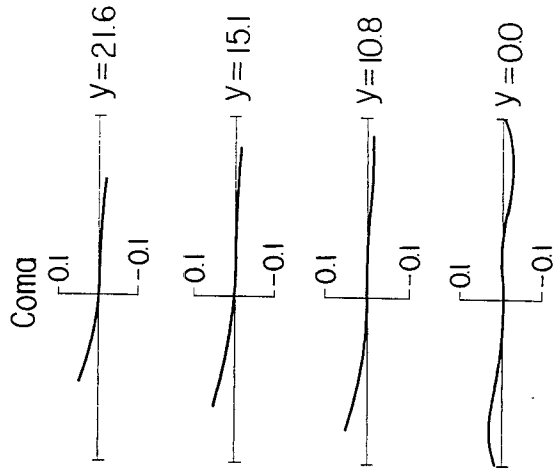
0.1
SPHERICAL ABERRATION
F2.0
g-LINE
d-LINE
DISTORTION
y=21.6
-2.5
0
2.5%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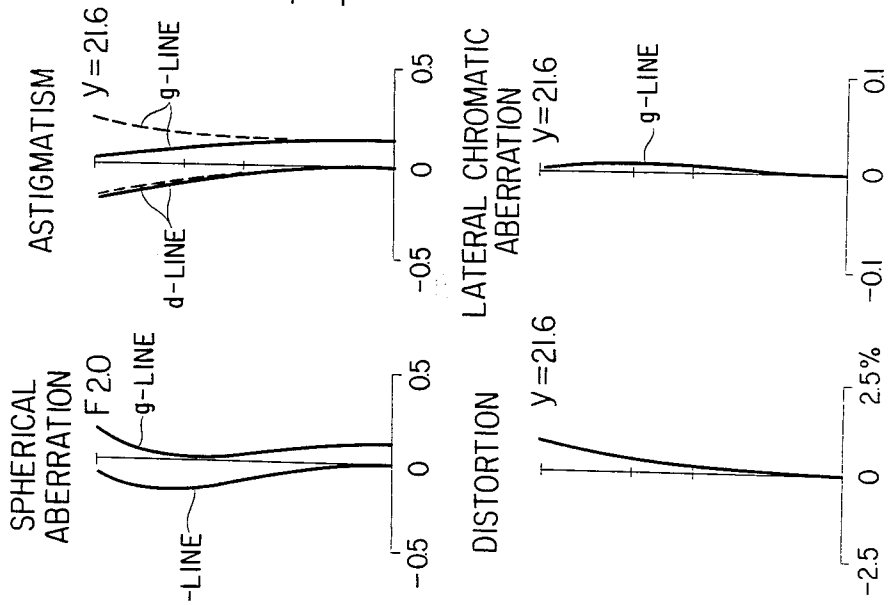
y=10.8
y=0.0

FIG. 10B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g-LINE
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SPHERICAL ABERRATION
F 2.0
g-LINE
d-LINE
LATERAL CHROMATIC ABERRATION
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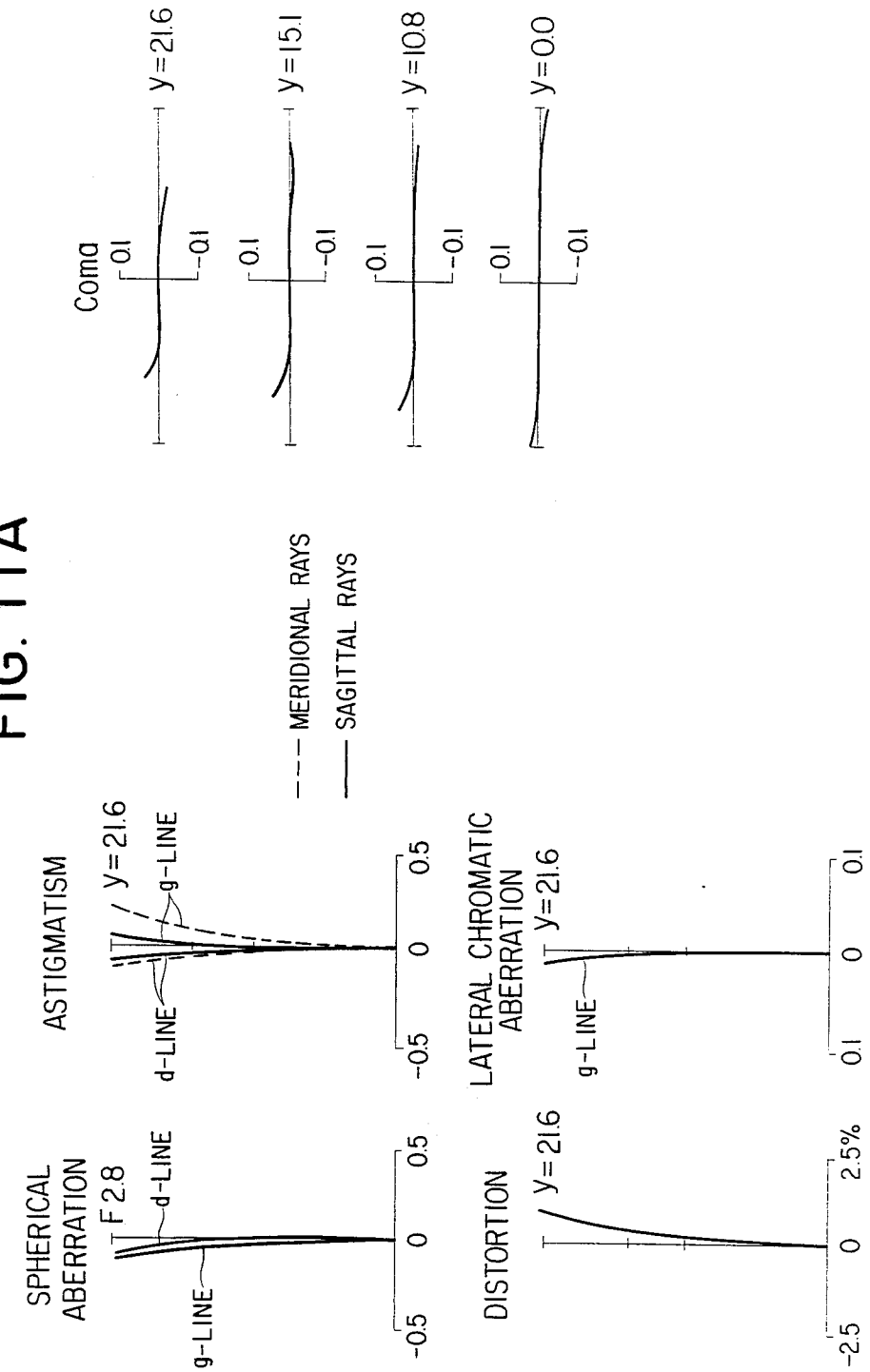
0.1
DISTORTION
y=21.6
-2.5
0
2.5%

FIG. 11A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y=10.8
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SAGITTAL RAYS
ASTIGMATISM
y=21.6
d-LINE
g-LINE
-0.5
0
0.5
SPHERICAL ABERRATION
F 2.8
d-LINE
g-LINE
LATERAL CHROMATIC ABERRATION
y=21.6
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DISTORTION
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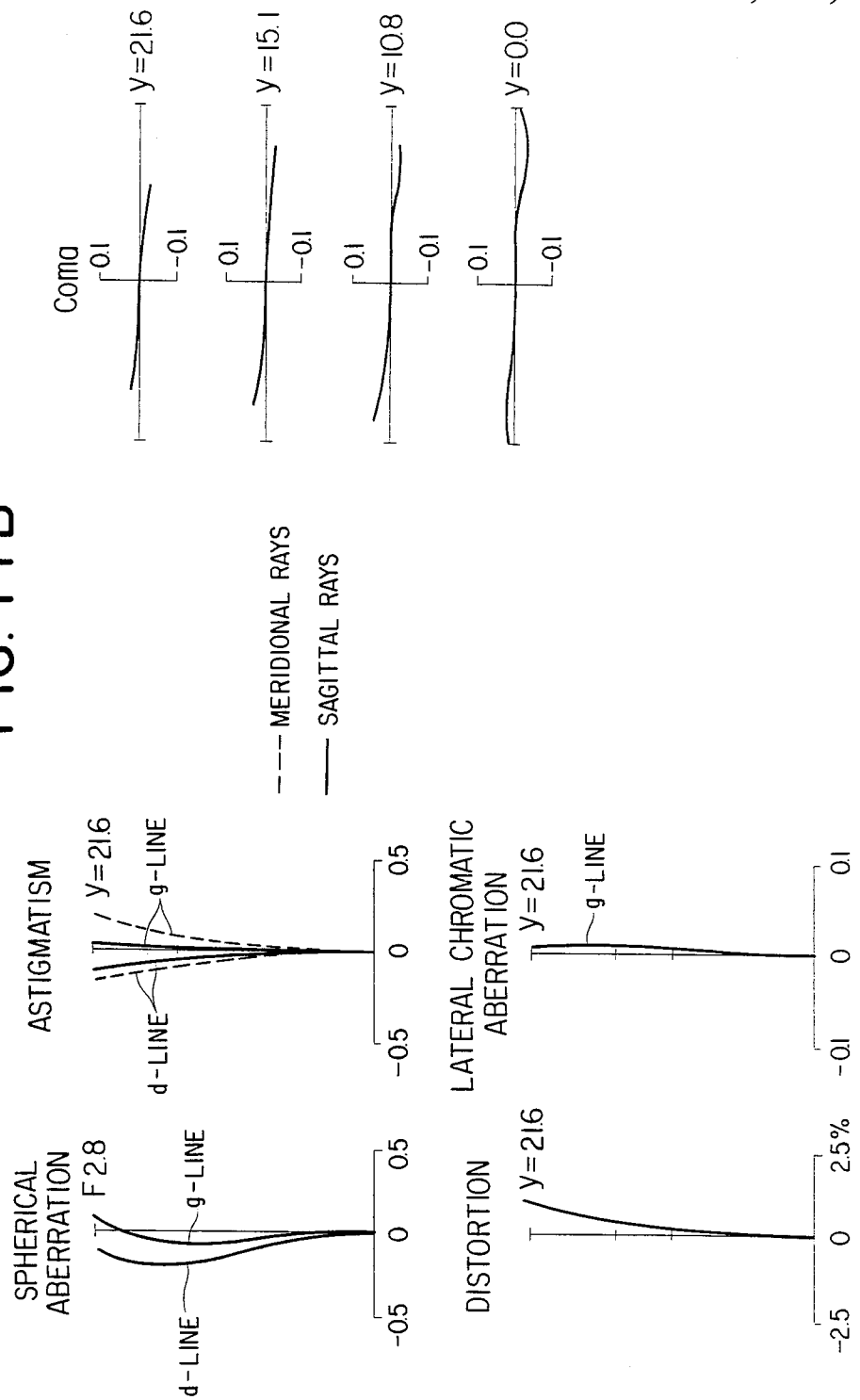
2.5%

FIG. 11B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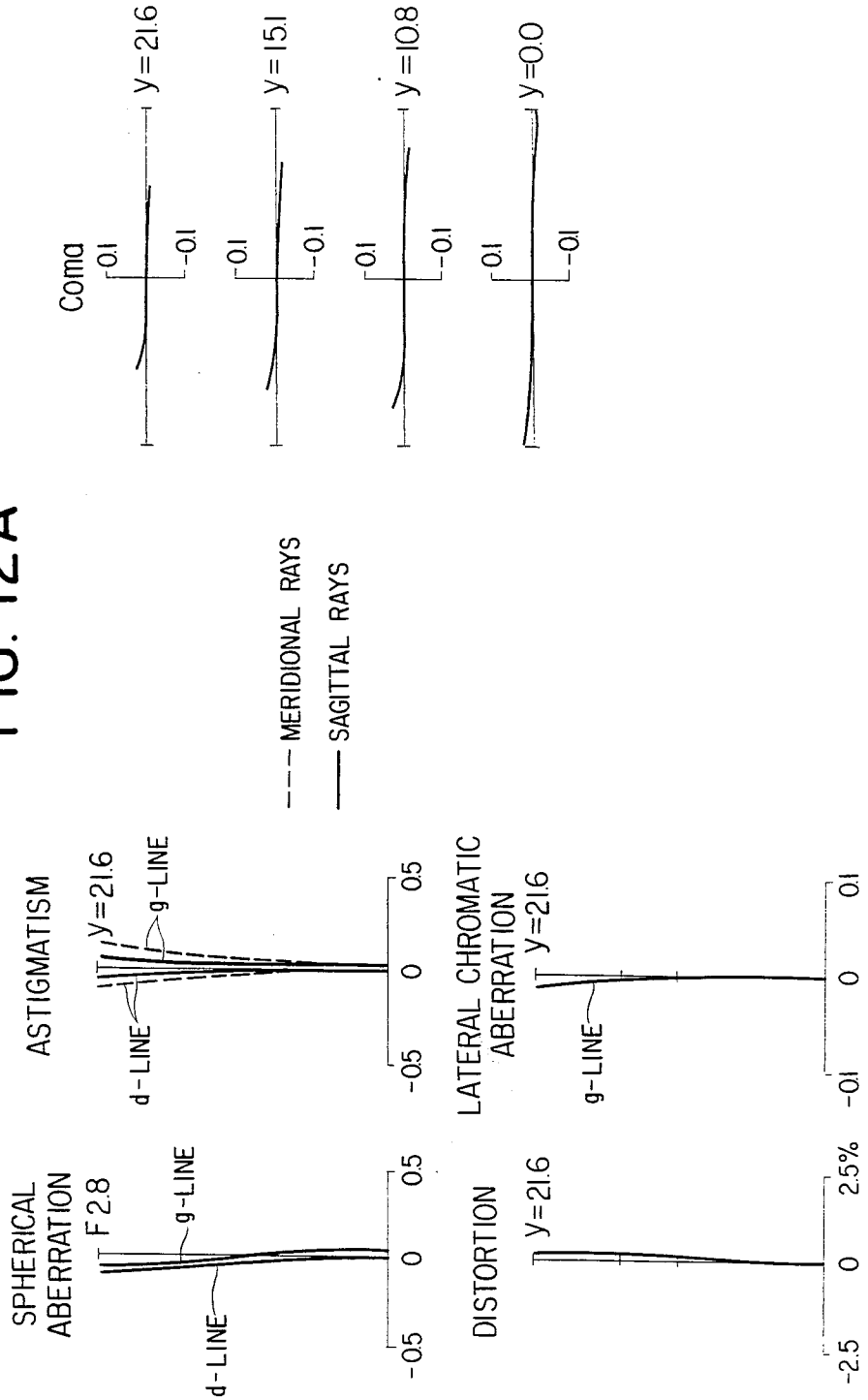
— SAGITTAL RAYS
ASTIGMATISM
y=21.6
g-LINE
d-LINE
0.5
0
-0.5
SPHERICAL ABERRATION F 2.8
LATERAL CHROMATIC ABERRATION
DISTORTION
2.5%
-2.5
-0.1

FIG. 12A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ASTIGMATISM
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d-LINE
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-0.5
SPHERICAL ABERRATION
F 2.8
LATERAL CHROMATIC ABERRATION
DISTORTION
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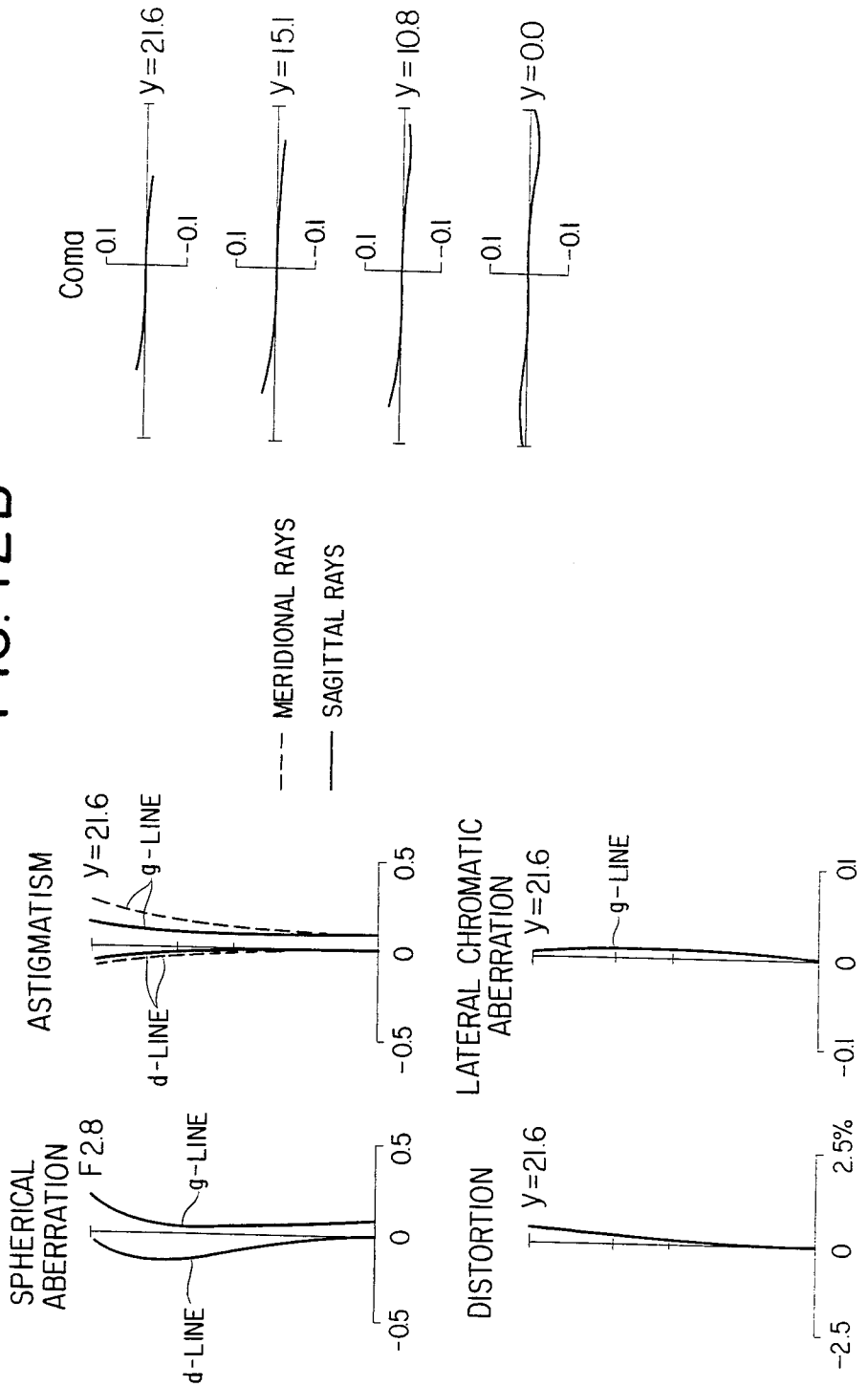
-2.5

FIG. 12B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d-LINE
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-0.5
SPHERICAL ABERRATION
F 2.8
LATERAL CHROMATIC ABERRATION
DISTORTION
2.5%
-2.5

FAST TELEPHOTO LENS

This is a continuation application of Ser. No. 633,297 filed July 23, 1984, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fast telephoto lens.

2. Description of the Prior Art

Fast telephoto lenses for still cameras, especially 35-mm still cameras have been demanded for indoor sports photography since strobes cannot be used for this purpose. In addition, indoor sports are played in a limited space, so a closest focusing distance image magnification is required to be about −0.1. In order to satisfy the above needs, pictures must be taken will full-aperture, resulting in a decrease in a focal depth. Therefore, a high-performance telephoto lens having no deviations in aberration from infinity to the closest focusing distance when full-aperture is performed is needed.

A conventional telephoto lens having an F-number of 2.0 and is disclosed in U.S. Pat. No. 4,176,913, assigned to the assignee of the present invention. This telephoto lens has a maximum focal length of about 200 mm. When the telephoto lens is focused on an object at the closest focusing distance, a plurality (two or three) of lens groups are shifted at different speeds by a floating mechanism, thereby obtaining a telephoto lens having an F-number of 2.0 and a focal length of 250 mm. However, at present, the floating mechanism is complicated, thus providing a complicated and large mechanism, and the deviations in aberration are not sufficiently corrected.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a telephoto lens which has a longer focal length of 300 to 400 mm, and an F-number of about 2.0 to 2.8, which does not utilize a floating mechanism, has a small deviation in aberration when the lens is focused on an object, and has a simple construction for shifting only one set of lens groups.

In principle, the fast internal focusing telephoto lens according to the present invention comprises positive, negative and positive lens groups from the object side and only the negative (second) lens group is shifted to obtain an in-focus state. A new lens configuration is found in these lens groups.

More specifically, the internal focusing telephoto lens according to the present invention comprises a first converging lens group G1, a diverging lens group G2 and a second converging lens group G3. When the telephoto lens is focused on an object at infinity, the first converging lens group G1 and the diverging lens group G2 constitute an afocal system, and the diverging lens group G2 is shifted toward the image, thereby focusing the telephoto lens from the object at infinity to the closest focusing distance. The first converging lens group G1 includes at least two positive lens components and a negative lens component from the object side. The diverging lens group G2 includes two negative lens components. At least one of these negative lens components comprises an achromatic lens component consisting of a positive lens and a negative lens adhered to the positive lens or slightly spaced apart from the positive lens. The second converging lens group G3 comprises at least one achromatic lens component consisting of a negative lens and a positive lens adhered to the negative lens or slightly spaced apart from each other.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 to 6 show lens configurations of telephoto lenses according to first to sixth embodiments of the present invention, respectively; and

FIGS. 7A and 7B to FIGS. 12A and 12B show various aberrations of the first to sixth embodiments, respectively, in which FIGS. 7A to 12A show the aberrations in the infinity in-focus state, and FIGS. 7B to 12B show aberrations in the closest distance in-focus state.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present inventions will be described with reference to the accompanying drawings.

According to the arrangement of lens components in FIG. 1, a first converging lens group G1 comprises two positive lens components and one negative lens component which are arranged from the object side. A diverging lens group G2 comprises an achromatic component and a negative lens component which are sequentially arranged from the object side. This achromatic component consists of positive and negative lens components. A second converging lens group G3 comprises two achromatic components each of which consists of positive and negative lens components adhered to each other.

According to the arrangement of lens components in FIG. 2, a meniscus lens component having a convex surface opposing the object side is additionally arranged at the image side of the first converging lens group G1 of FIG. 1.

According to the arrangement of lens components in FIG. 3, a diverging lens group G2 and a second converging lens group G3 have arrangement different from those in FIG. 1. More specifically, the diverging lens group G2 comprises a positive lens component and a negative lens component which are sequentially arranged from the object side and an achromatic lens component consisting of positive and negative lens components adhered to each other from the object side. The second converging lens group G3 comprises, in order from the object side, a positive lens component, a positive meniscus lens component having a convex surface opposing the image side, a negative meniscus lens component having a convex surface opposing the image side, a negative meniscus lens component having a convex surface opposing the image side, and an achromatic lens component consisting of a positive lens component and a negative lens component which are sequentially arranged from the object side and are adhered to each other.

The arrangement of the lens components shown in FIG. 4 is substantially the same as that in FIG. 2.

The arrangement of the lens components shown in FIG. 5 is substantially the same as that in FIG. 4, except that a second converging lens group G3 comprises an achromatic lens component consisting of a negative lens and a positive lens which are sequentially arranged from the object side and which are adhered to each other, a filter P, a negative meniscus lens component having a convex surface opposing the image side, and a positive lens component.

The arrangement of the lens components shown in FIG. 6 is substantially the same as that in FIG. 5.

According to the present invention, it was found that a lens system must be prepared to satisfy conditions (1) to (3) below so as to obtain a fast high-performance telephoto lens having a focal length of 300 to 400 mm and an F-number of 2.0 to 2.8.

$$0.7f \leqq f1 < f \quad (1)$$

$$0.12f \leqq f2 \leqq 0.48f \quad (2)$$

$$-1.50 \leqq (rb+ra)/(rb-ra) \leqq -0.50 \quad (3)$$

where

f: the focal length of the entire optical system

f1: the focal length of the first converging lens group

f2: the focal length of the diverging lens group

ra: the radius of curvature of a surface of the negative lens component in the diverging lens group that is located nearer the object, the surface being that closest to the object

rb: the radius of curvature of a surface of the negative lens component in the diverging lens group that is located nearer the object, the surface being that closest to the image

Condition (1) defines the range of focal length of the first converging lens group with respect to the focal length of the entire lens system. The focal length of the first converging lens group is the most important factor for correcting spherical aberration so as to obtain a fast telephoto lens. When the first converging lens group comprises three or four lenses, the range given by condition (1) is optimal. When the focal length of the first converging lens group G1 falls below the lower limit of the range given by condition (1), it is very difficult to correct the spherical aberration with the first converging lens group, resulting in a high-order curvature. In this case, correction cannot be performed to obtain a focal depth corresponding to the F-number of 2.0 to 2.8. In addition, a lens system constituted by the diverging lens group G2 and the second converging lens group G3 must magnify an image with a larger magnification factor. As a result, the secondary spectrum is increased. On the other hand, when the focal length exceeds the upper limit of the range given by condition (1), it is easy to correct the spherical aberration. However, the overall length of the telephoto lens is increased. In addition to this disadvantage, a shift distance of the diverging lens group for an in-focus state becomes longer than that of an extension type lens, resulting in inconvenience.

Condition (2) defines the optimal range of focal length of the diverging lens groups with respect to the overall focal length of the entire system. This condition is an important factor for correcting spherical aberration, astigmatism and coma, especially astigmatism. According to the lens system of the present invention, the first converging lens group and the diverging lens group constitute an afocal system for an object at infinity. Therefore, condition (2) determines a position of the diverging lens group G2 relative to the first converging lens group G1. When the focal length of the diverging lens group G2 falls below the lower limit of the range given by condition (2), the diverging lens group G2 is shifted toward the image from the first converging lens group G1. When the diaphragm position is located near the second converging lens group G3, the diverging lens group G2 receives the main light rays near the optical axis. As a result, the astigmatism generated by the first converging lens group G1 can no longer be corrected. At the same time, an asymmetrical component in coma is also increased, so a negative spherical aberration generated by the first converging lens group G1 can no longer be corrected, resulting in a great negative spherical aberration. However, when the focal length of the diverging lens group G2 exceeds the upper limit of the range given by condition (2), the diverging lens group G2 is located in the vicinity of the first converging lens group G1. A diameter of the diaphragm positioned in the vicinity of the second converging lens group G3 is increased, and a diaphragm mechanism is complicated. As a result, an automatic diaphragm cannot be employed.

Condition (3) is an optimal factor for correcting the spherical aberration so as to achieve a high-performance lens system under conditions (1) and (2). In order to obtain a telephoto lens having a focal length of 300 to 400 mm and an F-number of 2.0 to 2.8, the focal depth falls within the range between about 0.06 and 0.09. A deviation in spherical aberration must be minimized. The component of the diverging lens group which is located near the object contributes most to the correction of spherical aberration. Therefore, the shape of lenses of the component described above is very important. When the ratio $(rb+ra)/(rb-ra)$ exceeds the upper limit of the range given by condition (3), an annular spherical aberration is increased, and thus the spherical aberration is excessively corrected. However, when the ratio falls below the lower limit of the range given by condition (3), the aberration correction is insufficient. In addition, when the ratio falls outside the range, the asymmetrical component in coma is also increased.

In the fundamental arrangement of the telephoto lens according to the present invention, preferable conditions for providing a higher-performance lens system are derived as follows.

For the first converging lens group,

$$0.01 < d4/f1 < 0.09 \quad (4)$$

where

d4: the second space in the first converging lens group G1

Condition (4) is used for coma correction. Oblique rays passing through a lens portion away from the optical axis thereof are strongly converged at a surface (at the image side) of the second positive lens of the first converging lens group G1 which is counted from the object. The divergence degree for the strongly converged light rays strongly diverged by a surface of the negative lens (disposed immediately after the positive lens) which opposes the image is controlled by the space between the positive and negative lenses. As a result, coma is corrected.

When the ratio d4/f1 falls outside the range given by condition (4), an asymmetrical component in coma occurs, and proper coma correction cannot be performed. The above-mentioned surfaces of the positive and negative lenses also perform chromatic aberration. When the ratio d4/f1 exceeds the upper limit of the range given by the condition (4), achromatic correction cannot be performed.

In the diverging lens group G2, the negative lens component near the object preferably serves as the achromatic component so as to satisfy the following conditions.

$$0.1 < na - nb < 0.35 \quad (5)$$

$$18 < \nu b - \nu a \quad (6)$$

$$-0.5 < (rd+rc)/(rd-rc) < 0 \quad (7)$$

where

na: the refractive index with respect to the d-line of the positive lens of the achromatic component (of the diverging lens group G2) located near the object

nb: the refractive index with respect to the d-line of the negative lens of the achromatic component (of the diverging lens group G2) located near the object

νa: the Abbe number of the positive lens of the achromatic component (of the diverging lens group G2) located near the object

νb: the Abbe number of the negative lens of the achromatic component (of the diverging lens group G2) located near the object

rc: the radius of curvature of a surface of the negative lens component in the diverging lens group G2 that is located nearer the image, the surface being that nearest the object

rd: the radius of curvature of a surface of the negative lens component in the diverging lens group G2 that is located nearer the image, the surface being that nearest the image

Conditions (5) and (6) are important to correct the chromatic aberration as well as the spherical aberration. Condition (5) provides a difference between refractive indices of the positive and negative lenses, so that the converging behavior of the achromatic surface changes. Condition (6) changes the radius of curvature of the achromatic surface, also resulting in a change in converging behavior of the achromatic surface. Therefore, conditions (5) and (6) determine an optimal power of an achromatic surface so as to correct the spherical aberration with respect to all wavelengths. When a value (na−nb) falls below the lower limit of the range given by condition (5), the power of the achromatic surface at the d-line becomes weak and does not contribute to correction of the spherical aberration for the d-line. In this case, a lens material (i.e., glass) having such a low value is not the best choice. However, when the value (na−nb) exceeds the upper limit of the range given by condition (5), the converging power of the achromatic surface and then the spherical aberration are increased, and the aberration correction is insufficient. When a value ($\rightarrow$b−νa) falls below the lower limit of the range given by condition (6) in the same manner as in condition (5), the radius of curvature of the achromatic aberration and then the converging power of the converging lens group are too large to correct the chromatic aberration on the axis and the chromatic aberration of the magnification. Therefore, the spherical aberration correction becomes insufficient, resulting in inconvenience. The upper limit of the value ($\nu b - \nu a$) is determined by a commercially available glass material and is set to be about 70.

Condition (7) is associated with correction of close distance variations in spherical aberration and astigmatism. When a ratio (rd+rc)/(rd−rc) exceeds the upper limit of the range given by condition (7), the spherical aberration becomes greatly positive, and the image surface is positively curved. A difference between the infinity astigmatism and the closest distance astigmatism is increased, resulting in inconvenience. However, when the ratio (rd+rc)/(rd−rc) falls below the lower limit of the range given by condition (7), the spherical aberration becomes greatly negative, and the image surface is negatively curved. As a result, the difference between the infinity aberration and the closest distance aberration is increased, resulting in inconvenience.

As described above in detail, according to the present invention, a simple three-group type internal focusing telephoto lens is used to constitute a fast telephoto lens.

The present invention is not limited to the first to sixth embodiments described above. In each of the first to sixth embodiments, the first converging lens group G1 comprises two positive lens components and one negative lens component which are sequentially arranged from the object side. However, a positive lens component may be added to give four lenses in the first converging lens group so as to shorten the overall length thereof. When a 300-mm telephoto lens is provided, one or two achromatic components are preferably used. When a 400-mm telephoto lens is provided, a negative lens and a positive lens are added to each achromatic component, thereby properly correcting astigmatism and distortion.

The specifications of the respective telephoto lenses according to the first to sixth embodiments are listed below. In the following tables, reference symbols r1, r2, r3, . . . are radii of curvature, respectively; d1, d2, d3, . . . , thicknesses at the centers of the respective lenses and lens distances, respectively; n1, n2, n3, . . . , refractive indices of the respective lenses with respect to the d-line (λ=587.6 nm), respectively; and ν1, ν2, ν3, . . . , the Abbe numbers of the respective lenses, respectively.

First embodiment f = 300 F-number 2.0				
r1=213.382	d1=23.000	n1=1.49782	ν1=82.3	G1
r2=−738.293	d2=0.300			
r3=168.324	d3=23.000	n2=1.49782	ν2=82.3	
r4=−848.097	d4=8.200			
r5=−531.204	d5=8.100	n3=1.75692	ν3=31.7	
r6=41.072	d6=91.540			
r7=−7864.019	d7=7.900	n4=1.79886	ν4=34.1	G2
r8=−105.904	d8=3.000	n5=1.51454	ν5=54.6	
r9=193.539	d9=10.450			
r10=−114.709	d10=3.950	n6=1 46450	ν6=65.8	
r11=86.161	d11=31.231			
r12=376.118	d12=1.500	n7=1.68893	ν7=31.1	G3
r13=100.0	d13=7.000	n8=1.69350	ν8=53.8	
r14=−1707.134	d14=2.000			
r15=224.029	d15=2.350	n9=1.69895	ν9=30.1	
r16=130.0	d16=8.500	n10=1.69680	ν10=55.6	
r17=−205.257				
Bf=111.055				

Second embodiment f = 300 F-number 2.0				
r1=396.963	d1=15.00	n1=1.62041	ν1=60.3	G1
r2=−856.209	d2=0.400			
r3=169.663	d3=25.00	n2=1.49782	ν2=82.3	
r4=−848.700	d4=2.350			
r5=−708.000	d5=5.000	n3=1.75692	ν3=31.7	
r6=295.194	d6=1.400			
r7=171.269	d7=16.000	n4=1.49782	ν4=82.3	
r8=686.191	d8=78.913			
r9=1756.745	d9=10.000	n5=1.79504	ν5=28.6	G2
r10=−140.240	d10=3.000	n6=1.51454	ν6=54.6	
r11=138.770	d11=9.626			
r12=−165.595	d12=3.950	n7=1.58913	ν7=61.2	
r13=87.786	d13=23.602			
r14=628.332	d14=1.500	n8=1.68893	ν8=31.1	G3
r15=130.000	d15=7.000	n9=1.69350	ν9=53.8	
r16=−727.144	d16=2.000			
r17=254.899	d17=2.350	n10=1.69895	ν10=30.1	
r18=127.000	d18=8.500	n11=1.69680	ν11=55.6	
r19=−169.604	Bf=110.073			

Third embodiment f = 300 F-number 2.0			
r1=196.956	d1=23.000	n1=1.49782	ν1=82.3
r2=−1307.161	d2=0.300		
r3=195.829	d3=23.000	n2=1.49782	ν2=82.3

-continued

r4=−516.352	d4=9.035			G1
r5=−380.362	d5=8.100	n3=1.75692	ν3=31.7	
r6=721.299	d6=94.902			
r7=−2258.410	d7=10.000	n4=1.79886	ν4=34.0	
r8=−117.177	d8=2.000			
r9=−101.703	d9=3.000	n5=1.46450	ν5=65.8	G2
r10=148.618	d10=20.495			
r11=−95.192	d11=5.000	n6=1.69350	ν6=53.8	
r12=−61.177	d12=3.950	n7=1.51118	ν7=50.9	
r13=93.433	d13=24.547			
r14=98.544	d14=10.000	n8=1.62041	ν8=60.3	
r15=−121.912	d15=3.300			
r16=−261.503	d16=5.000	n9=1.62041	ν9=60.3	
r17=−102.467	d17=3.000			
r18=−92.976	d18=3.000	n10=1.75520	ν10=27.6	G3
r19=−511.672	d19=8.000			
r20=−70.661	d20=3.000	n11=1.80518	ν11=25.4	
r21=−94.501	d21=0.090			
r22=88.159	d22=10.000	n12=1.60342	ν12=38.1	
r23=−100.000	d23=3.000	n13=1.62041	ν13=60.3	
r24=357.774	Bf=46.847			

Fourth embodiment f = 300 F-number 2.0

r1=443.373	d1=14.500	n1=1.49782	ν1=82.3	
r2=−745.663	d2=0.500			
r3=235.410	d3=21.000	n2=1.49782	ν2=82.3	
r4=−599.816	d4=6.850			G1
r5=−527.848	d5=6.000	n3=1.74950	ν3=35.2	
r6=473.787	d6=1.700			
r7=176.900	d7=15.000	n4=1.49782	ν4=82.3	
r8=558.189	d8=102.701			
r9=749.672	d9=8.000	n5=1.79504	ν5=28.6	
r10=−189.496	d10=3.650	n6=1.51454	ν6=54.6	
r11=125.271	d11=12.000			G2
r12=−148.765	d12=4.800	n7=1.46450	ν7=65.8	
r13=97.985	d13=28.388			
r14=−1754.216	d14=1.500	n8=1.68893	ν8=31.1	
r15=110.000	d15=7.750	n9=1.69350	ν9=53.8	
r16=−317.940	d16=2.000			
r17=169.454	d17=2.400	n10=1.69895	ν10=30.1	G3
r18=113.525	d18=8.000	n11=1.69680	ν11=55.6	
r19=−254.060	Bf=112.223			

Fifth embodiment f = 400 F-number 2.8

r1=366.543	d1=15.000	n1=1.49782	ν1=82.3	
r2=−644.512	d2=.000			
r3=213.552	d3=21.000	n2=1.49782	ν2=82.3	
r4=−441.810	d4=5.000			G1
r5=−394.853	d5=4.800	n3=1.74950	ν3=35.2	
r6=432.180	d6=1.300			
r7=156.381	d7=14.000	n4=1.49782	ν4=82.3	
r8=1095.641	d8=86.847			
r9=−46400.000	d9=7.000	n5=1.78470	ν5=26.1	
r10=−139.436	d10=2.500	n6=1.65160	ν6=58.5	
r11=128.330	d11=10.000			G2
r12=−172.383	d12=3.500	n7=1.51680	ν7=64.1	
r13=104.035	d13=18.449			
r14=487.163	d14=1.500	n8=1.67163	ν8=38.9	
r15=98.542	d15=10.000	n9=1.59319	ν9=67.9	
r16=−100.861	d16=25.500			
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	
r18=∞	d18=7.700			G3
r19=−161.289	d19=2.800	n11=1.78797	ν11=47.5	
r20=−458.625	d20=1.000			
r21=609.162	d21=5.700	n12=1.53172	ν12=49.1	
r22=−191.968	Bf=111.255			

Sixth embodiment f = 400 F-number 2.8

r1=404.620	d1=12.400	n1=1.49782	ν1=82.3	
r2=−739.128	d2=.500			
r3=229.061	d3=19.000	n2=1.49782	ν2=82.3	
r4=−576.364	d4=6.500			G1
r5=−504.589	d5=5.700	n3=1.74950	ν3=35.2	
r6=450.293	d6=1.600			
r7=174.251	d7=14.300	n4=1.49782	ν4=82.3	
r8=610.132	d8=102.683			
r9=774.302	d9=7.500	n5=1.79504	ν5=28.6	
r10=−170.747	d10=3.400	n6=1.51454	ν6=54.6	
r11=112.007	d11=11.200			G2
r12=−135.143	d12=4.500	n7=1.46450	ν7=65.8	
r13=98.477	d13=25.175			
r14=537.096	d14=1.500	n8=1.67163	ν8=38.9	

-continued

r15=109.866	d15=9.700	n9=1.59319	ν9=67.9	
r16=−106.723	d16=26.000			
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	
r18=∞	d18=7.800			G3
r19=−180.104	d19=2.900	n11=1.79631	ν11=41.0	
r20=−975.725	d20=1.000			
r21=119.226	d21=5.800	n12=1.53172	ν12=49.1	
r22=3284.360	Bf=113.852			

In the first embodiment, f1/f=0.90 and f2/f=0.35. When the diverging lens group G2 is shifted by 21.0 toward the image, closest distance photography with the magnification factor $\beta=-0.086$ can be performed.

In the second embodiment, f1/f=0.75 and f2/f=0.29. When the diverging lens group G2 is shifted by 16.8 toward the image, closest distance photography with the magnification factor $\beta=-0.100$ can be performed.

In the third embodiment, f1/f−0.75 and f2/f=0.35. When the diverging lens group G2 is shifted by 21.0 toward the image, closest distance photography with the magnification factor $\beta=-0.086$ can be performed.

In the fourth embodiment, f1/f=0.90 and f2/f=0.35. When the diverging lens group G2 is shifted by 21.0 toward the image, closest distance photography with the magnification factor $\beta=-0.089$ can be performed.

In the fifth embodiment, f1/f=0.54 and f2/f=0.20. When the diverging lens group G2 is shifted by 13.5 toward the image, closest distance photography with the magnification factor $\beta=-0.116$ can be performed.

In the sixth embodiment, f1/f=0.65 and f2/f=0.25. When the diverging lens group G2 is shifted by 19.8 toward the image, closest distance photography with the magnification factor $\beta=-0.118$ can be performed. It should be noted that filters P are inserted in the second converging lens groups G3 in the fifth and sixth embodiments, respectively.

The various aberrations of the respective embodiments are shown in FIGS. 7A and 7B to FIGS. 12A to 12B. The aberrations of each embodiment include spherical aberration (Sph), astigmatism (Ast), distortion (Dis), lateral chromatic aberration (Lat Chr) of the g-line (λ=435.8 nm) with respect to the d-line (λ=587.6 nm), and coma (Coma). FIGS. 7A to 12A show the various aberrations in the infinity in-focus state according to the first to sixth embodiments, and FIGS. 7B to 12B show the various aberrations in the closest distance in-focus state according to the first to sixth embodiments.

The fast telephoto lenses according to the respective embodiments have an excellent imaging performance irrespective of infinity or closest distance image magnification. It is thus apparent that the deviations in aberrations in the in-focus state are properly corrected.

I claim:

1. A fast telephoto lens, which has an F-number of approximately 2.0 to 2.8, consisting of:

a first converging lens group;

a diverging lens group; and

a second converging lens group;

said first converging lens group, said diverging lens group and said second converging lens group being arranged in succession from the object side, said first converging lens group and said diverging lens group being arranged to constitute an afocal system with respect to an object at infinity, said diverging lens group being shifted toward an image so as to focus said fast telephoto lens on a close

distance object, said first converging lens group including at least two positive lens components and one negative lens component which are sequentially arranged from the object side, said diverging lens group including two negative lens components at least one of which consists of an achromatic lens component constituted by a positive lens and a negative lens, said second converging lens group including at least one achromatic lens component constituted by a negative lens and a positive lens, and said fast telephoto lens satisfying conditions below:

$$0.7f \leqq f_1 < f$$

$$-0.5 < (rd+rc)/(rd-rc) < 0$$

where

f: overall focal length of said fast telephoto lens

f_1: focal length of said first converging lens group

rc: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the image, the surface being that closest to the object

rd: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the image, the surface being that closest to the image.

2. A fast telephoto lens according to claim **1**, wherein said fast telephoto lens further satisfies conditions below:

$$0.12f \leqq f_2 \leqq 0.48f$$

$$-1.50 \leqq (rb + ra)/(rb - ra) \leqq -0.50$$

$$0.01 < d_4/f_1 < 0.09$$

$$0.1 < na - nb < 0.35$$

$$18 < \nu b - \nu a$$

where

f_2: focal lenth of said diverging lens group

ra: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the object, the surface being that closest to the object

rb: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the object, the surface being that closest to the image

d_4: a second space in said first converging lens group

na: refractive index of the positive lens of the achromatic component of said diverging lens group, the positive lens being located near the object

nb: refractive index of the negative lens of the achromatic component of said diverging lens group, the negative lens being located near the object

νa: Abbe number of the positive lens of the achromatic component of said diverging lens group, the positive lens being located near the object

νb: Abbe number of the negative lens of the achromatic component of said diverging lens group, the negative lens being located near the object.

3. A fast telephoto lens according to claim **1**, characterized by the following data:

f = 300 F-number 2.0				
r1=213.382	d1=23.000	n1=1.49782	ν1=82.3	G1
r2=−738.293	d2=0.300			
r3=168.324	d3=23.000	n2=1.49782	ν2=82.3	
r4=−848.097	d4=8.200			
r5=−531.204	d5=8.100	n3=1.75692	ν3=31.7	
r6=41.072	d6=91.540			
r7=−7864.019	d7=7.900	n4=1.79886	ν4=34.1	G2
r8=−105.904	d8=3.000	n5=1.51454	ν5=54.6	
r9=193.539	d9=10.450			
r10=−114.709	d10=3.950	n6=1.46450	ν6=65.8	
r11=86.161	d11=31.231			
r12=376.118	d12=1.500	n7=1.68893	ν7=31.1	G3
r13=100.0	d13=7.000	n8=1.69350	ν8=53.8	
r14=−1707.134	d14=2.000			
r15=224.029	d15=2.350	n9=1.69895	ν9=30.1	
r16=130.0	d16=8.500	n10=1.69680	ν10=55.6	
r17=−205.257				
	Bf=111.055			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

4. A fast telephoto lens according to claim **1**, characterized by the following data:

f = 300 F-number 2.0				
r1=396.963	d1=15.00	n1=1.62041	ν1=60.3	G1
r2=−856.209	d2=0.400			
r3=169.663	d3=25.00	n2=1.49782	ν2=82.3	
r4=−848.700	d4=2.350			
r5=−708.000	d5=5.000	n3=1.75692	ν3=31.7	
r6=295.194	d6=1.400			
r7=171.269	d7=16.000	n4=1.49782	ν4=82.3	
r8=686.191	d8=78.913			
r9=1756.745	d9=10.000	n5=1.79504	ν5=28.6	G2
r10=−140.240	d10=3.000	n6=1.51454	ν6=54.6	
r11=138.770	d11=9.626			
r12=−165.595	d12=3.950	n7=1.58913	ν7=61.2	
r13=87.786	d13=23.602			
r14=628.332	d14=1.500	n8=1.68893	ν8=31.1	G3
r15=130.000	d15=7.000	n9=1.69350	ν9=53.8	
r16=−727.144	d16=2.000			
r17=254.899	d17=2.350	n10=1.69895	ν10=30.1	
r18=127.000	d18=8.500	n11=1.69680	ν11=55.6	
r19=−169.604	Bf=110.073			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

5. A fast telephoto lens according to claim **1**, characterized by the following data:

f = 300 F-number 2.0				
r1=196.956	d1=23.000	n1=1.49782	ν1=82.3	G1
r2=−1307.161	d2=0.300			
r3=195.829	d3=23.000	n2=1.49782	ν2=82.3	
r4=−516.352	d4=9.035			
r5=−380.362	d5=8.100	n3=1.75692	ν3=31.7	

-continued

f = 300 F-number 2.0				
r6=721.299	d6=94.902			
r7=−2258.410	d7=10.000	n4=1.79886	ν4=34.0	G2
r8=−117.177	d8=2.000			
r9=−101.703	d9=3.000	n5=1.46450	ν5=65.8	G2
r10=148.618	d10=20.495			G2
r11=−95.192	d11=5.000	n6=1.69350	ν6=53.8	G2
r12=−61.177	d12=3.950	n7=1.51118	ν7=50.9	G2
r13=93.433	d13=24.547			
r14=98.544	d14=10.000	n8=1.62041	ν8=60.3	G3
r15=−121.912	d15=3.300			G3
r16=−261.503	d16=5.000	n9=1.62041	ν9=60.3	G3
r17=−102.467	d17=3.000			G3
r18=−92.976	d18=3.000	n10=1.75520	ν10=27.6	G3
r19=−511.672	d19=8.000			G3
r20=−70.661	d20=3.000	n11=1.80518	ν11=25.4	G3
r21=−94.501	d21=0.090			G3
r22=88.159	d22=10.000	n12=1.60342	ν12=38.1	G3
r23=−100.000	d23=3.000	n13=1.62041	ν13=60.3	G3
r24=357.774	Bf=46.847			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

6. A fast telephoto lens according to claim 1, characterized by the following data:

f =300 F-number 2.0				
r1=443.373	d1=14.500	n1=1.49782	ν1=82.3	G1
r2=−745.663	d2=0.500			G1
r3=235.410	d3=21.000	n2=1.49782	ν2=82.3	G1
r4=−599.816	d4=6.850			G1
r5=−527.848	d5=6.000	n3=1.74950	ν3=35.2	G1
r6=473.787	d6=1.700			G1
r7=176.900	d7=15.000	n4=1.49782	ν4=82.3	G1
r8=558.189	d8=102.701			
r9=749.672	d9=8.000	n5=1.79504	ν5=28.6	G2
r10=−189.496	d10=3.650	n6=1.51454	ν6=54.6	G2
r11=125.271	d11=12.000			G2
r12=−148.765	d12=4.800	n7=1.46450	ν7=65.8	G2
r13=97.985	d13=28.388			
r14=−1754.216	d14=1.500	n8=1.68893	ν8=31.1	G3
r15=110.000	d15=7.750	n9=1.69350	ν9=53.8	G3
r16=−317.940	d16=2.000			G3
r17=169.454	d17=2.400	n10=1.69895	ν10=30.1	G3
r18=113.525	d18=8.000	n11=1 69680	ν11=55.6	G3
r19=−254.060	Bf=112.223			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

7. A fast telephoto lens according to claim 1, characterized by the following data:

f = 400 F-number 2.8				
r1=366.543	d1=15.000	n1=1.49782	ν1=82.3	G1
r2=−644.512	d2=.000			G1
r3=213.552	d3=21.000	n2=1.49782	ν2=82.3	G1
r4=−441.810	d4=5.000			G1

-continued

f = 400 F-number 2.8				
r5=−394.853	d5=4.800	n3=1.74950	ν3=35.2	G1
r6=432.180	d6=1.300			
r7=156.381	d7=14.000	n4=1.49782	ν4=82.3	G1
r8=1095.641	d8=86.847			
r9=−46400.000	d9=7.000	n5=1.78470	ν5=26.1	G2
r10=−139.436	d10=2.500	n6=1.65160	ν6=58.5	G2
r11=128.330	d11=10.000			G2
r12=−172.383	d12=3.500	n7=1.51680	ν7=64.1	G2
r13=104.035	d13=18.449			
r14=487.163	d14=1.500	n8=1.67163	ν8=38.9	G3
r15=98.542	d15=10.000	n9=1.59319	ν9=67.9	G3
r16=−100.861	d16=25.500			G3
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	G3
r18=∞	d18=7.700			G3
r19=−161.289	d19=2.800	n11=1.78797	ν11=47.5	G3
r20=−458.625	d20=1.000			G3
r21=609.162	d21=5.700	n12=1.53172	ν12=49.1	G3
r22=−191.968	Bf=111.255			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

8. A fast telephoto lens according to claim 1, characterized by the following data:

f = 400 F-number 2.8				
r1=404.620	d1=12.400	n1=1.49782	ν1=82.3	G1
r2=−739.128	d2=.500			G1
r3=229.061	d3=19.000	n2=1.49782	ν2=82.3	G1
r4=−576.364	d4=6.500			G1
r5=−504.589	d5=5.700	n3=1.74950	ν3=35.2	G1
r6=450.293	d6=1.600			G1
r7=174.251	d7=14.300	n4=1.49782	ν4=82.3	G1
r8=610.132	d8=102.683			
r9=774.302	d9=7.500	n5=1.79504	ν5=28.6	G2
r10=−170.747	d10=3.400	n6=1.51454	ν6=54.6	G2
r11=112.007	d11=11.200			G2
r12=−135.143	d12=4.500	n7=1.46450	ν7=65.8	G2
r13=98.477	d13=25.175			
r14=537.096	d14=1.500	n8=1.67163	ν8=38.9	G3
r15=109.866	d15=9.700	n9=1.59319	ν9=67.9	G3
r16=−106.723	d16=26.000			G3
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	G3
r18=∞	d18=7.800			G3
r19=−180.104	d19=2.900	n11=1.79631	ν11=41.0	G3
r20=−975.725	d20=1.000			G3
r21=119.226	d21=5.800	n12=1.53172	ν12=49.1	G3
r22=3284.360	Bf=113.852			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

9. A fast telephoto lens, which has an F-number of approximately 2.0 to 2.8, comprising:

a first converging lens group;

a diverging lens group; and

a second converging lens group;

said first converging lens group, said diverging lens group and said second converging lens group being

arranged in succession from the object side, said first converging lens group and said diverging lens group being arranged to constitute an afocal system with respect to an object at infinity, said diverging lens group being shifted toward an image so as to focus said fast telephoto lens on a close distance object, said first converging lens group including at least two positive lens components and one negative lens component which are sequentially arranged from the object side, said diverging lens group including two negative lens components at least one of which consists of an achromatic lens component constituted by a positive lens and a negative lens, said second converging lens group including at least one achromatic lens component constituted by a negative lens and a positive lens, and said fast telephoto lens satisfying conditions below:

$$0.7f \leqq f_1 < f$$

$$-0.5 < (rd + rc)/(rd - rc) < 0$$

$$0.12f \leqq f_2 \leqq 0.48f$$

$$-1.50 \leqq (rb + ra)/(rb - ra) \leqq -0.50$$

$$0.01 < d_4/f_1 < 0.09$$

$$0.1 < na - nb < 0.35$$

$$18 < \nu b - \nu a$$

where

f: overall focal length of said fast telephoto lens

f_1: focal length of said first converging lens group

rc: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the image, the surface being the closest to the object

rd: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the image, the surface being that closest to the image

f_2: focal length of said diverging lens group

ra: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the object, the surface being that closest to the object

rb: radius of curvature of a surface of the negative lens component of said diverging lens group that is located nearer the object, the surface being that closest to the image

d_4: a second space in said first converging lens group

na: refractive index of the positive lens of the achromatic component of said diverging lens group, the positive lens being located near the object

nb: refractive index of the negative lens of the achromatic component of said diverging lens group, the negative lens being located near the object

νa: Abbe number of the positive lens of the achromatic component of said diverging lens group, the positive lens being located near the object

νb: Abbe number of the negative lens of the achromatic component of said diverging lens group, the negative lens being located near the object.

10. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 300 F-number 2.0				
r1=213.382	d1=23.000	n1=1.49782	ν1=82.3	G1
r2=−738.293	d2=0.300			
r3=168.324	d3=23.000	n2=1.49782	ν2=82.3	
r4=−848.097	d4=8.200			
r5=−531.204	d5=8.100	n3=1.75692	ν3=31.7	
r6=41.072	d6=91.540			
r7=−7864! 019	d7=7.900	n4=1.79886	ν4=34.1	G2
r8=−105.904	d8=3.000	n5=1.51454	ν5=54.6	
r9=193.539	d9=10.450			
r10=−114.709	d10=3.950	n6=1.46450	ν6=65.8	
r11=86.161	d11=31.231			
r12=376.118	d12=1.500	n7=1.68893	ν7=31.1	G3
r13=100.0	d13=7.000	n8=1.69350	ν8=53.8	
r14=−1707.134	d14=2.000			
r15=224.029	d15=2.350	n9=1.69895	ν9=30.1	
r16=130.0	d16=8.500	n10=1.69680	ν10=55.6	
r17=−205.257				
	Bf=111.055			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

11. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 300 F-number 2.0				
r1=396.963	d1=15.00	n1=1.62041	ν1=60.3	G1
r2=−856.209	d2=0.400			
r3=169.663	d3=25.00	n2=1.49782	ν2=82.3	
r4=−848.700	d4=2.350			
r5=−708.000	d5=5.000	n3=1.75692	ν3=31.7	
r6=295.194	d6=1.400			
r7=171.269	d7=16.000	n4=1.49782	ν4=82.3	
r8=686.191	d8=78.913			G2
r9=1756.745	d9=10.000	n5=1.79504	ν5=28.6	
r10=−140.240	d10=3.000	n6=1.51454	ν6=54.6	
r11=138.770	d11=9.626			
r12=−165.595	d12=3.950	n7=1.58913	ν7=61.2	
r13=87.786	d13=23.602			
r14=628.332	d14=1.500	n8=1.68893	ν8=31.1	G3
r15=130.000	d15=7.000	n9=1.69350	ν9=53.8	
r16=−727.144	d16=2.000			
r17=254.899	d17=2.350	n10=1.69895	ν10=30.1	
r18=127.000	d18=8.500	n11=1.69680	ν11=55.6	
r19=−169.604	Bf=110.073			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

12. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 300 F-number 2.0				
r1=196.956	d1=23.000	n1=1.49782	ν1=82.3	G1
r2=−1307.161	d2=0.300			
r3=195.829	d3=23.000	n2=1.49782	ν2=82.3	
r4=−516.352	d4=9.035			
r5=−380.362	d5=8.100	n3=1.75692	ν3=31.7	

-continued

f = 300 F-number 2.0				
r6=721.299	d6=94.902			
r7=−2258.410	d7=10.000	n4=1.79886	ν4=34.0	G2
r8=−117.177	d8=2.000			
r9=−101.703	d9=3.000	n5=1.46450	ν5=65.8	G2
r10=148.618	d10=20.495			G2
r11=−95.192	d11=5.000	n6=1.69350	ν6=53.8	G2
r12=−61.177	d12=3.950	n7=1.51118	ν7=50 9	G2
r13=93.433	d13=24.547			
r14=98.544	d14=10.000	n8=1.62041	ν8=60.3	G3
r15=−121.912	d15=3.300			G3
r16=−261.503	d16=5.000	n9=1.62041	ν9=60.3	G3
r17=−102.467	d17=3.000			G3
r18=−92.976	d18=3.000	n10=1.75520	ν10=27.6	G3
r19=−511.672	d19=8.000			G3
r20=−70.661	d20=3.000	n11=1.80518	ν11=25.4	G3
r21=−94.501	d21=0.090			G3
r22=88.159	d22=10.000	n12=1.60342	ν12=38.1	G3
r23=−100.000	d23=3.000	n13=1.62041	ν13=60.3	G3
r24=357.774	Bf=46.847			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

13. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 300 F-number 2.0				
r1=443.373	d1=14.500	n1=1.49782	ν1=82.3	G1
r2=−745.663	d2=0.500			G1
r3=235.410	d3=21.000	n2=1.49782	ν2=82.3	G1
r4=−599.816	d4=6.850			G1
r5=−527.848	d5=6.000	n3=1.74950	ν3=35.2	G1
r6=473.787	d6=1.700			G1
r7=176.900	d7=15.000	n4=1.49782	ν4=82.3	G1
r8=558.189	d8=102.701			
r9=749.672	d9=8.000	n5=1.79504	ν5=28.6	G2
r10=−189.496	d10=3.650	n6=1.51454	ν6=54.6	G2
r11=125.271	d11=12.000			G2
r12=−148.765	d12=4.800	n7=1.46450	ν7=65.8	G2
r13=97.985	d13=28.388			
r14=−1754.216	d14=1.500	n8=1.68893	ν8=31.1	G3
r15=110.000	d15=7.750	n9=1.69350	ν9=53.8	G3
r16=−317.940	d16=2.000			G3
r17=169.454	d17=2.400	n10=1.69895	ν10=30.1	G3
r18=113.525	d18=8.000	n11=1.69680	ν11=55.6	G3
r19=−254.060	Bf=112.223			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

14. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 400 F-number 2.8				
r1=366.543	d1=15.000	n1=1.49782	ν1=82.3	G1
r2=−644.512	d2=.000			G1
r3=213.552	d3=21.000	n2=1.49782	ν2=82.3	G1
r4=−441.810	d4=5.000			G1
r5=−394.853	d5=4.800	n3=1.74950	ν3=35.2	G1
r6=432.180	d6=1.300			G1
r7=156.381	d7=14.000	n4=1.49782	ν4=82.3	G1
r8=1095.641	d8=86.847			
r9=−46400.000	d9=7.000	n5=1.78470	ν5=26.1	G2
r10=−139.436	d10=2.500	n6=1.65160	ν6=58.5	G2
r11=128.330	d11=10.000			G2
r12=−172.383	d12=3.500	n7=1.51680	ν7=64.1	G2
r13=104 035	d13=18.449			
r14=487.163	d14=1.500	n8=1.67163	ν8=38.9	G3
r15=98.542	d15=10.000	n9=1.59319	ν9=67.9	G3
r16=−100.861	d16=25.500			G3
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	G3
r18=∞	d18=7.700			G3
r19=−161.289	d19=2.800	n11=1.78797	ν11=47.5	G3
r20=−458.625	d20=1.000			G3
r21=609.162	d21=5.700	n12=1.53172	ν12=49.1	G3
r22=−191.968	Bf=111.255			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

15. A fast telephoto lens according to claim **9**, characterized by the following data:

f = 400 F-number 2.8				
r1=404.620	d1=12.400	n1=1.49782	ν1=82.3	G1
r2=−739.128	d2=.500			G1
r3=229.061	d3=19.000	n2=1.49782	ν2=82.3	G1
r4=−576.364	d4=6.500			G1
r5=−504.589	d5=5.700	n3=1.74950	ν3=35.2	G1
r6=450.293	d6=1.600			G1
r7=174.251	d7=14.300	n4=1.49782	ν4=82.3	G1
r8=610.132	d8=102.683			
r9=774.302	d9=7.500	n5=1.79504	ν5=28.6	G2
r10=−170.747	d10=3.400	n6=1.51454	ν6=54.6	G2
r11=112.007	d11=11.200			G2
r12=−135.143	d12=4.500	n7=1.46450	ν7=65.8	G2
r13=98.477	d13=25.175			
r14=537.096	d14=1.500	n8=1.67163	ν8=38.9	G3
r15=109.866	d15=9.700	n9=1.59319	ν9=67.9	G3
r16=−106.723	d16=26.000			G3
r17=∞	d17=2.000	n10=1.51680	ν10=64.1	G3
r18=∞	d18=7.800			G3
r19=−180.104	d19=2.900	n11=1.79631	ν11=41.0	G3
r20=−975.725	d20=1.000			G3
r21=119.226	d21=5.800	n12=1.53172	ν12=49.1	G3
r22=3284.360	Bf=113.852			

where r1, r2, r3, . . . are radii of curvature of successive lens surfaces in order from the object side; d1, d2, d3, . . . are thicknesses at the centers of respective lenses and lens distances in order from the object side; n1, n2, n3, . . . are refractive indices of respective lenses with respect to the d-line (λ=587.6 nm) in order from the object side; ν1, ν2, ν3, . . . are the Abbe numbers of respective lenses in order from the object side; and Bf is the back focal length of the telephoto lens.

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