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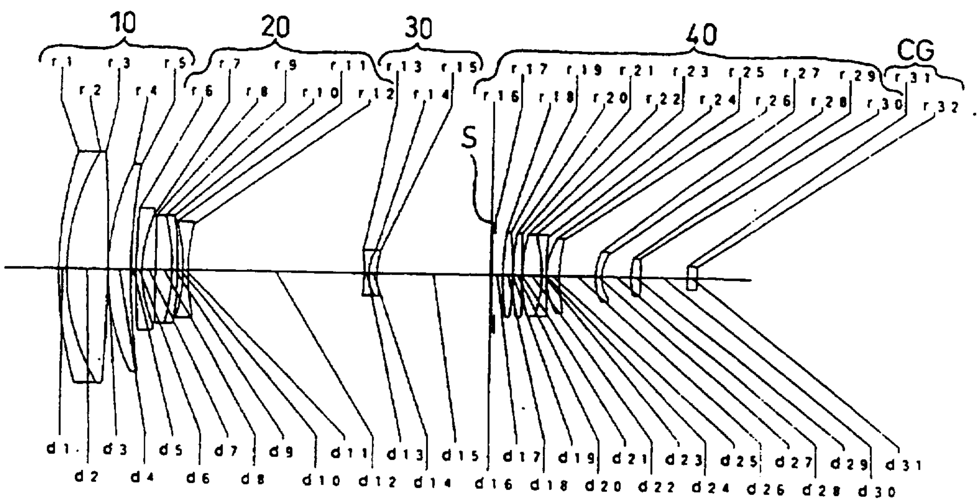
UK CL (Edition O) G2J JB7C8D
INT CL[6] G02B

(54) Four group zoom lens system having high zoom ratio

(57) A zoom lens system of high zoom ratio includes a first positive lens group 10, a second negative lens group 20, a third negative lens group 30, and a fourth positive lens group 40, arranged in this order from the object side. The second and third lens groups are moved without moving the first and fourth lens groups upon zooming. The lens system satisfies the condition (1) $1 < (D_{3W} - D_{3T})/f_W < 6$, wherein D_{3W} represents the distance between the third lens group and the fourth lens group at the short focal length extremity, D_{3T} represents the distance between the third lens group and the fourth lens group at the long focal length extremity, and f_W represents the focal length of the entire lens system at the short focal length extremity. CG is a glass cover for a CCD image pickup and S is a diaphragm.

Fig. 1



GB 2 316 500 A

Fig. 1

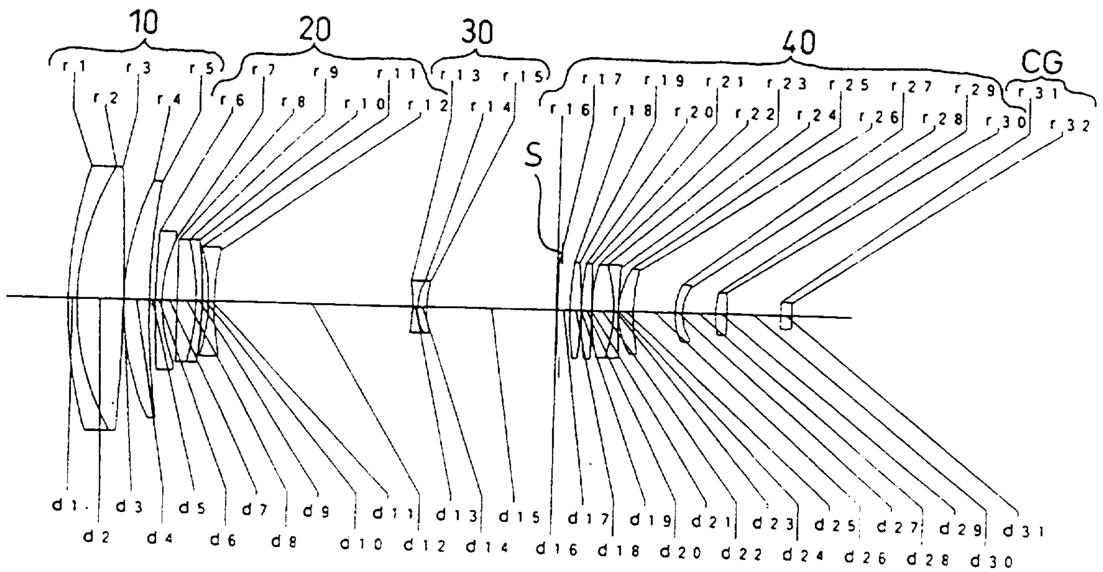
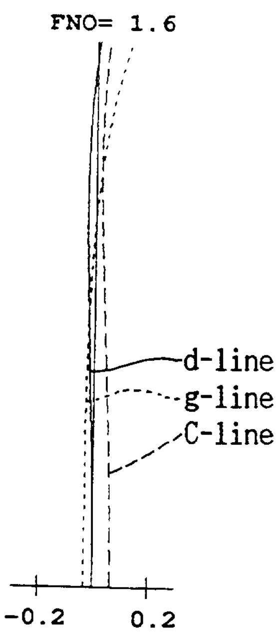


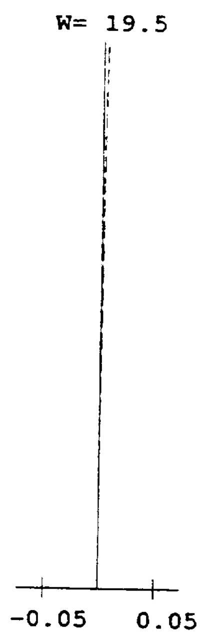
Fig.2A



SPHERICAL ABERRATION

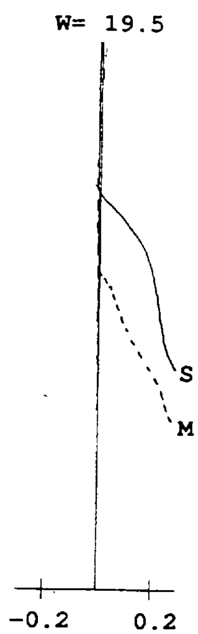
CHROMATIC ABERRATION

Fig.2B



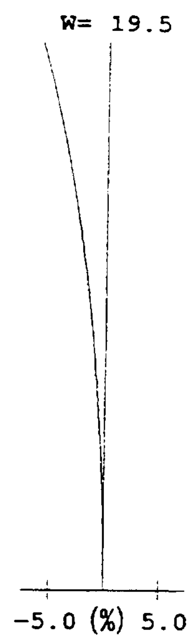
TRANSVERSE CHROMATIC ABERRATION

Fig.2C



ASTIGMATISM

Fig.2D



DISTORTION

Fig. 3

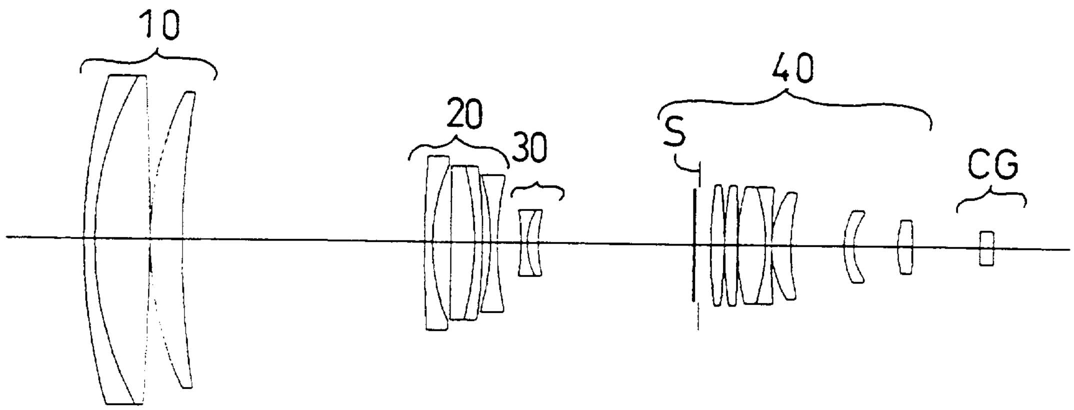
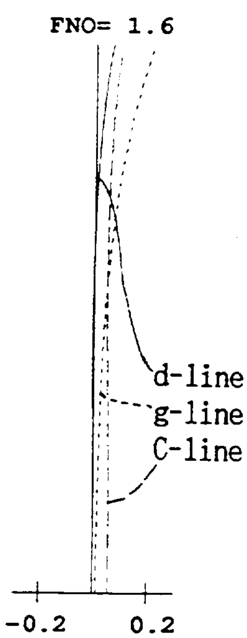


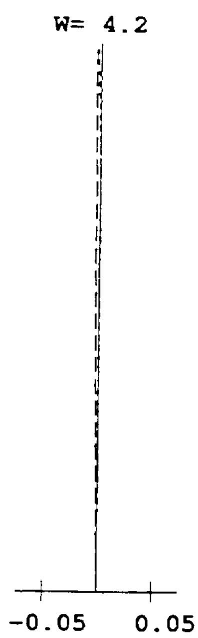
Fig.4A



SPHERICAL ABERRATION

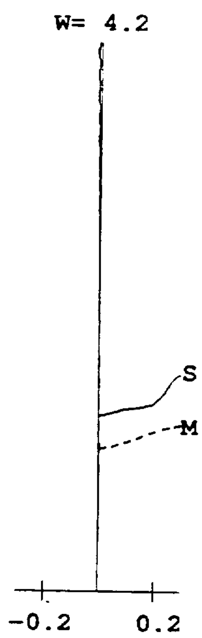
CHROMATIC ABERRATION

Fig.4B



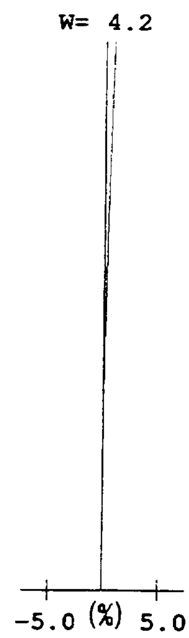
TRANSVERSE CHROMATIC ABERRATION

Fig.4C



ASTIGMATISM

Fig.4D



DISTORTION

Fig. 5

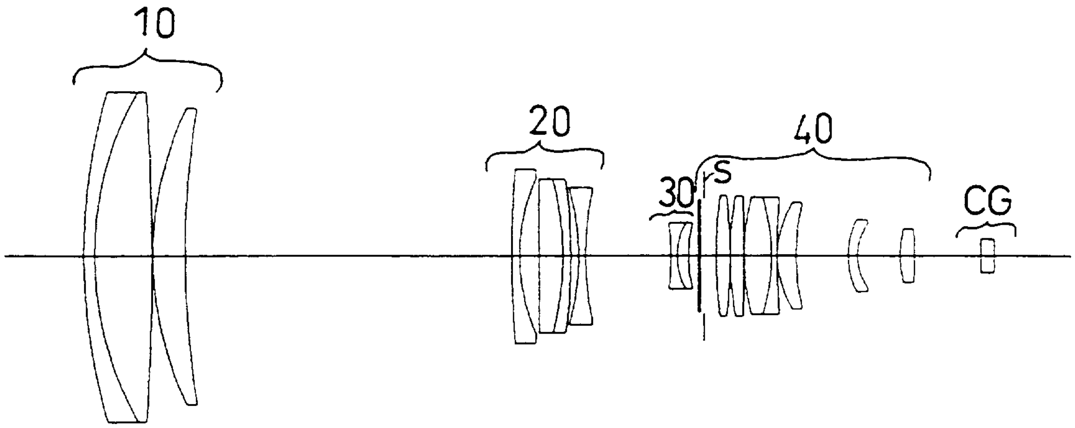
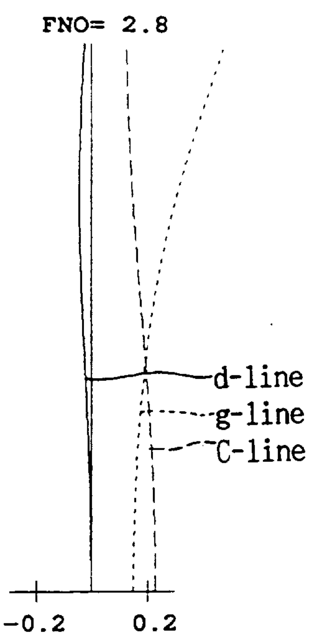


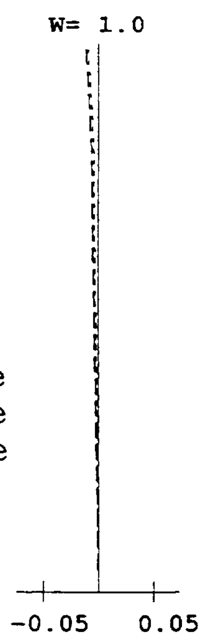
Fig.6A



SPHERICAL ABERRATION

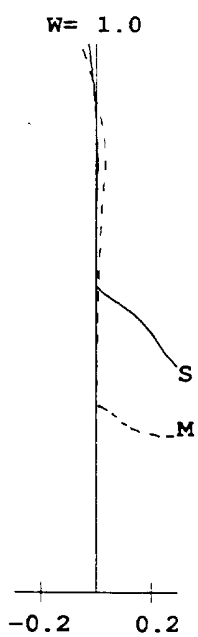
CHROMATIC ABERRATION

Fig.6B



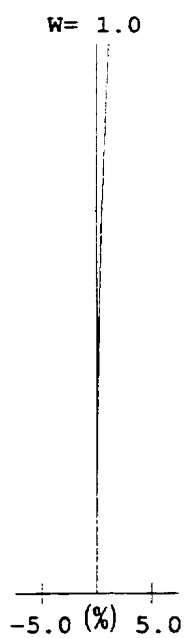
TRANSVERSE CHROMATIC ABERRATION

Fig.6C



ASTIGMATISM

Fig.6D



DISTORTION

Fig. 7

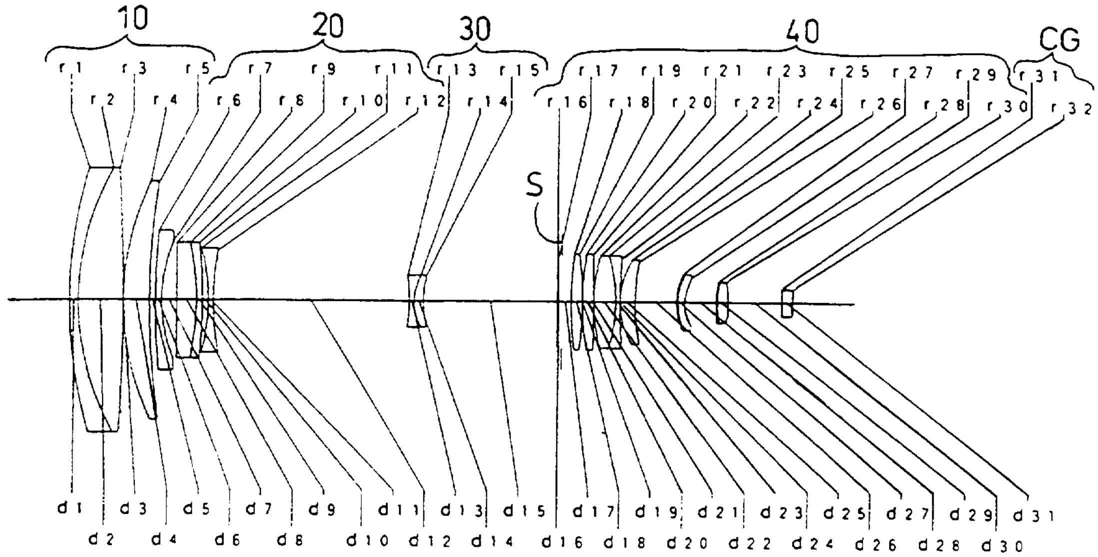
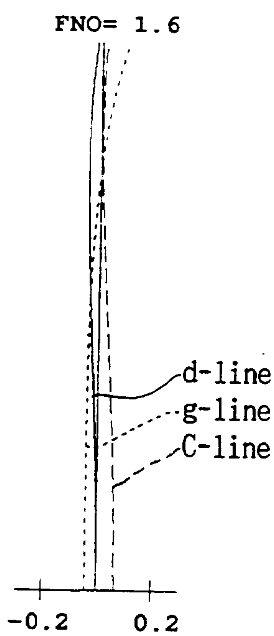


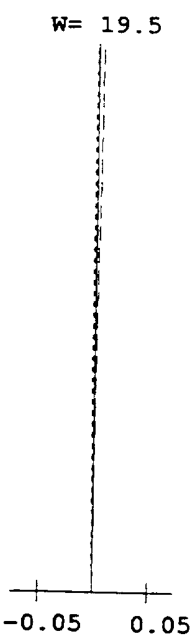
Fig. 8A



SPHERICAL ABERRATION

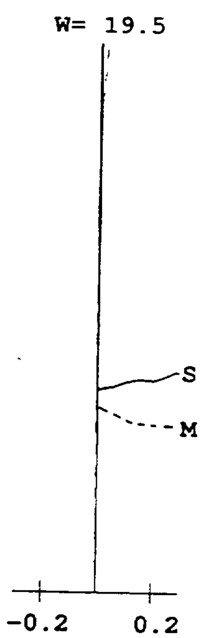
CHROMATIC ABERRATION

Fig. 8B



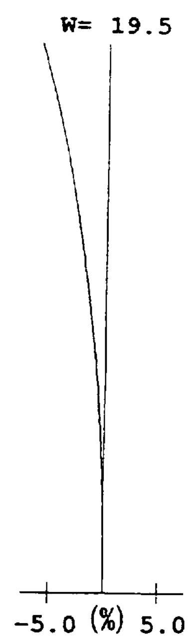
TRANSVERSE CHROMATIC ABERRATION

Fig. 8C



ASTIGMATISM

Fig. 8D



DISTORTION

Fig. 9

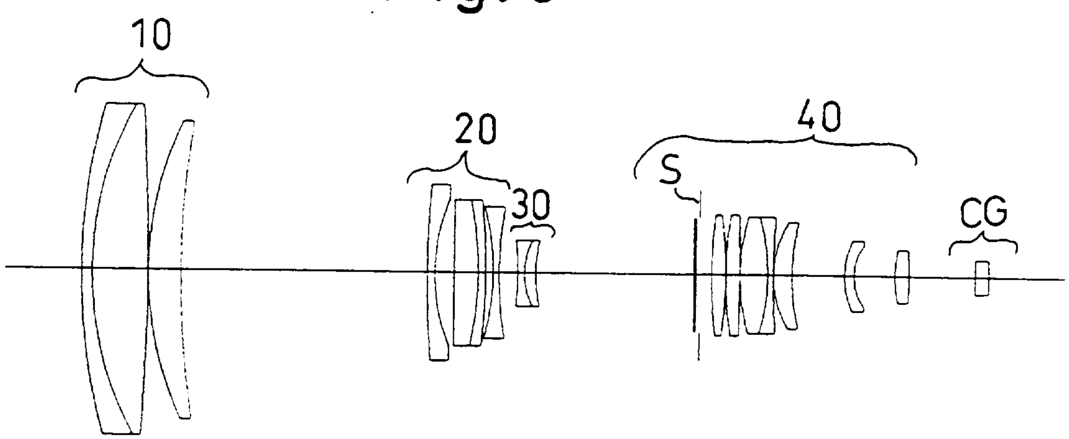


Fig. 10A Fig. 10B Fig. 10C Fig. 10D

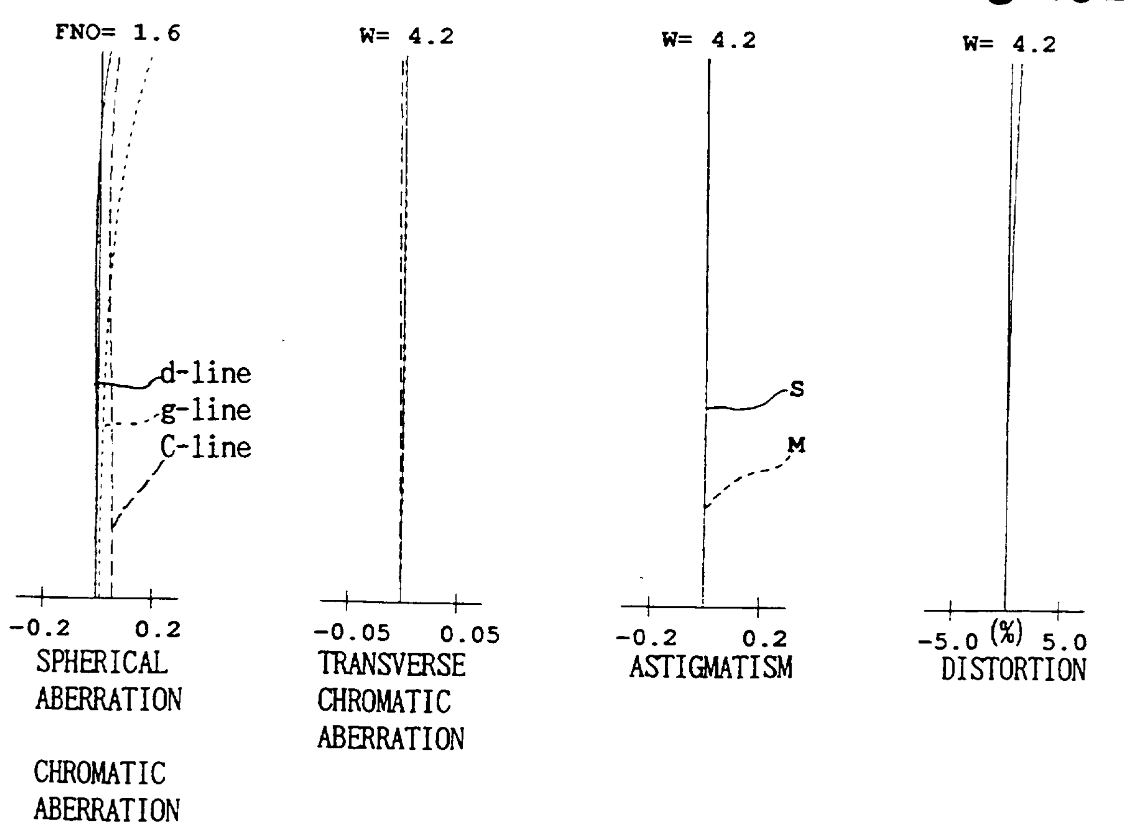


Fig. 11

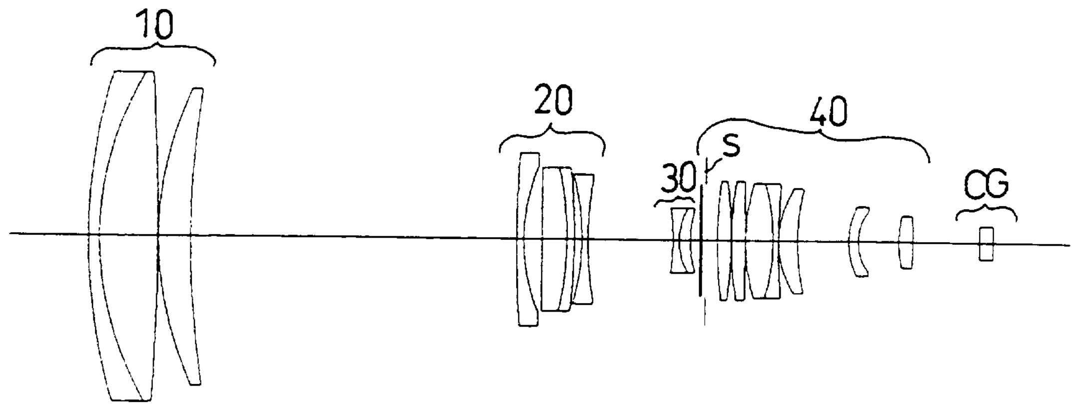


Fig.12A Fig.12B Fig.12C Fig.12D

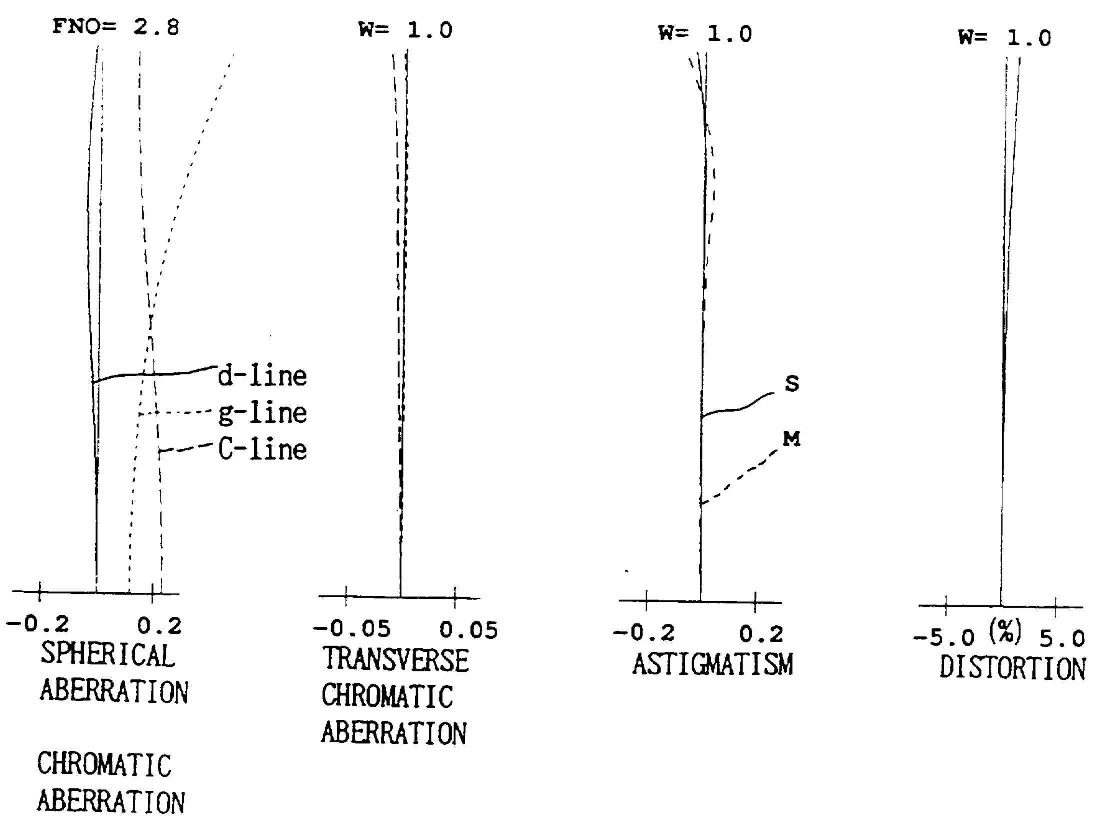


Fig. 13

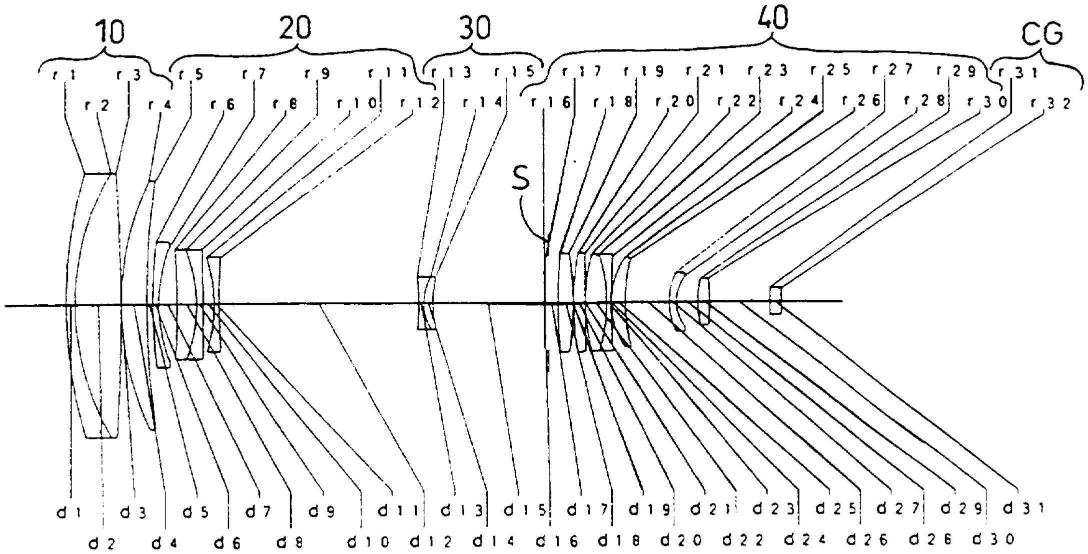
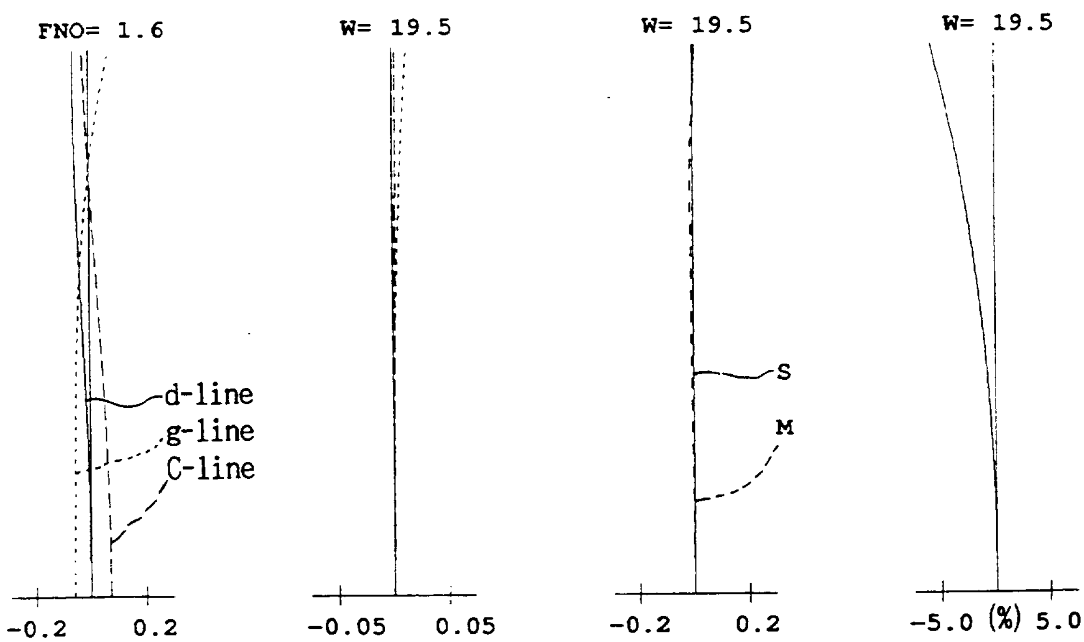


Fig. 14A Fig. 14B Fig. 14C Fig. 14D



SPHERICAL ABERRATION

CHROMATIC ABERRATION

TRANSVERSE CHROMATIC ABERRATION

ASTIGMATISM

DISTORTION

Fig.15

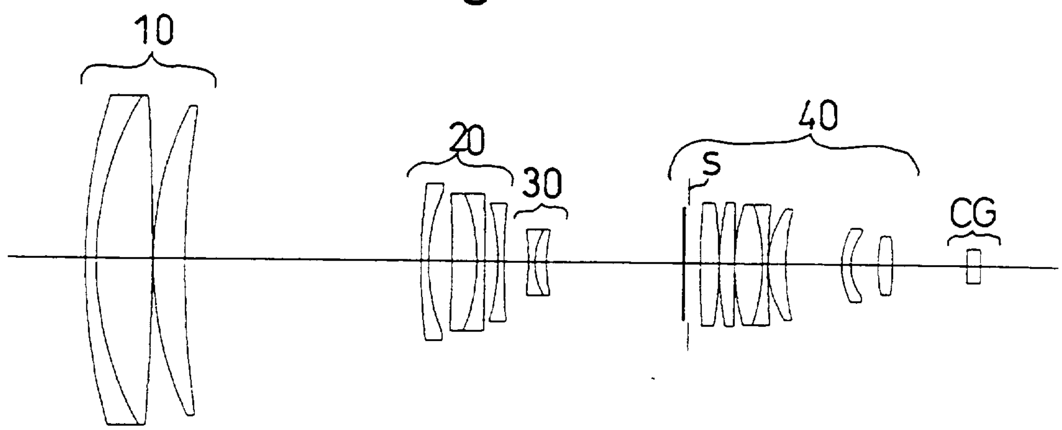


Fig.16A Fig.16B Fig.16C Fig.16D

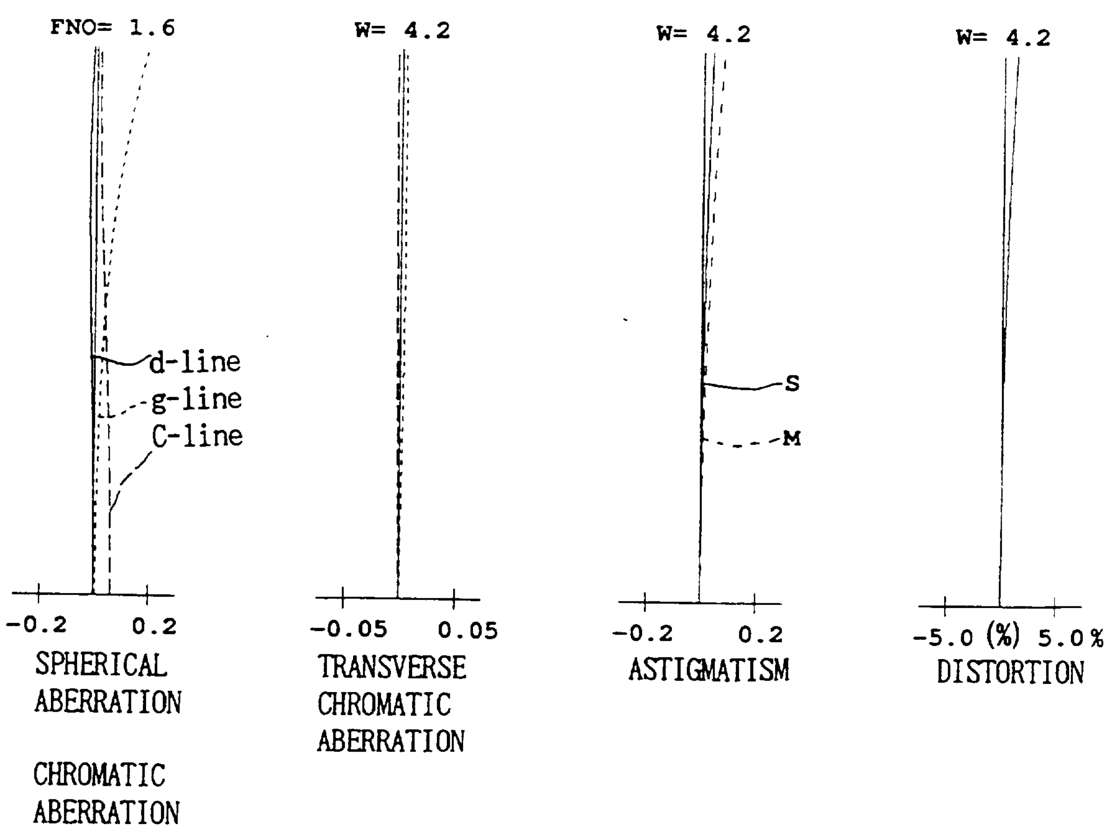


Fig. 17

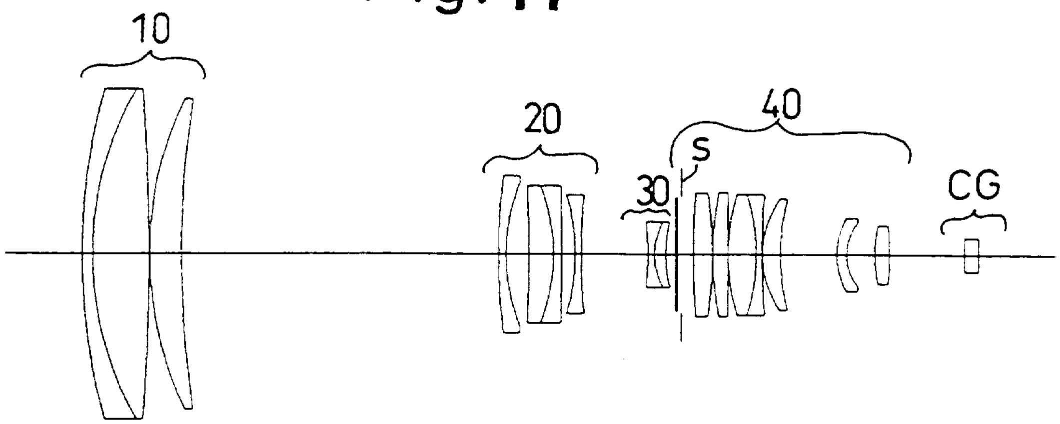


Fig.18A

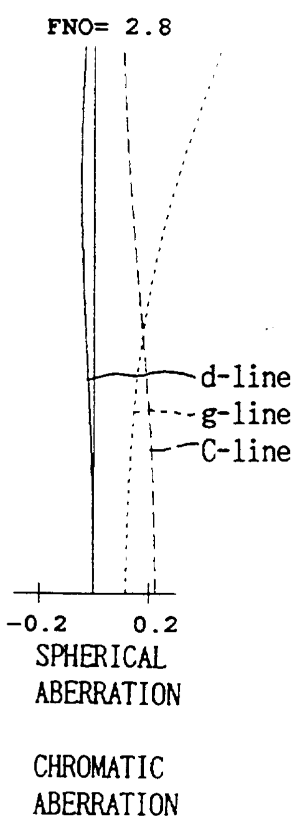


Fig.18B

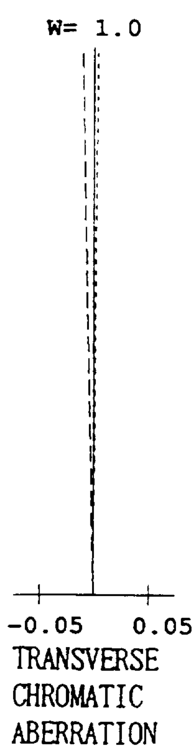


Fig.18C

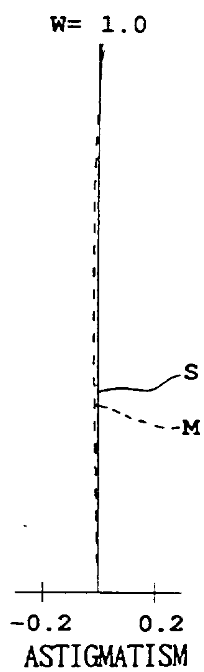


Fig.18D

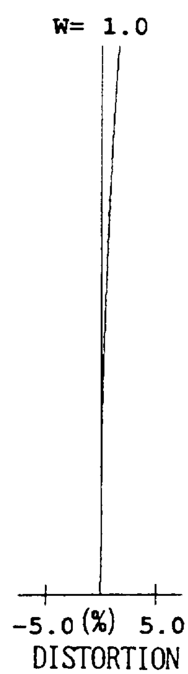
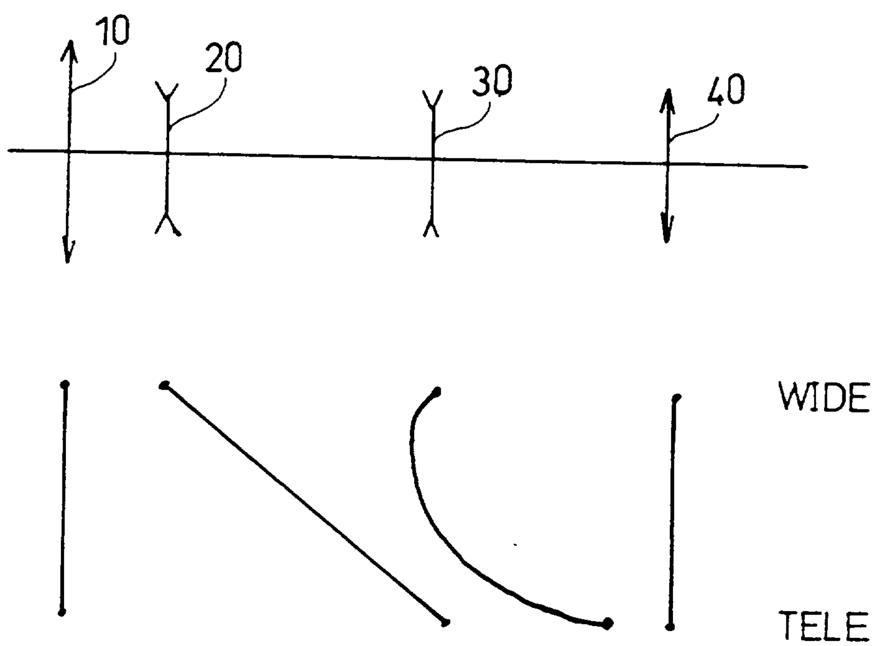


Fig. 19



ZOOM LENS SYSTEM HAVING HIGH ZOOM RATIO

The present invention relates to a zoom lens system having a high zoom ratio, which can be applied to a TV camera such as a CCTV camera.

In accordance with a variety of CCTV cameras, there has been a need for a zoom lens having a high zoom ratio. However, the zoom ratio of a conventional zoom lenses is, in many cases, in the range of approximately 10 to 15. If the zoom ratio is more than 15, the lens performance is reduced.

It is an object of the present invention to provide a zoom lens system having a high zoom ratio which is approximately equal to 20 with a high performance.

According to the present invention, there is provided a zoom lens system having high zoom ratio comprising a first lens group having positive refracting power, a second lens group having negative refracting power, a third lens group having negative refracting power, and a fourth lens group having positive refracting power, said four lens groups being arranged in this order from the object side, wherein the second and third lens groups are moved without moving the first and fourth lens groups upon zooming, and wherein the following condition (1) is satisfied;

(1) $1 < (D_{3W} - D_{3T})/f_w < 6$

wherein D_{3W} represents the distance between the third lens group and the fourth lens group at the short focal length extremity, D_{3T} represents the distance between the third lens group and the fourth lens group at the long focal length extremity, and f_w represents the focal length of the entire lens system at the short focal length extremity.

Preferably, the zoom lens system further satisfies the following condition (2);

(2) $6 < (D_{2w} + D_{3w})/f_w < 12$

wherein D_{2w} represents the distance between the second lens group and the third lens group at the short focal length extremity.

Preferably, the zoom lens system satisfies the following conditions (3) and (4);

(3) $0.05 < f_w/f_1 < 0.12$

(4) $-0.5 < f_w/f_2 < -0.1$

wherein f_1 represents the focal length of the first lens group and f_2 represents the focal length of the second lens group.

It is preferable that at least one lens element of the first lens group satisfies the following condition (5);

(5) $80 < \nu_{d1}$

wherein ν_{d1} represents the Abbe number of said at least one lens element of the first lens group.

It is preferable that at least one lens element of the fourth lens group satisfies the following condition (6);

(6) $80 < \nu_{d4}$

wherein ν_{d4} represents the Abbe number of said at least one lens element of the fourth lens group.

Examples of the present invention will be described below in detail with reference to the accompanying drawings, in which;

Figure 1 is a schematic view showing a lens arrangement of a first embodiment of a zoom lens system of high zoom ratio at a short focal length extremity, of the present invention;

Figures 2A, 2B, 2C and 2D are aberration diagrams of a zoom lens system shown in Fig. 1;

Figure 3 is a schematic view showing the lens arrangement of a first embodiment of a zoom lens system of high zoom ratio at an intermediate focal length, of the present invention;

Figures 4A, 4B, 4C and 4D are aberration diagrams of a zoom lens system shown in Fig. 3;

Figure 5 is a schematic view showing the lens arrangement of a first embodiment of a zoom lens system of high zoom ratio at a long focal length extremity, of the present invention;

Figures 6A, 6B, 6C and 6D are aberration diagrams of a zoom lens system shown in Fig. 5;

Figure 7 is a schematic view showing a lens arrangement of a second embodiment of a zoom lens system of high zoom ratio at a short focal length extremity, of the present invention;

Figures 8A, 8B, 8C and 8D are aberration diagrams of a zoom lens system shown in Fig. 7;

Figure 9 is a schematic view showing the lens arrangement of a second embodiment of a zoom lens system of high zoom ratio at an intermediate focal length, of the present invention;

Figures 10A, 10B, 10C and 10D are aberration diagrams of a zoom lens system shown in Fig. 9;

Figure 11 is a schematic view showing the lens arrangement of a second embodiment of a zoom lens system of high zoom ratio at a long focal length extremity, of the present invention;

Figures 12A, 12B, 12C and 12D are aberration diagrams of a zoom lens system shown in Fig. 11;

Figure 13 is a schematic view showing a lens arrangement of a third embodiment of a zoom lens system of high zoom ratio at the short focal length extremity, of the present invention;

Figures 14A, 14B, 14C and 14D are aberration diagrams of a zoom lens system shown in Fig. 13;

Figure 15 is a schematic view showing the lens arrangement of a third embodiment of a zoom lens system of high zoom ratio at an intermediate focal length, of the present invention;

Figures 16A, 16B, 16C and 16D are aberration diagrams of a zoom lens system shown in Fig. 15;

Figure 17 is a schematic view showing the lens arrangement of a third embodiment of a zoom lens system of high zoom ratio at a long focal length extremity, of the present invention;

Figures 18A, 18B, 18C and 18D are aberration diagrams of a zoom lens system shown in Fig. 17; and,

Figure 19 shows tracks of movement of lens groups of a zoom lens system of high zoom ratio during the zooming operation, of the present invention.

As may be seen in Fig. 19, a zoom lens system of high zoom ratio of the present embodiment is comprised of a first positive lens group 10, a second negative lens group 20, a third negative lens group 30, and a fourth positive lens group 40. These lens groups 10 through 40 are arranged in this order from the object side. Upon zooming, the first and fourth positive lens groups 10 and 40 are not moved and the second lens group 20 (variator) and the third lens group 30 (compensator) are moved. The focusing operation is carried out by the first lens group 10. Since the second and third lens groups 20 and 30 have a negative refracting power, the axial bundle is made incident upon the fourth lens group 40 as divergent light.

In the four-lens group type zoom lens system having positive, negative, negative and positive lens groups from the object side, the diameter of the third lens group can be reduced by decreasing the distance between the third lens group and the fourth lens group at a short focal length extremity, to thereby restrict the aberrations produced at the position far from the optical axis. The third lens group is moved close to the fourth lens group to correct the focal position at the long focal length extremity. However, in the optical arrangement in which the F-number at a long focal length extremity is larger than the F-number at the short focal length extremity, no eclipse of the on-axis light occurs if the third lens group comes close to the fourth lens group.

The condition (1) specifies movement distance of the third lens group from the short focal length extremity to the long focal length extremity. If the condition (1) is satisfied, the diameter of the third lens group can be decreased. Consequently, the aberration produced at the peripheral portion of the lens can be reduced, thus resulting in a high performance.

If the ratio defined in the condition (1) exceeds the upper limit, the total length of the lenses is increased. If the ratio defined in the condition (1) is smaller than the lower limit, the diameter of the third lens group (compensator) is increased so that aberrations occur due to light passing through the portion of the third lens group distant from the optical axis.

The condition (2) specifies movement distance of the second lens group. If the condition (2) is satisfied, the movement distance of the second lens group is large enough to obtain a zoom ratio which is approximately equal to or more than 20. If the ratio defined in the condition (2) exceeds the upper limit, the total lens length becomes unacceptably large. If the ratio defined in the condition

(2) is smaller than the lower limit, it is impossible to obtain the zoom ratio of approximately 20.

The condition (3) specifies power of the first lens group. If the condition (3) is satisfied, the aberration of the first lens group can be restricted, thus resulting in less influence by the aberrations over the entire focal length range from the short focal length extremity to the long focal length extremity.

If the power of the first lens group is larger than the upper limit specified in the condition (3), the comatic aberration of the first lens group is so large that there is an influence by the comatic aberration over the entire focal length range from the short focal length extremity to the long focal length extremity. If the ratio defined in the condition (3) is smaller than the lower limit, the moving distance of the lens of the first lens group upon focusing becomes large and the diameter of the frontmost lens element of the first lens group must be increased.

The condition (4) specifies power of the second lens group. If the condition (4) is satisfied, the aberration of the second lens group can be restricted, thus resulting in less influence by the aberrations over the entire focal length range from the short focal length extremity to the long focal length extremity. Moreover, the aberration fluctuation during zooming can be reduced.

If the ratio defined in the condition (4) is larger than the upper limit, the movement distance of the second lens group upon zooming is large and the total lens length is increased. If the power of the second lens is so large that the ratio defined in the condition (4) is smaller than the lower limit, the comatic aberration of the second lens group is so large that there is an influence by the comatic aberration over the entire focal length range from the short focal length extremity to the long focal length extremity. Furthermore, the balance of aberration in the entire focal length range is worsened due to the comatic aberration upon zooming.

The conditions (5) and (6) specify the Abbe number of at least one glass lens element of the first and fourth lens groups. In particular, if the condition (5) is satisfied, the longitudinal chromatic aberration at the long focal length extremity can be compensated. If both the conditions (5) and (6) are satisfied, the longitudinal chromatic aberration not only at the long focal length extremity but also at the short focal length extremity can be compensated.

Numerical examples of the zoom lens system of the present invention will be discussed below.

<Embodiment 1>

Figs. 1 through 6 show a first embodiment of the zoom lens system of high zoom ratio. Figs. 1, 3 and 5 show a lens arrangement of the zoom lens system at the short focal length extremity, an intermediate focal length and the long focal length extremity, respectively. In the first embodiment, the lens system is composed of a first positive lens group 10, a second negative lens group 20, a third negative lens group 30, a fourth positive lens group 40, and a glass cover CG. These lens groups 10 through 40 and the glass cover CG are arranged in this order from the object side. The first and fourth lens groups 10 and 40 are stationary. Upon zooming, the second and third lens groups 20 and 30 are moved. A diaphragm S is located in the fourth lens group 40. Figs. 2A through 2D, Figs. 4A through 4D and Figs. 6A through 6D show aberration diagrams of the zoom lens system shown in Fig. 1, at the short focal length extremity, the intermediate focal length extremity, and the long focal length extremity, respectively.

Numerical data of the lens system is shown in Table 1 below. In the aberration diagrams, d-line, g-line and C-line represent the chromatic aberrations represented by spherical aberrations and lateral chromatic aberrations at the respective wavelengths, SA represents the spherical aberrations, SC represents the sine conditions, S represents the Sagittal rays, and M represents the Meridional rays, respectively.

In the following tables and drawings, F_{NO} designates the F-number, F the focal length, W the half angle of view, f_B the back focal distance including the glass cover (reduced back focal distance between the last surface of the fourth lens group and the CCD image pickup surface, i.e., the last surface of the glass cover), R the radius of curvature, D the distance between the lenses, N_d the refractive index of the d-line, and ν_d the Abbe number, respectively.

Table 1

F_{NO}=1:1.6-1.6-2.8

F=12.02-54.00-234.00 (zoom ratio ; 19.47)

W=19.5-4.2-1.0

f_B=19.83 (=D_{30}+D_{31}/N_{31}, reduced back focal distance)

Surface No.	R	D	N_d	ν_d
1	150.760	2.80	1.80518	25.4
2	87.610	14.50	1.61800	63.4
3	-685.601	0.20	-	-
4	92.459	8.00	1.49700	81.6
5	247.372	2.00-61.62-82.76	-	-
6	345.600	2.00	1.61800	63.4
7	51.954	4.80	-	-
8	∞	6.00	1.84666	23.8
9	-76.291	2.00	1.72000	43.7

10	-152.991	2.00	-	-
11	-65.500	1.80	1.72916	54.7
12	82.000	63.37- 6.01-21.54	-	-
13	-68.000	1.60	1.61772	49.8
14	17.416	2.90	1.80518	25.4
15	35.459	41.42-39.17- 2.50	-	-
16	∞	0.50	1.51633	64.1
17	∞	1.00	-	-
diaphragm	∞	3.00	-	-
18	123.000	3.50	1.80400	46.6
19	-123.000	0.10	-	-
20	99.000	3.30	1.69680	55.5
21	-1154.546	0.10	-	-
22	61.697	7.00	1.48749	70.2
23	-51.212	1.50	1.80518	25.4
24	200.755	0.10	-	-
25	26.525	4.80	1.49700	81.6
26	61.254	13.30	-	-
27	20.675	2.40	1.74950	35.3
28	14.000	11.00	-	-
29	27.915	3.70	1.51633	64.1
30	-98.790	17.52	-	-
31	∞	3.50	1.51633	64.1
32	∞	-	-	-

<Embodiment 2>

Figs. 7 through 12 show a second embodiment of a zoom lens of high zoom ratio, **of** the present invention. Figs. 7, 9 and 11 show a lens arrangement thereof at the short focal length extremity, an intermediate focal length, and the long focal length extremity. Figs. 8A through 8D, Figs. 10A through 10D and Figs. 12A through 12D show aberration diagrams of the zoom lens system shown in Figs. 7, 9 and 11, respectively. Numerical data of the second embodiment of the lens system is shown in Table 2 below.

Table 2

F_{NO}=1:1.6-1.6-2.8

F=12.00-54.00-234.00(zoom ratio;19.50)

W=19.5-4.2-1.0

f_B=19.44 (=D_{30}+D_{31}/N_{31}, reduced back focal distance)

surface No.	R	D	N_d	ν_d
1	151.327	2.80	1.78470	26.3
2	86.000	14.40	1.61800	63.4
3	-704.000	0.20	-	-
4	93.500	8.00	1.49700	81.6
5	249.207	2.00-62.15-83.22	-	-
6	275.000	1.90	1.61800	63.4
7	50.165	4.80	-	-

8	-5402.519	6.20	1.84666	23.8
9	-86.000	1.90	1.76200	40.1
10	-160.000	1.90	-	-
11	-64.907	1.60	1.72916	54.7
12	96.200	62.32- 4.84-21.55	-	-
13	-69.120	1.60	1.61772	49.8
14	17.380	2.90	1.80518	25.4
15	35.200	42.89-40.23- 2.44	-	-
16	∞	0.50	1.51633	64.1
17	∞	1.00	-	-
diaphragm	∞	3.00	-	-
18	121.500	3.50	1.80400	46.6
19	-121.500	0.10	-	-
20	98.849	3.50	1.69680	55.5
21	-2100.000	0.10	-	-
22	54.344	7.00	1.48749	70.2
23	-54.344	1.40	1.80518	25.4
24	167.164	0.10	-	-
25	26.041	4.70	1.49700	81.6
26	57.091	13.20	-	-
27	21.500	2.40	1.74950	35.3
28	13.900	10.40	-	-
29	27.682	3.70	1.51633	64.1
30	-84.000	17.13	-	-

31	∞	3.50	1.51633	64.1
32	∞	-	-	-

<Embodiment 3>

Figs. 13 through 18 show a third embodiment of a zoom lens of high zoom ratio **of** the present invention. Figs. 13, 15 and 17 show a lens arrangement thereof at the short focal length extremity, an intermediate focal length extremity, and the long focal length extremity, respectively. Figs. 14A through 14D, Figs. 16A through 16D and Figs. 18A through 18D show aberration diagrams of the zoom lens system shown in Fig. 13, 15 and 17, respectively. Numerical data of the third embodiment of the lens system is shown in Table 3 below.

Table 3

F_{NO}=1:1.6-1.6-2.8

F=12.01-54.00-234.00(zoom ratio ; 19.48)

W=19.5-4.2-1.0

f_B=21.81 (=D_{30}+D_{31}/N_{31}, reduced back focal distance)

surface No.	R	D	N_d	ν_d
1	151.258	2.80	1.78470	26.1
2	84.538	14.41	1.61800	63.4
3	-644.580	0.19	-	-

4	92.764	8.00	1.49700	81.6
5	264.927	2.00-59.34-80.90	-	-
6	159.493	1.89	1.61800	63.4
7	48.238	5.90	-	-
8	-354.221	6.26	1.84666	23.8
9	-48.062	1.99	1.79453	40.5
10	-924.540	3.38	-	-
11	-55.348	1.60	1.72916	54.7
12	186.546	63.40- 6.16-17.29	-	-
13	-71.085	1.66	1.62000	49.5
14	17.261	2.88	1.80518	25.4
15	35.428	35.22-35.12- 2.44	-	-
16	∞	0.50	1.51633	64.1
17	∞	1.00	-	-
diaphragm	∞	3.00	-	-
18	206.388	4.81	1.80400	46.6
19	-105.253	0.10	-	-
20	79.867	3.73	1.70400	54.7
21	7149.677	0.10	-	-
22	54.143	7.05	1.48749	70.2
23	-51.224	1.43	1.80518	25.4
24	194.522	0.10	-	-
25	25.511	4.50	1.49700	81.6
26	62.363	14.00	-	-

27	19.509	2.39	1.74950	35.3
28	13.157	6.98	-	-
29	35.332	3.70	1.51633	64.1
30	-78.910	19.50	-	-
31	∞	3.50	1.51633	64.1
32	∞	-	-	-

Values of the ratios defined in the conditions (1) through (6) for each embodiment are shown in Table 4 below.

Table 4

	embodiment 1	embodiment 2	embodiment 3
formula(1)	3.24	3.39	2.73
formula(2)	9.09	9.13	8.57
formula(3)	0.09	0.09	0.09
formula(4)	-0.30	-0.30	-0.34
formula(5)	81.6	81.6	81.6
formula(6)	81.6	81.6	81.6

As can be seen from Table 4, the numerical values of the first through third embodiments satisfy the conditions (1) through (6).

With the present invention, a zoom lens system having a high zoom ratio of approximately 20 and high performance can be obtained.

CLAIMS:-

1. A zoom lens system of high zoom ratio comprising a first lens group having positive refracting power, a second lens group having negative refracting power, a third lens group having negative refracting power, and a fourth lens group having positive refracting power, said four lens groups being arranged in this order from an object side, wherein the second and third lens groups are moved without moving the first and fourth lens groups upon zooming, and wherein the following condition (1) is satisfied;

(1) $1 < (D_{3W} - D_{3T})/f_w < 6$

wherein D_{3W} represents the distance between the third lens group and the fourth lens group at a short focal length extremity, D_{3T} represents the distance between the third lens group and the fourth lens group at a long focal length extremity, and f_w represents the focal length of the entire lens system at the short focal length extremity.

2. A zoom lens system according to claim 1, wherein said lens system satisfies the following condition (2);

(2) $6 < (D_{2w} + D_{3w})/f_w < 12$

wherein D_{2w} represents the distance between the second lens group and the third lens group at the short focal length extremity.

3. A zoom lens system according to claim 1 or 2, wherein

said lens system satisfies the following conditions (3) and (4);

(3) $0.05 < f_w/f_1 < 0.12$

(4) $-0.5 < f_w/f_2 < -0.1$

wherein f_1 represents the focal length of the first lens group and f_2 represents the focal length of the second lens group.

4. A zoom lens system according to any preceding claim, wherein at least one lens element of the first lens group satisfies the following condition (5);

(5) $80 < \nu_{d1}$

wherein ν_{d1} represents the Abbe number of said at least one lens element of the first lens group.

5. A zoom lens system according to any preceding claim, wherein at least one lens element of the fourth lens group satisfies the following condition (6);

(6) $80 < \nu_{d4}$

wherein ν_{d4} represents the Abbe number of said at least one lens element of the fourth lens group.

6. A zoom lens system substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Claims searched: 1-6

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G2J(JB7C8D)

Int Cl (Ed.6): G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 1497551 A	(CANON) Fig 3	1 at least
"	GB 1437620 A	(SCHNEIDER) Ex 1,2	"
"	GB 1304470 A	(") table on p 5	"
"	GB 1190873 A	(") lower table p 9	"
"	GB 1134776 A	(") table p 4	"
"	GB 1109913 A	(RANK) upper table p 12	"
"	GB 1066501 A	(") "	"
"	GB 1064323 A	(") p 12	"
"	GB 0941754 A	(IOW) pp 4-5	"
"	GB 0685945 A	(WATSON) p 5 ll 35-69	"
"	US 5282089 A	(ASAHI) Ex 2	"
"	US 4080047 A	(MINOLTA) Table 4	"
"	US 3912376 A	(") Table 1	"

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