US012386162B2

(12) **United States Patent**
Sashima et al.

(10) **Patent No.: US 12,386,162 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **OPTICAL SYSTEM, OPTICAL APPARATUS, AND METHOD OF MANUFACTURING OPTICAL SYSTEM**

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(73) Assignee: **Nikon Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 394 days.

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§ 371 (c)(1),
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PCT Pub. Date: **Nov. 21, 2019**

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(51) **Int. Cl.**
G02B 15/22 (2006.01)
G02B 15/14 (2006.01)
G02B 15/20 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 15/22*** (2013.01); ***G02B 15/143103*** (2019.08); ***G02B 15/20*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 15/22; G02B 15/143103
(Continued)

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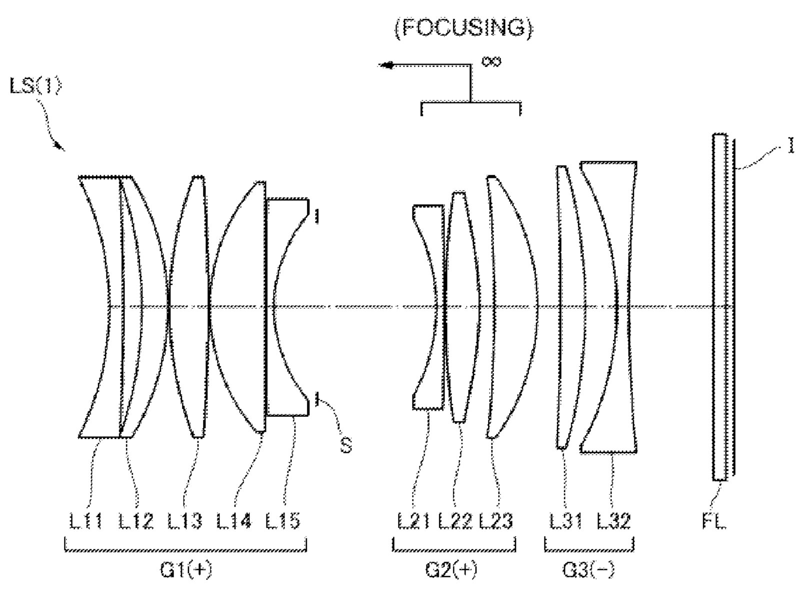
Primary Examiner — Zachary W Wilkes
(74) *Attorney, Agent, or Firm* — Potomac Law Group, PLLC

(57) **ABSTRACT**

An optical system comprises a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein, when focusing, the second lens group moves along an optical axis, and the optical system satisfies the conditional expressions 0.100<BFa/f<0.500 and −5.000<(−G1R1)/f<500.000, where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image, f is a focal length of the optical system, and G1R1 is a radius of curvature of a lens surface on the object side for a lens component disposed farthest on the object side in the first lens group.

13 Claims, 95 Drawing Sheets



(58) **Field of Classification Search**
USPC 359/784, 693
See application file for complete search history.

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JP	2012-181508	A		9/2012
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JP	2013-061547	A		4/2013
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JP	2014-095841	A		5/2014
JP	2014-102358	A		6/2014
JP	2014-235176	A		12/2014
JP	2016-090725	A		5/2016
JP	2016-099552	A		5/2016
JP	2016-161644	A		9/2016
JP	2016-212288	A		12/2016
JP	2017-215491	A		12/2017
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FIG. 1

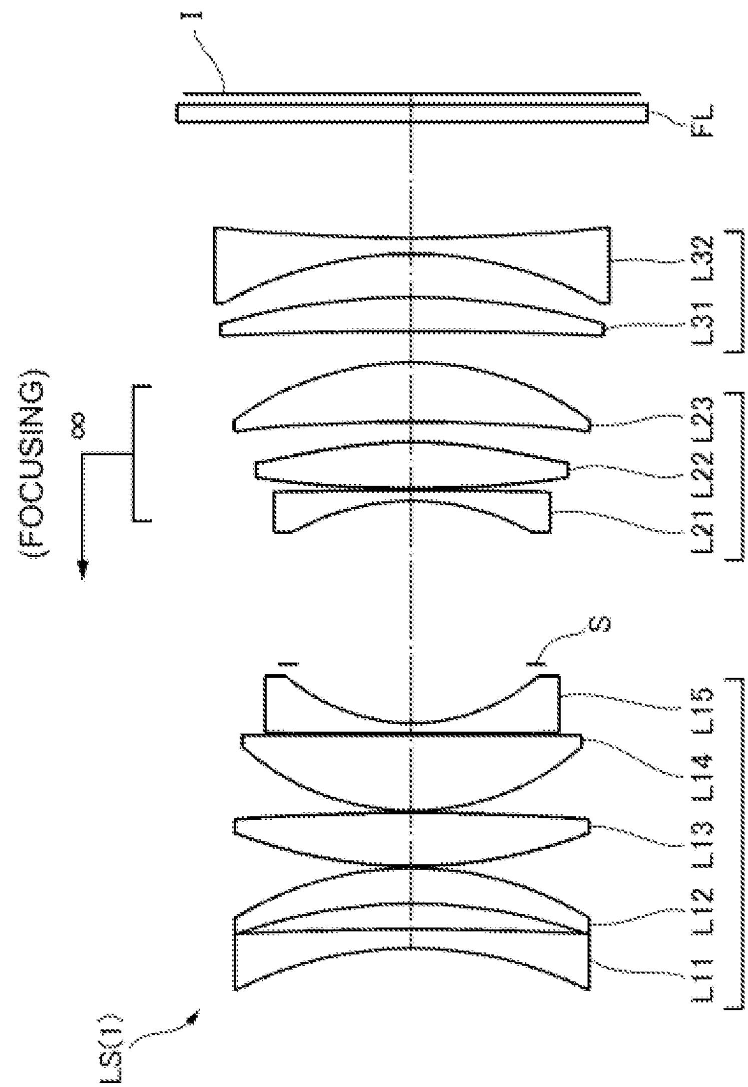
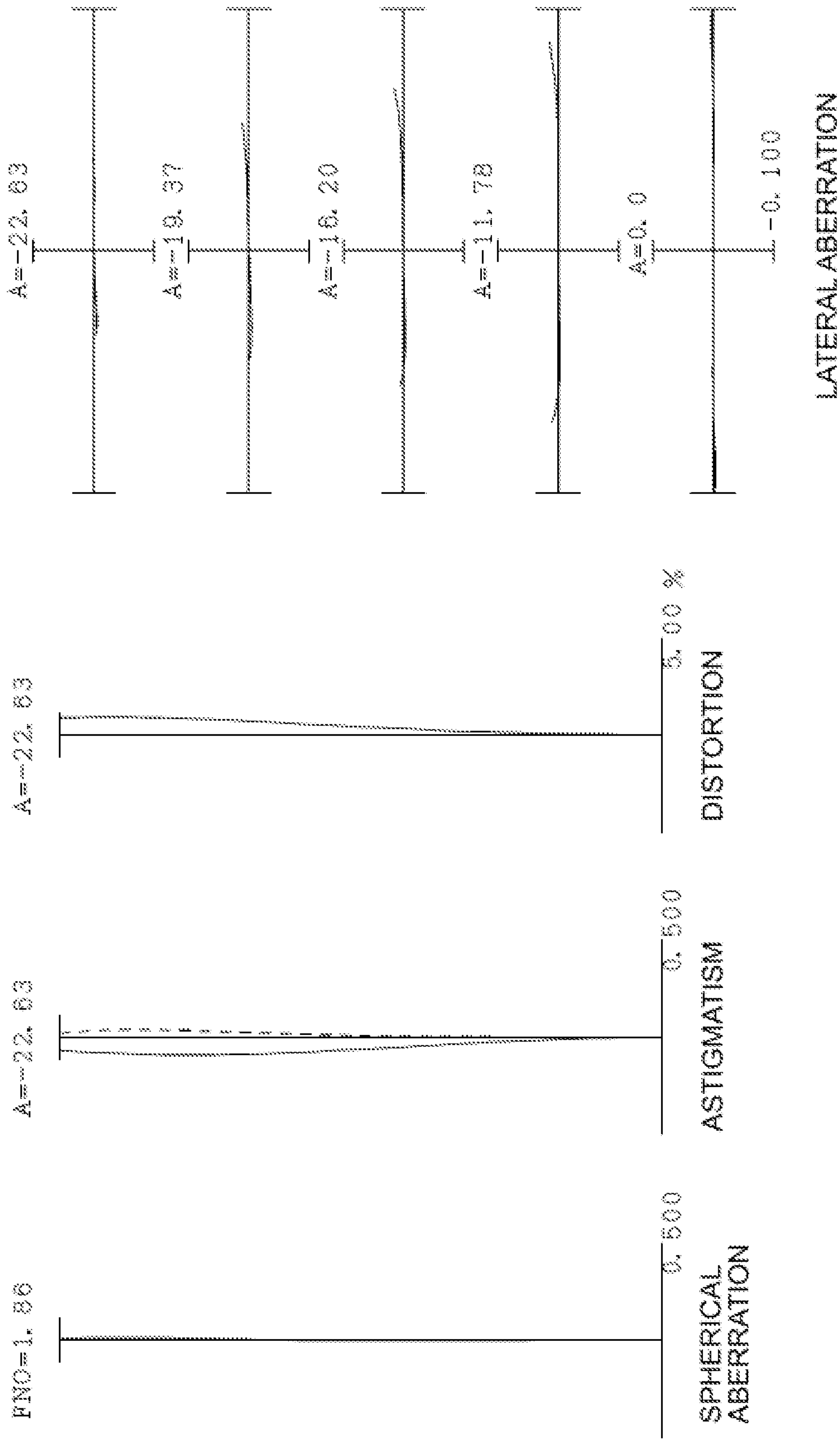

I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L15
L14
L13
L12
L11
G1(+)
LS(1)

FIG. 2A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0.500
SPHERICAL ABERRATION
A=-22.63
0.500
ASTIGMATISM
A=-22.63
5.00 %
DISTORTION
A=-22.63
A=-19.37
A=-16.20
A=-11.78
A=0.0
-0.100
LATERAL ABERRATION

FIG. 2B

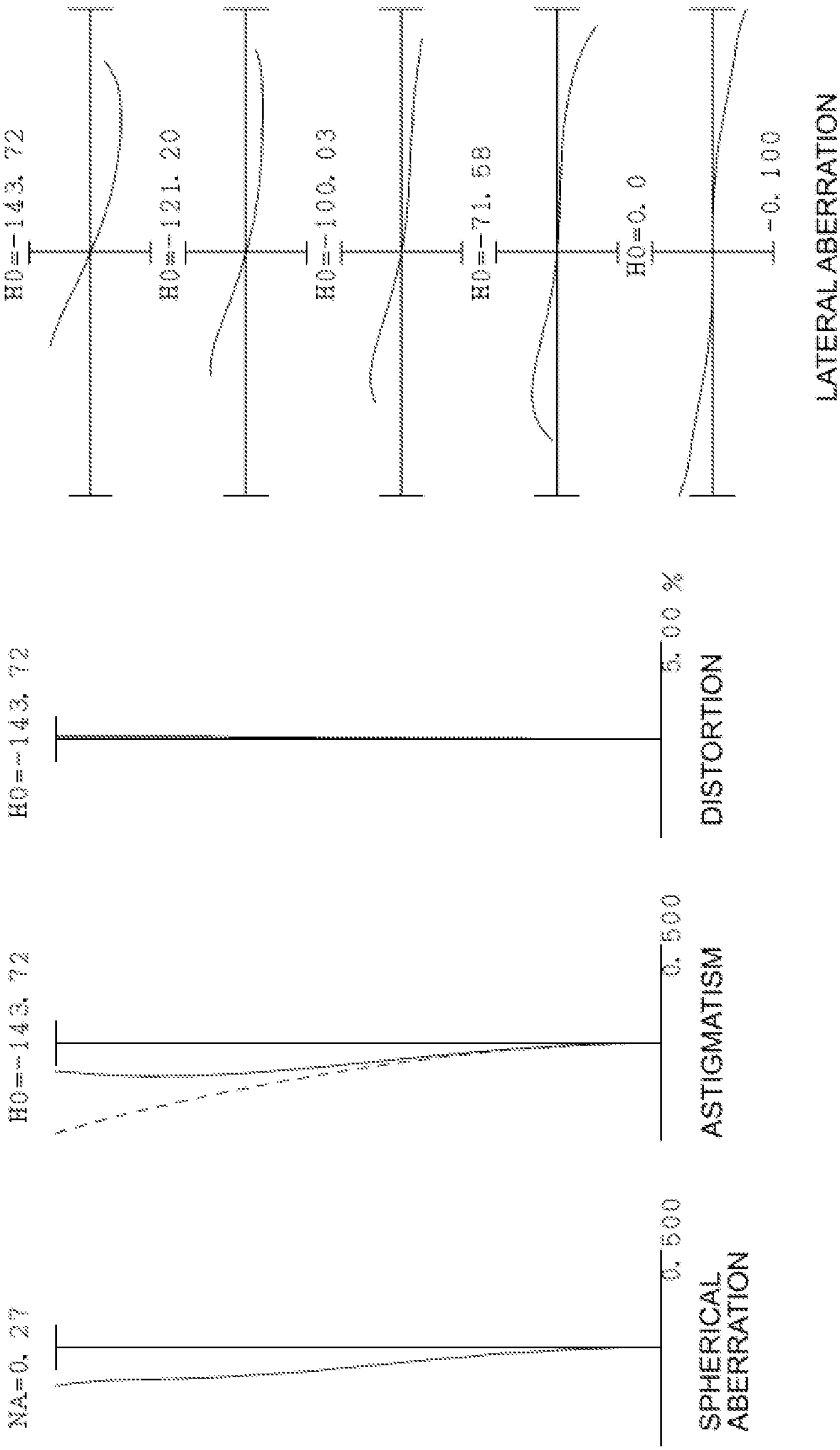

NA=0. 27
0. 500
SPHERICAL ABERRATION
H0=−143. 72
0. 500
ASTIGMATISM
H0=−143. 72
5. 00 %
DISTORTION
H0=−143. 72
H0=−121. 20
H0=−100. 03
H0=−71. 58
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 3

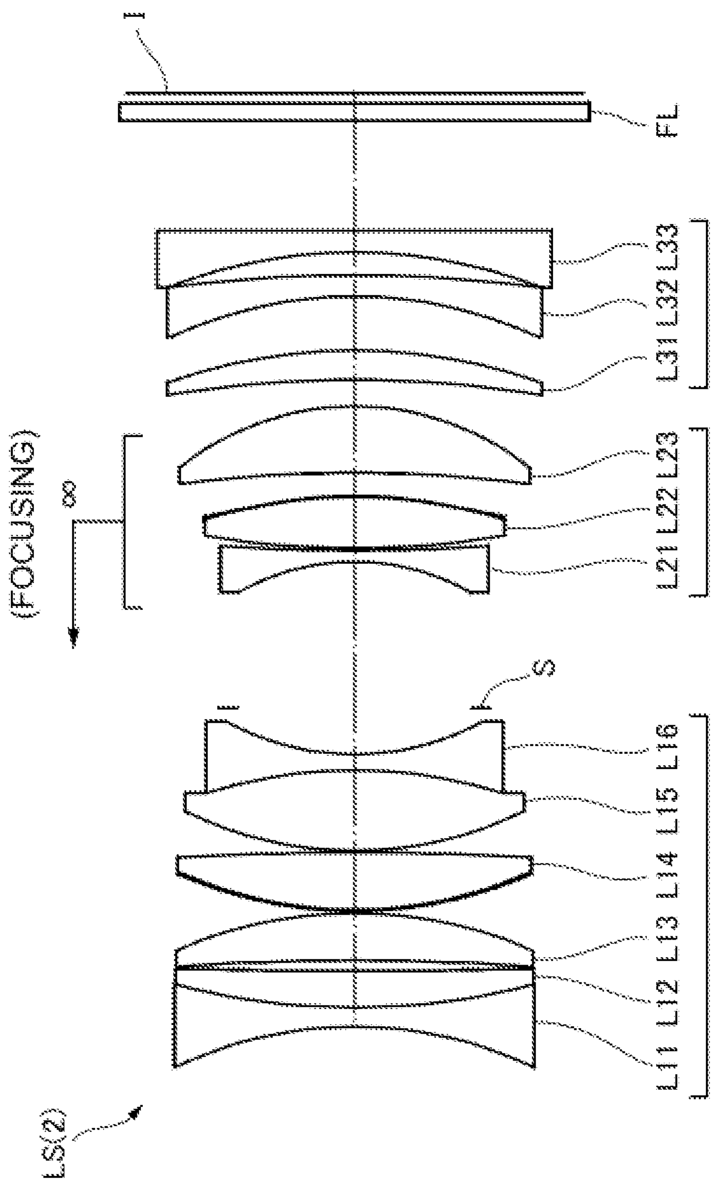

I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(2)

FIG. 4A

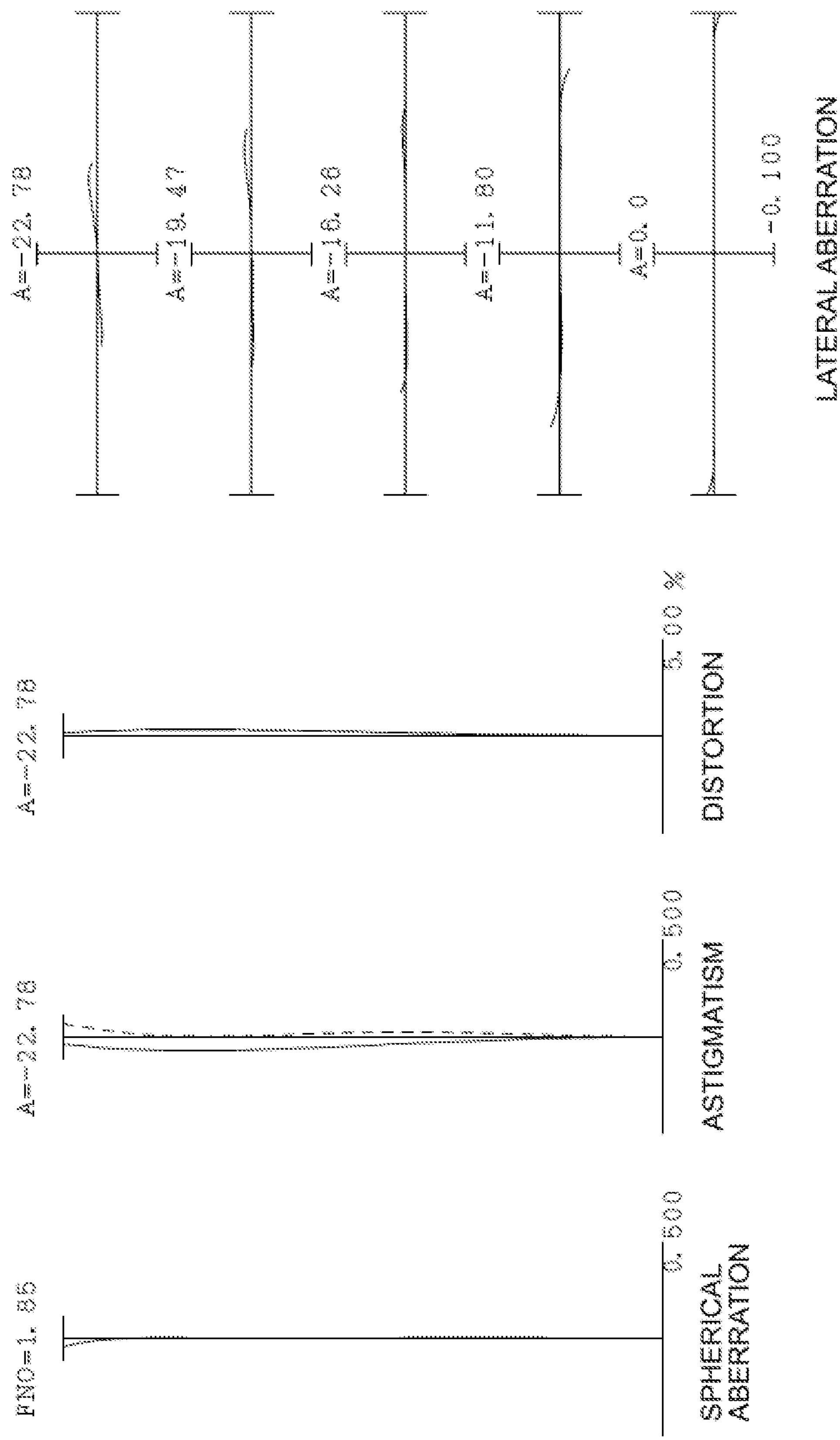

FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=−22. 78
0. 500
ASTIGMATISM
A=−22. 78
5. 00 %
DISTORTION
A=−22. 78
A=−19. 47
A=−16. 28
A=−11. 80
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 4B

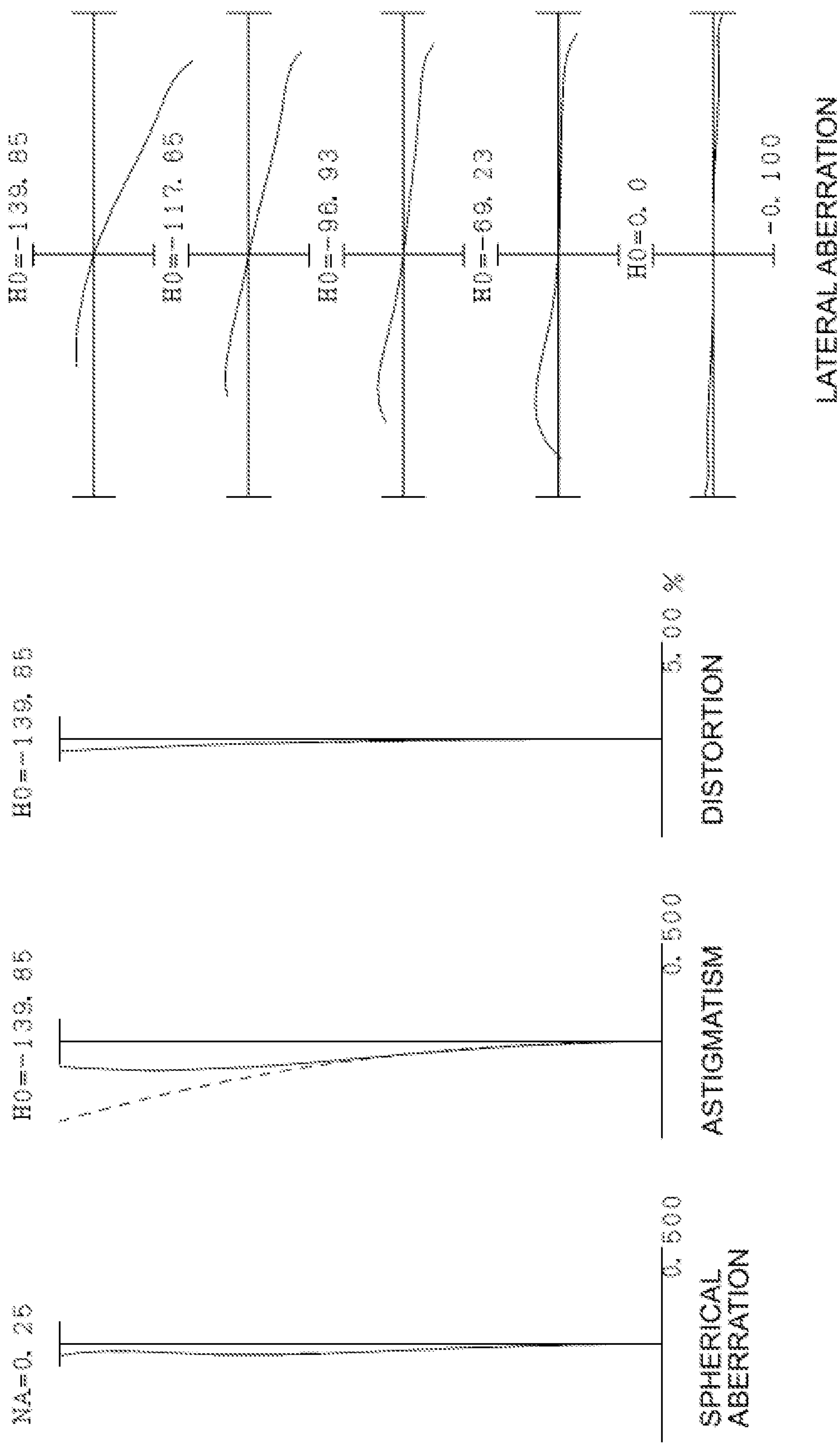

H0=-139.85
H0=-117.65
H0=-96.93
H0=-69.23
H0=0.0
-0.100
LATERAL ABERRATION
H0=-139.85
5.00 %
DISTORTION
H0=-139.85
0.500
ASTIGMATISM
NA=0.25
0.500
SPHERICAL ABERRATION

FIG. 5

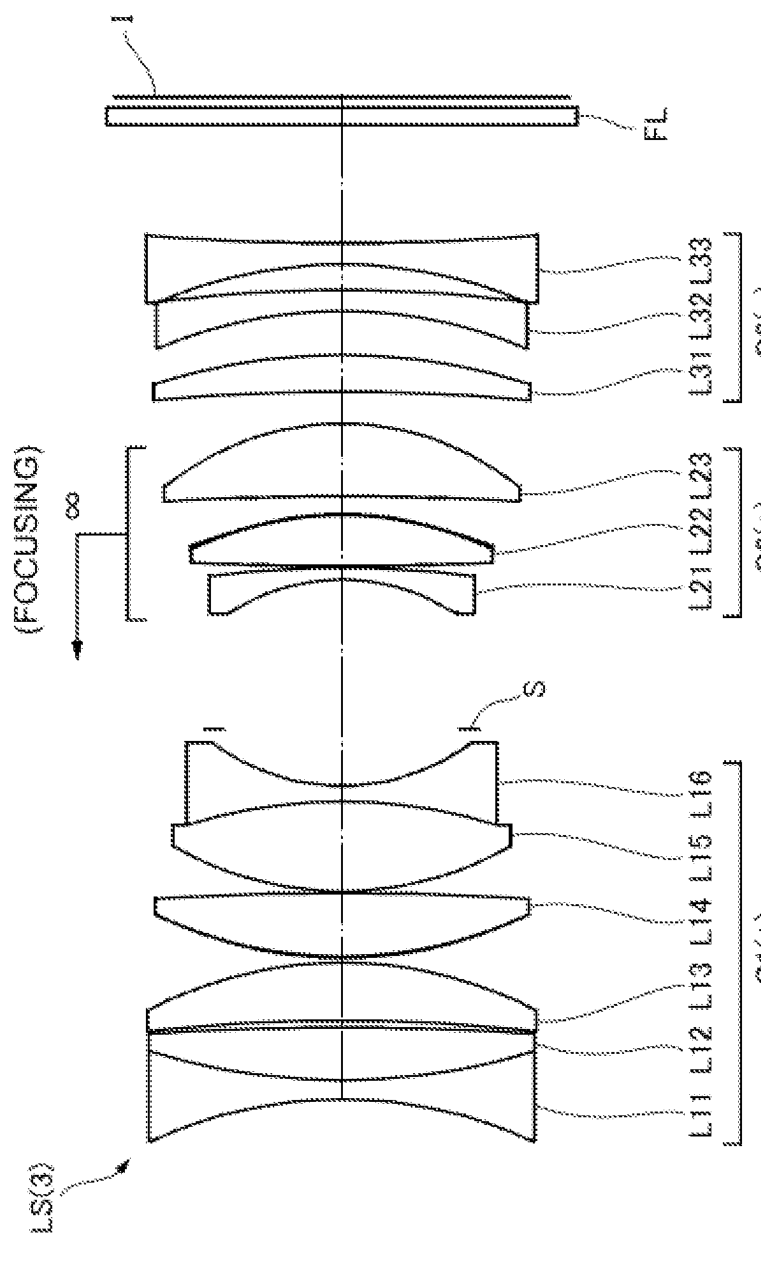

I
FL
L31 L32 L33
G3(−)
(FOCUSING)
∞
L21 L22 L23
G2(+)
S
L11 L12 L13 L14 L15 L16
G1(+)
LS(3)

FIG.6A

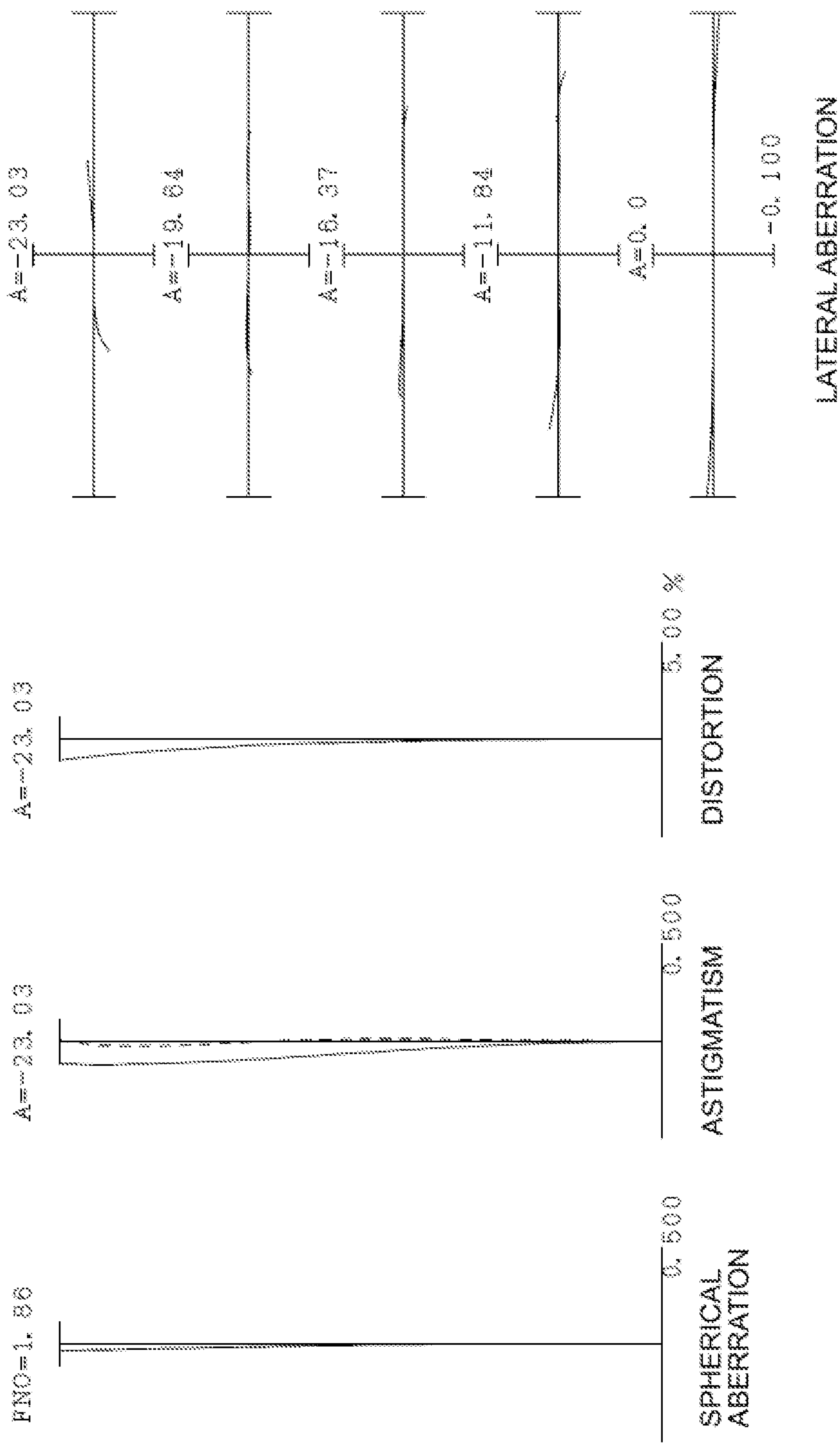

FNO=1. 86
0. 500
SPHERICAL ABERRATION
A=−23. 03
0. 500
ASTIGMATISM
A=−23. 03
5. 00 %
DISTORTION
A=−23. 03
A=−19. 64
A=−16. 37
A=−11. 84
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 6B

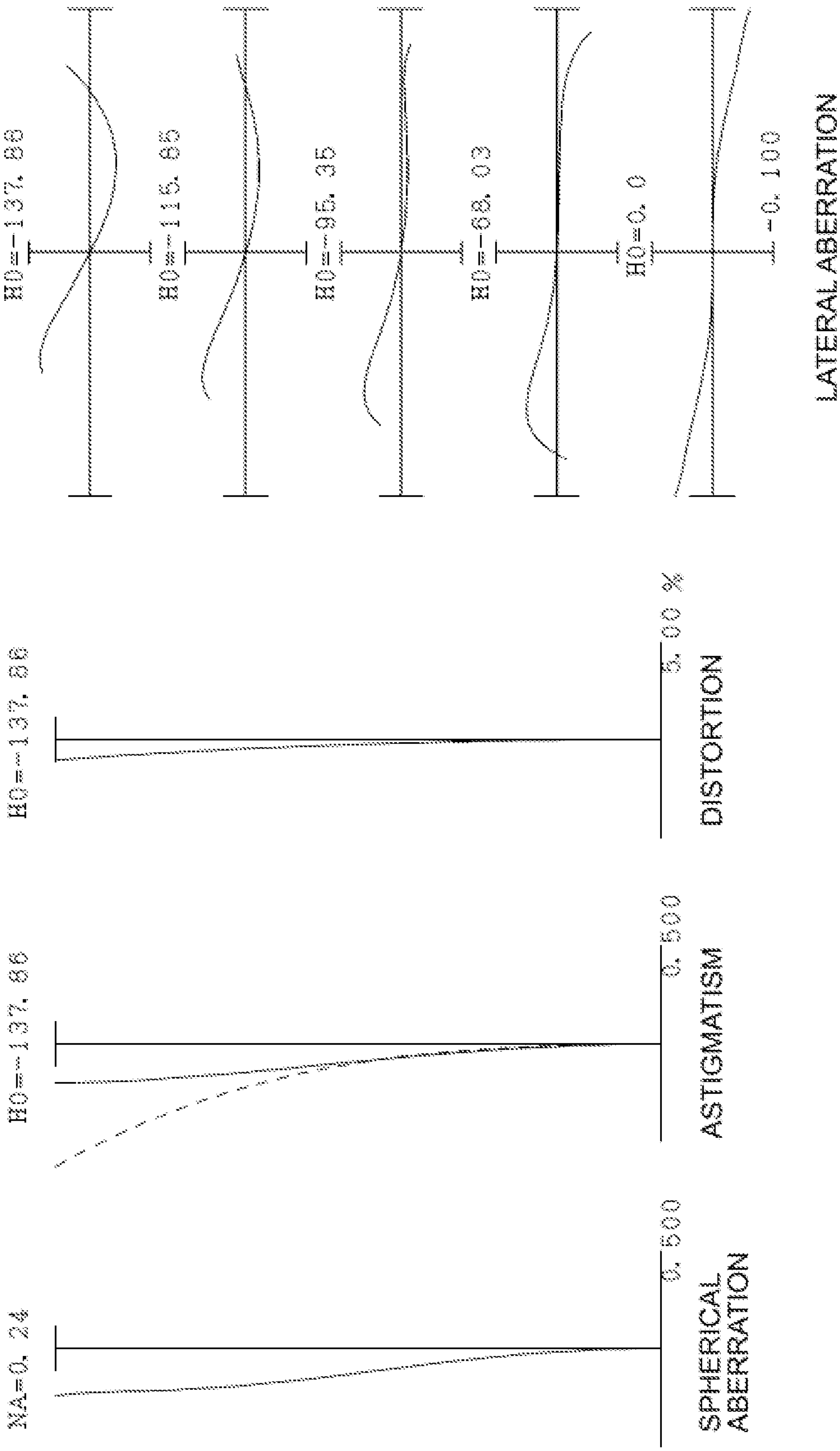

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=−137. 86
0. 500
ASTIGMATISM
H0=−137. 86
5. 00 %
DISTORTION
H0=−137. 86
H0=−115. 65
H0=−95. 35
H0=−68. 03
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 7

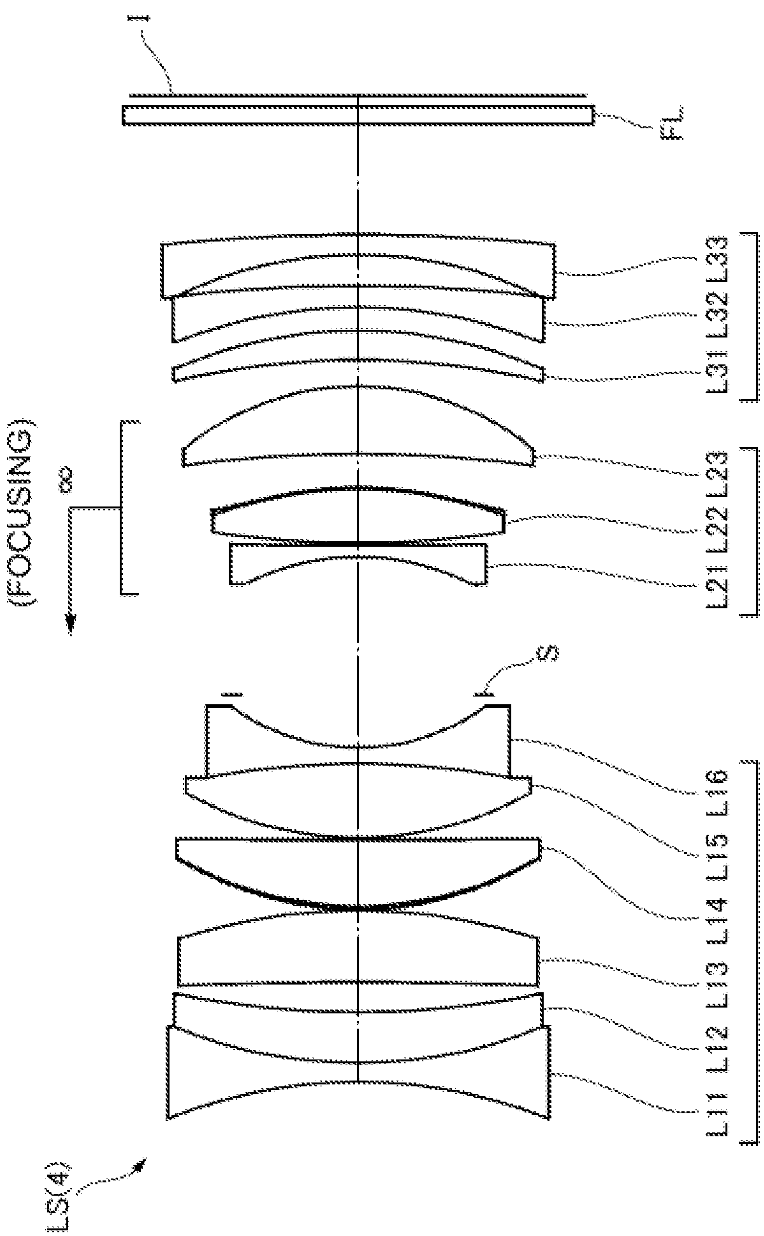
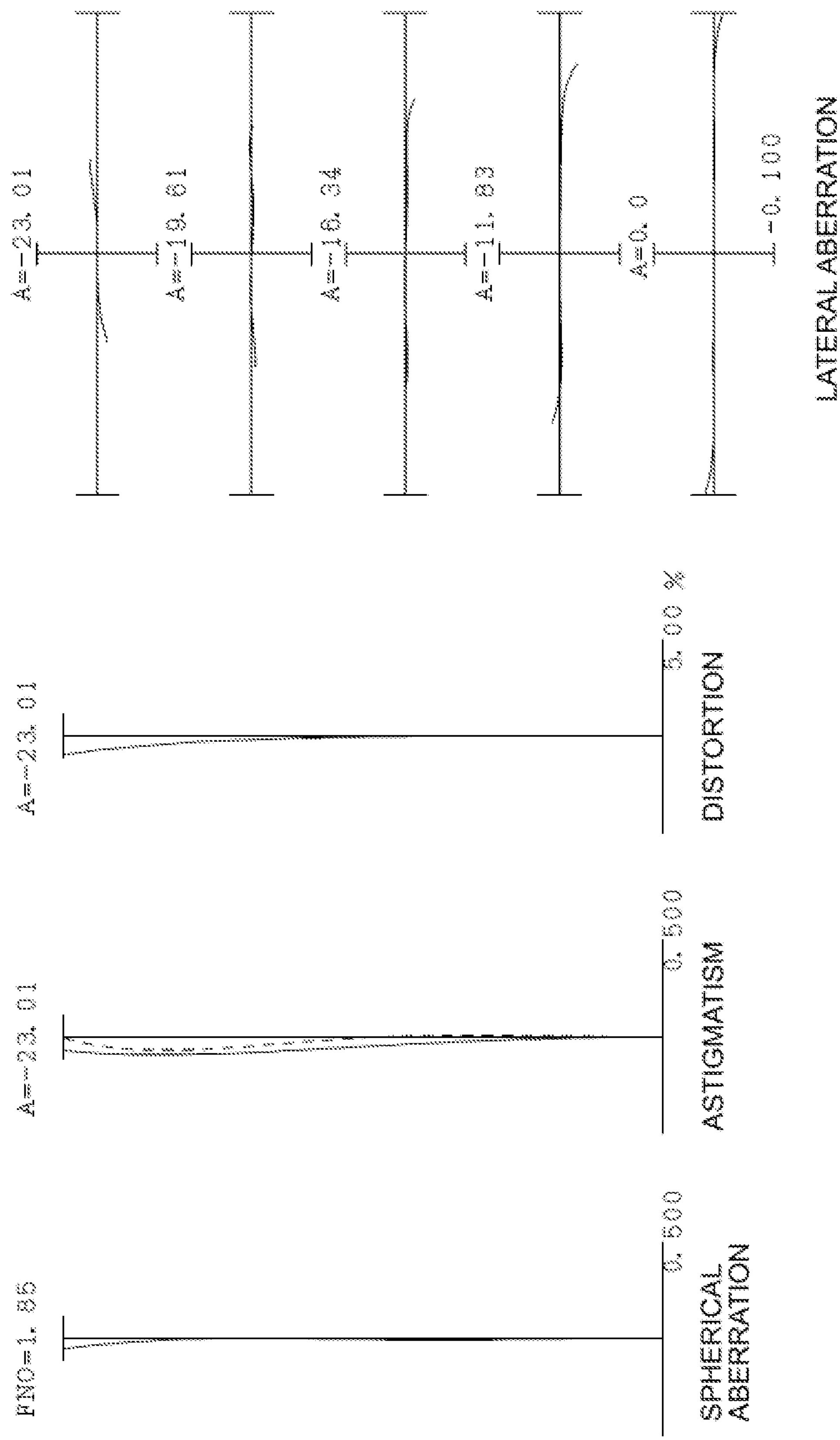
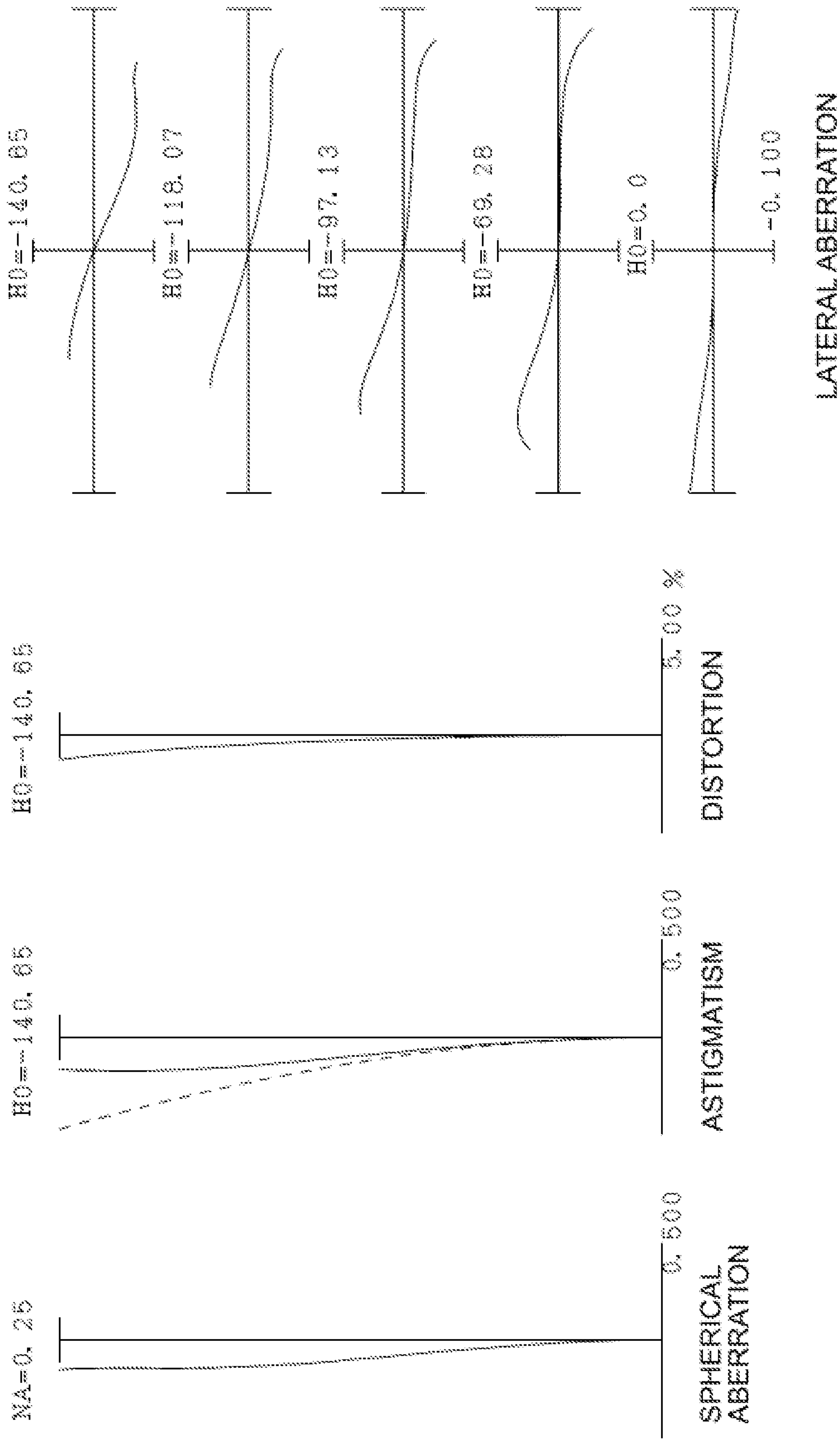

I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(4)

FIG. 8A



FNO=1.85
0.500
SPHERICAL ABERRATION
A=-23.01
0.500
ASTIGMATISM
A=-23.01
5.00 %
DISTORTION
A=-23.01
A=-19.61
A=-16.34
A=-11.83
A=0.0
-0.100
LATERAL ABERRATION

FIG. 8B



NA=0. 25
0. 500
SPHERICAL ABERRATION
H0=-140. 65
0. 500
ASTIGMATISM
H0=-140. 65
5. 00 %
DISTORTION
H0=-140. 65
H0=-118. 07
H0=-97. 13
H0=-69. 28
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 9

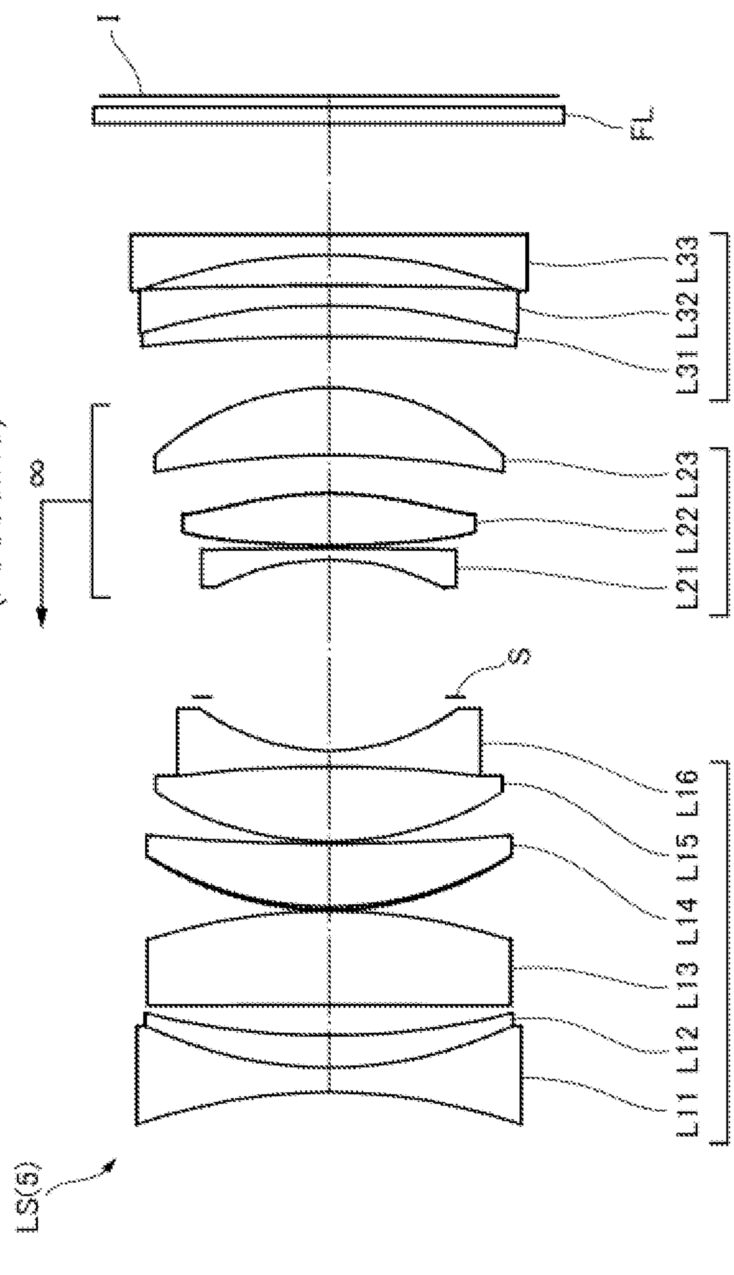

I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(5)

FIG. 10A

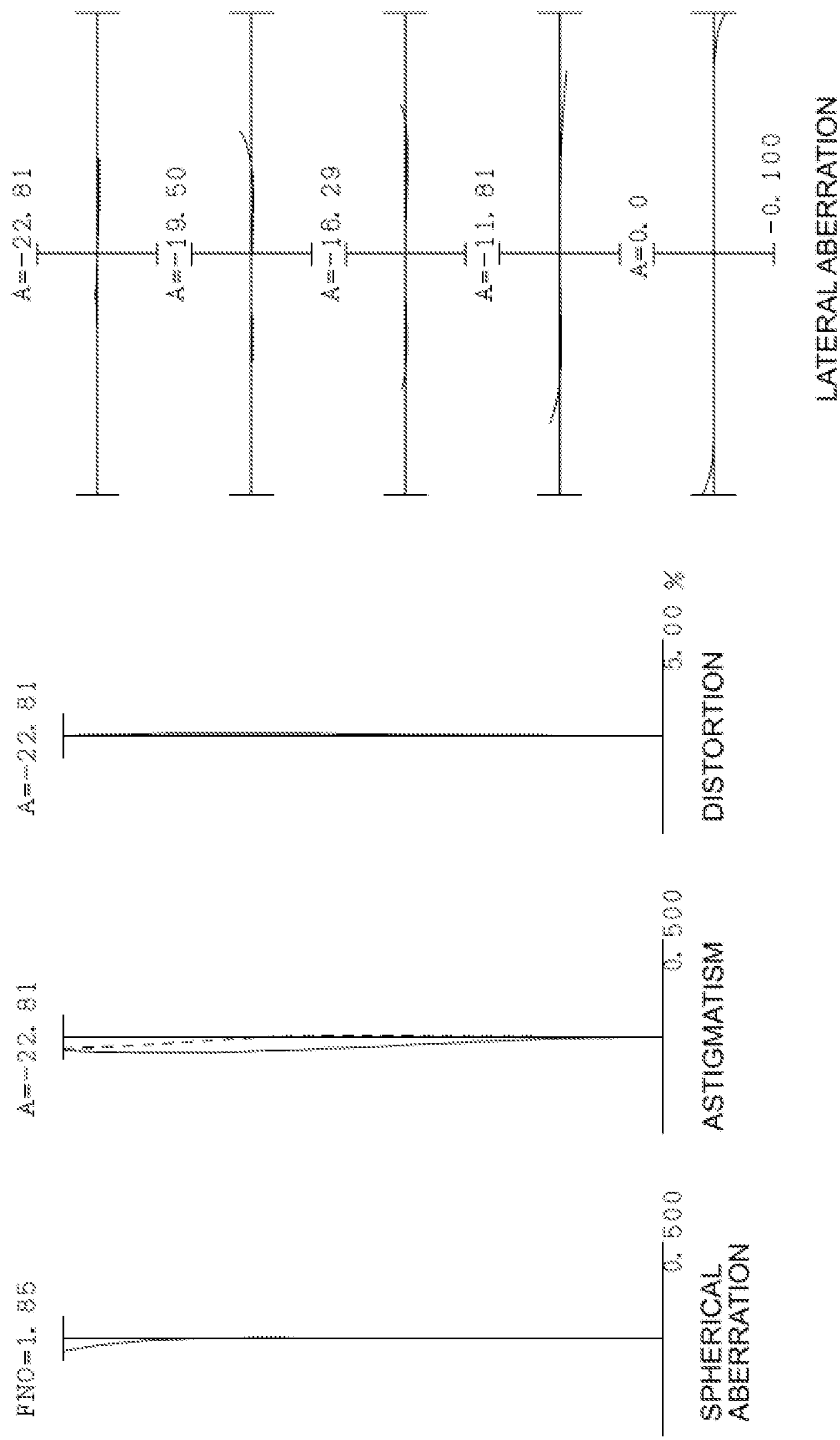

FNO=1.85
0.500
SPHERICAL ABERRATION
A=-22.81
0.500
ASTIGMATISM
A=-22.81
5.00 %
DISTORTION
A=-22.81
A=-19.50
A=-16.29
A=-11.81
A=0.0
-0.100
LATERAL ABERRATION

FIG. 10B

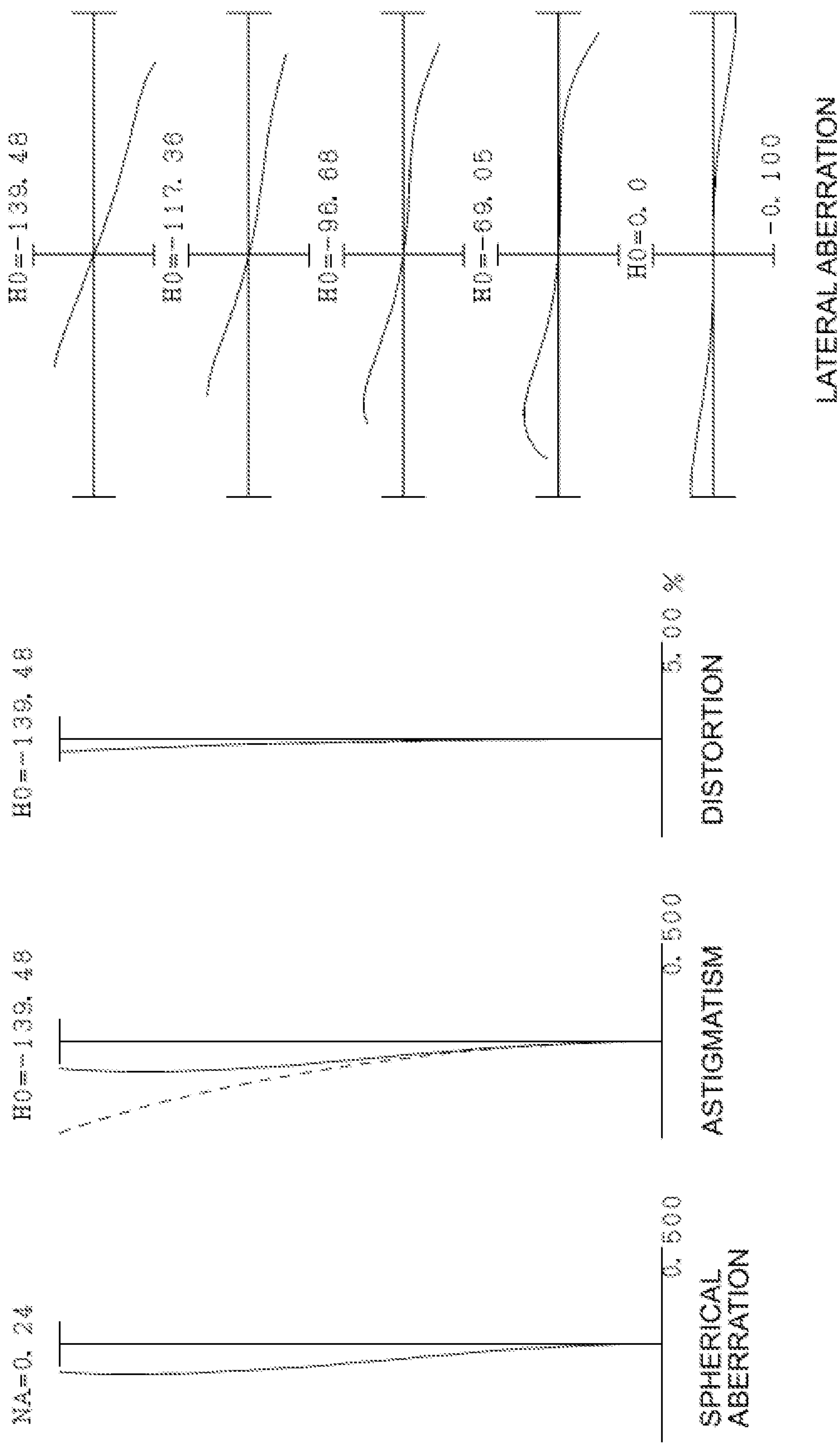

H0=-139.48
H0=-117.36
H0=-96.68
H0=-69.05
H0=0.0
-0.100
LATERAL ABERRATION
H0=-139.48
5.00 %
DISTORTION
H0=-139.48
0.500
ASTIGMATISM
NA=0.24
0.500
SPHERICAL ABERRATION

FIG. 11

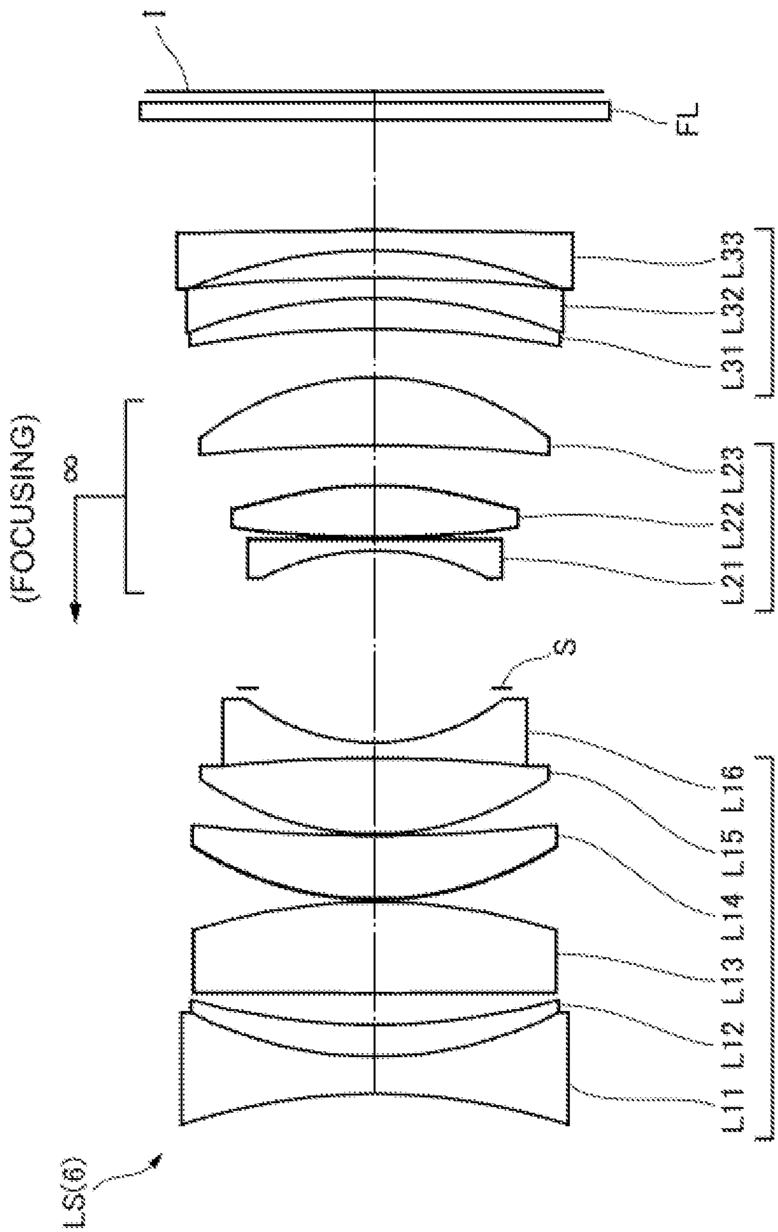

I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(6)

FIG. 12A

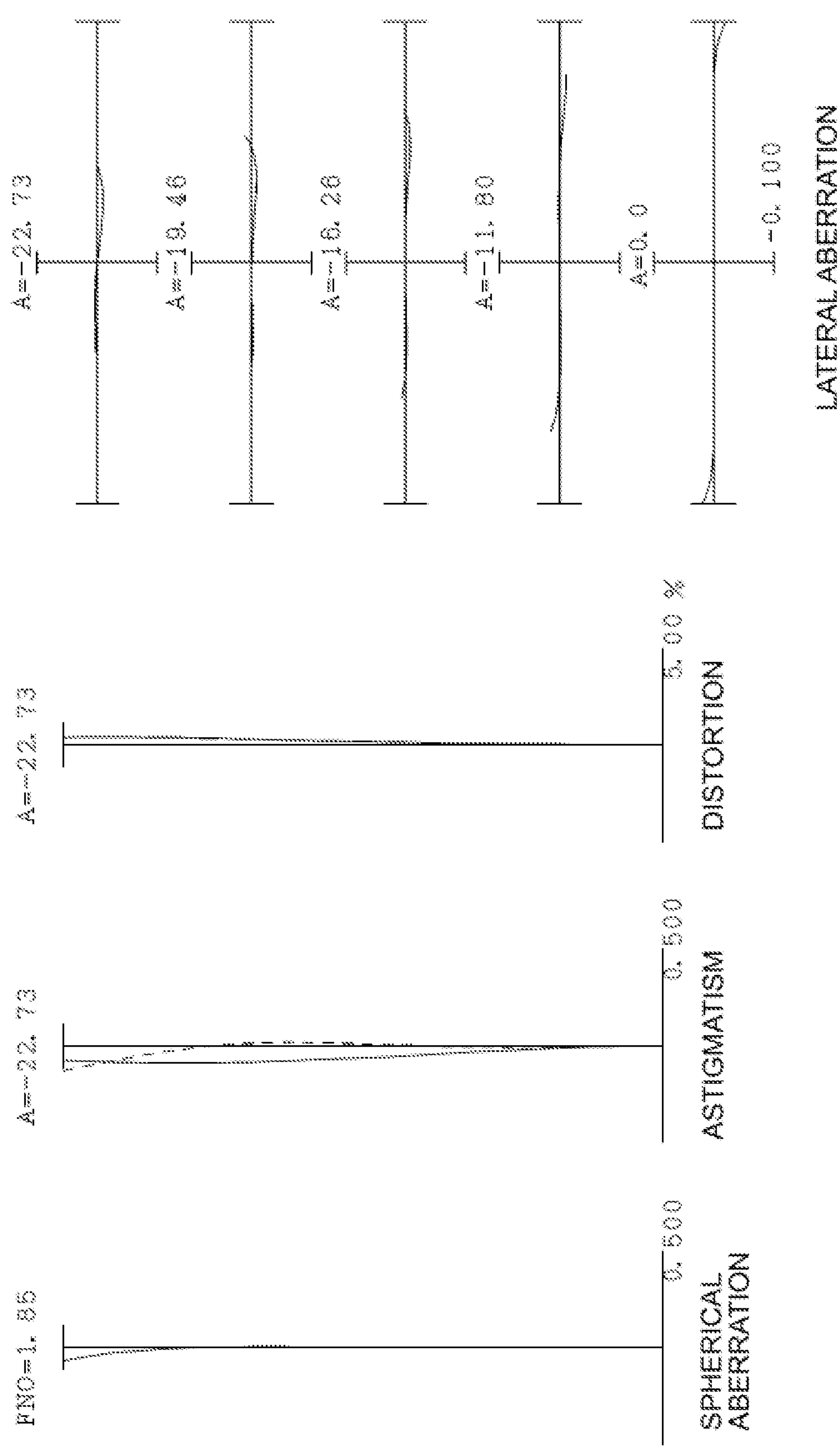

FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=−22. 73
0. 500
ASTIGMATISM
A=−22. 73
5. 00 %
DISTORTION
A=−22. 73
A=−19. 46
A=−16. 28
A=−11. 80
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 12B

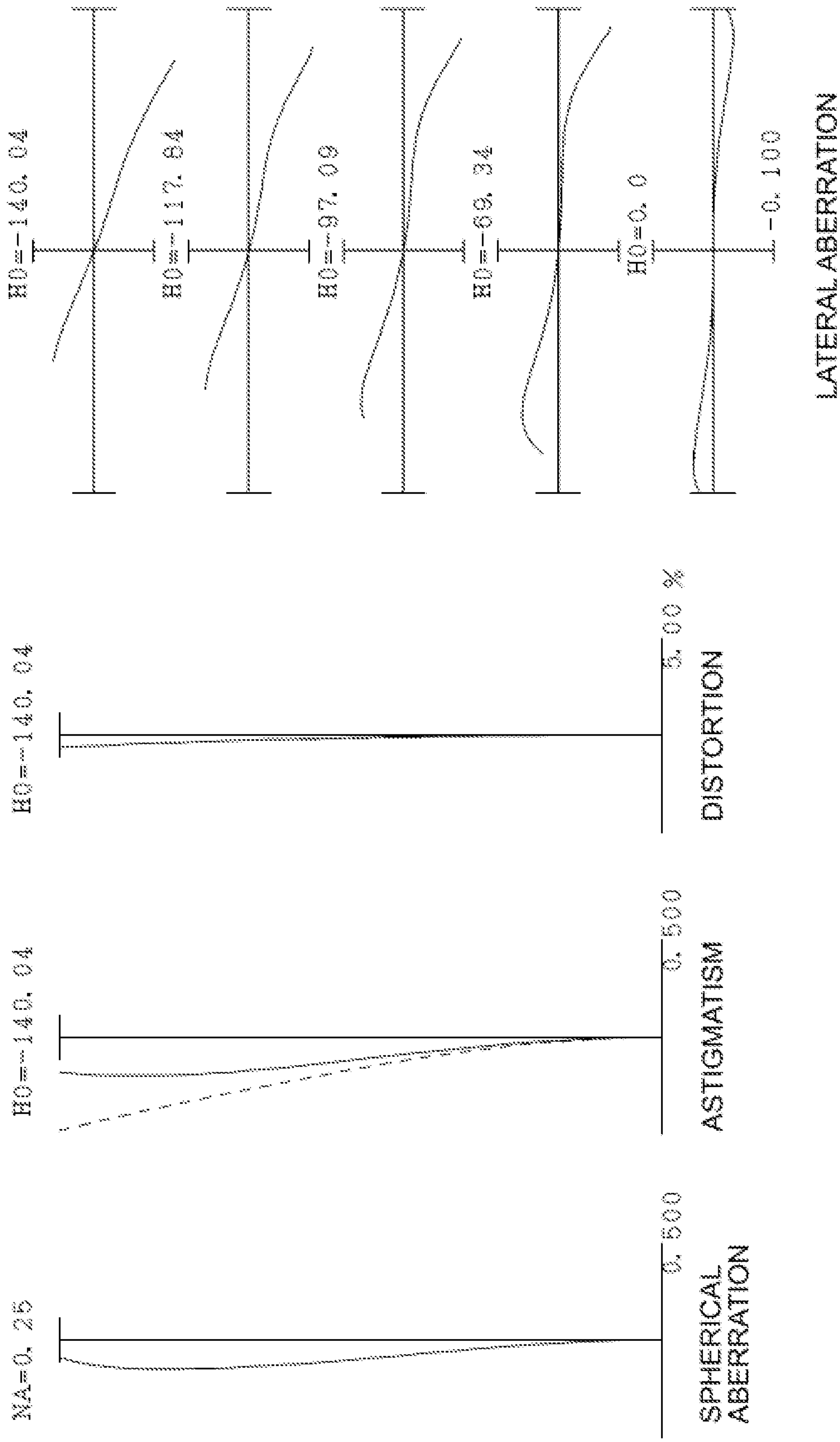

NA=0. 25
0. 500
SPHERICAL ABERRATION
H0=-140. 04
0. 500
ASTIGMATISM
H0=-140. 04
5. 00 %
DISTORTION
H0=-140. 04
H0=-117. 84
H0=-97. 09
H0=-69. 34
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 13

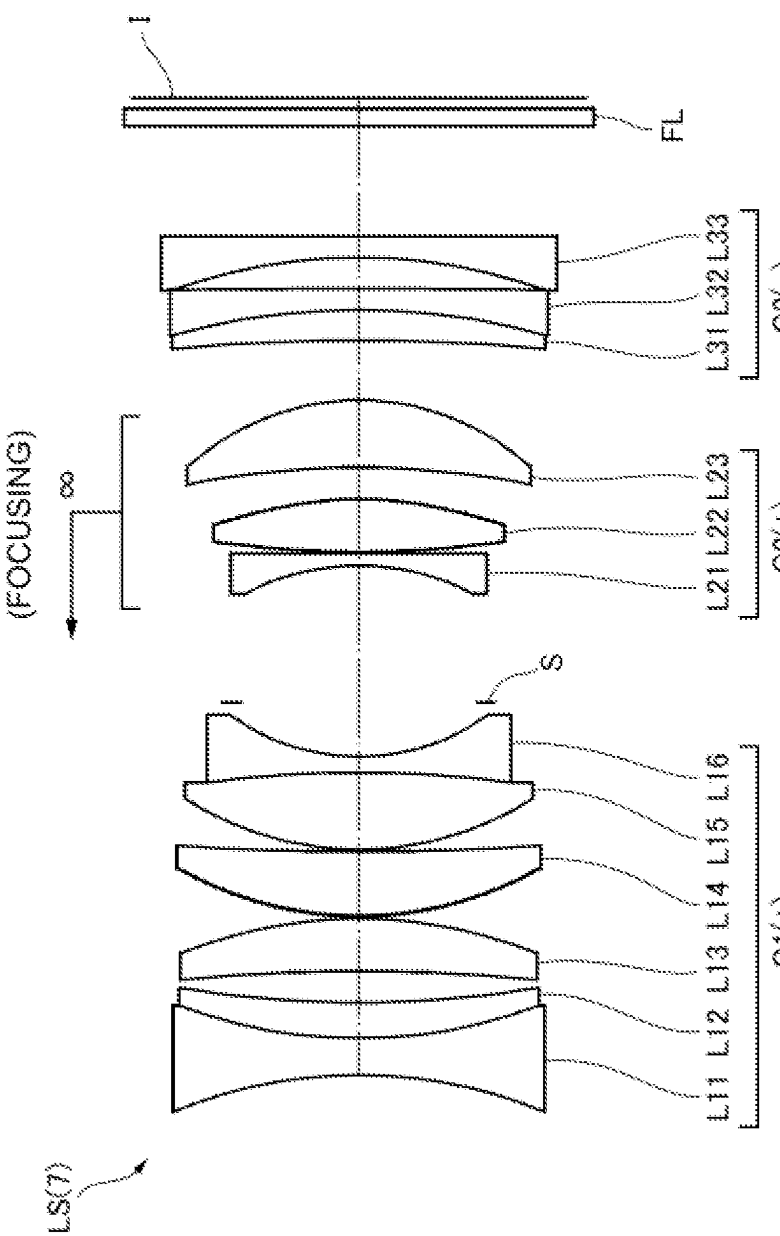

I
FL
L31 L32 L33
G3(−)
(FOCUSING)
∞
L21 L22 L23
G2(+)
S
L11 L12 L13 L14 L15 L16
G1(+)
LS(7)

FIG. 14A

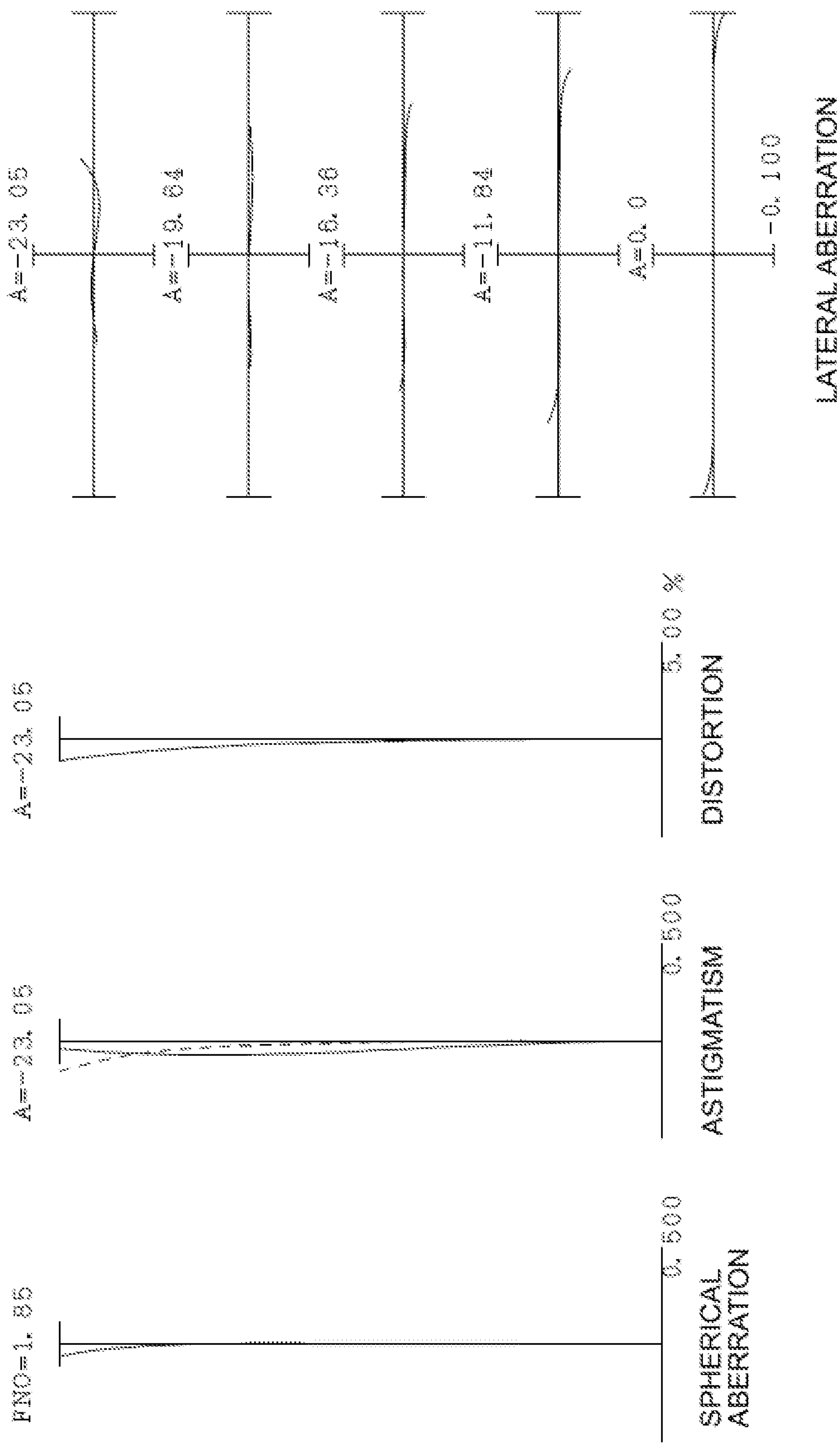

A=-23. 05
A=-19. 64
A=-16. 38
A=-11. 84
A=0. 0
-0. 100
LATERAL ABERRATION
A=-23. 05
5. 00 %
DISTORTION
A=-23. 05
0. 500
ASTIGMATISM
FNO=1. 85
0. 500
SPHERICAL ABERRATION

FIG. 14B

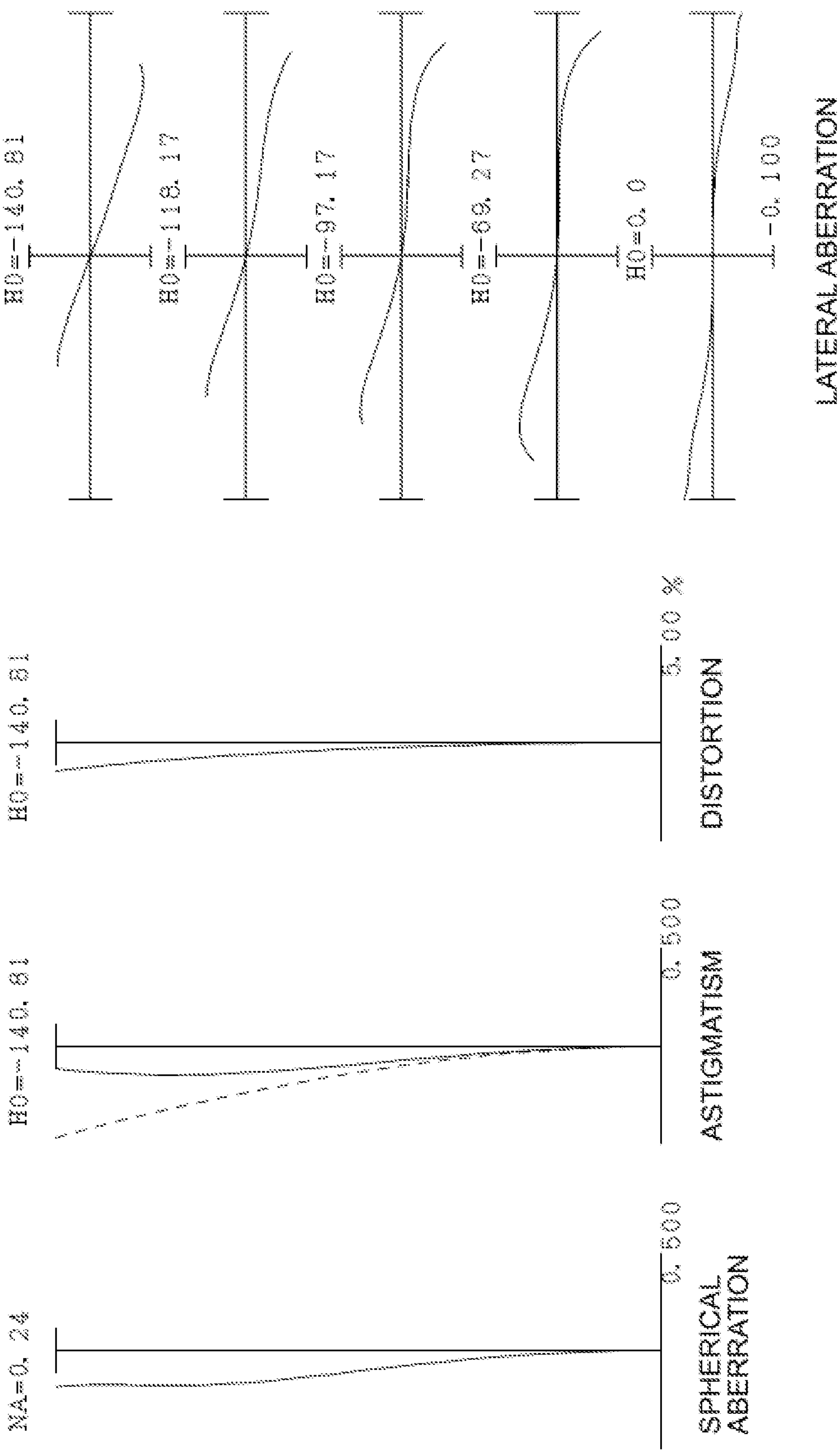

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=-140. 81
0. 500
ASTIGMATISM
H0=-140. 81
5. 00 %
DISTORTION
H0=-140. 81
H0=-118. 17
H0=-97. 17
H0=-69. 27
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 15

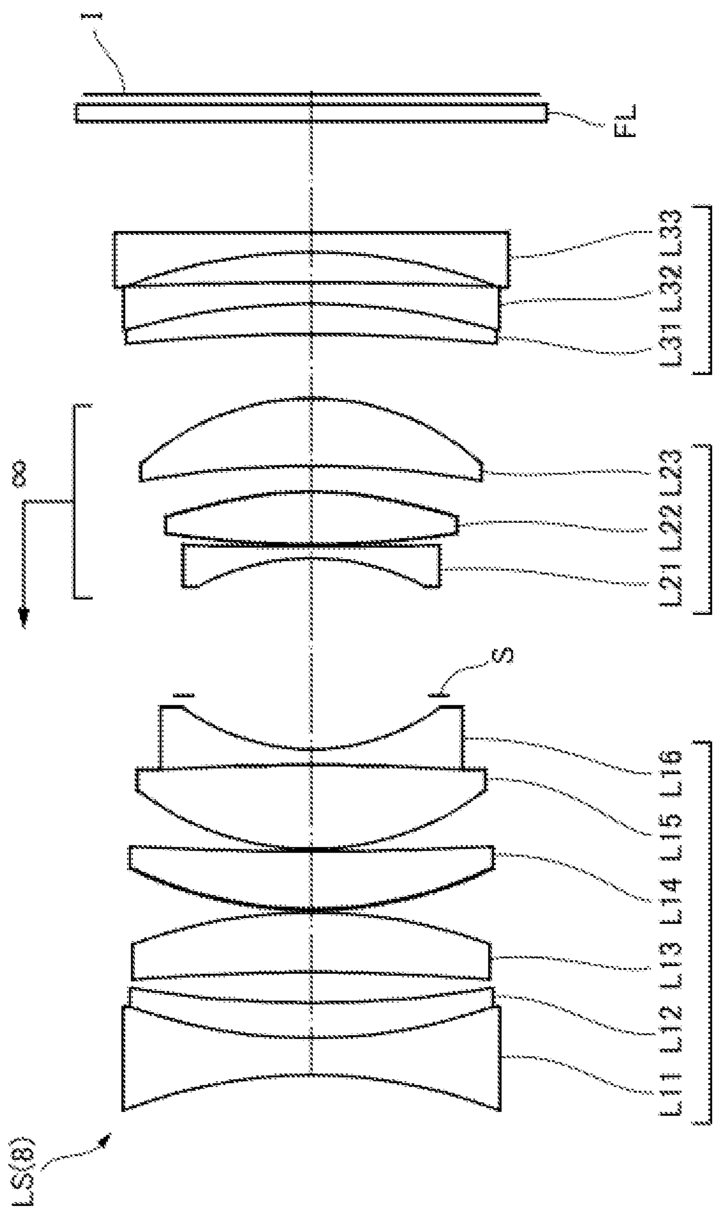

I
FL
(FOCUSING)
∞
S
L11 L12 L13 L14 L15 L16
G1(+)
L21 L22 L23
G2(+)
L31 L32 L33
G3(−)
LS(8)

FIG. 16A

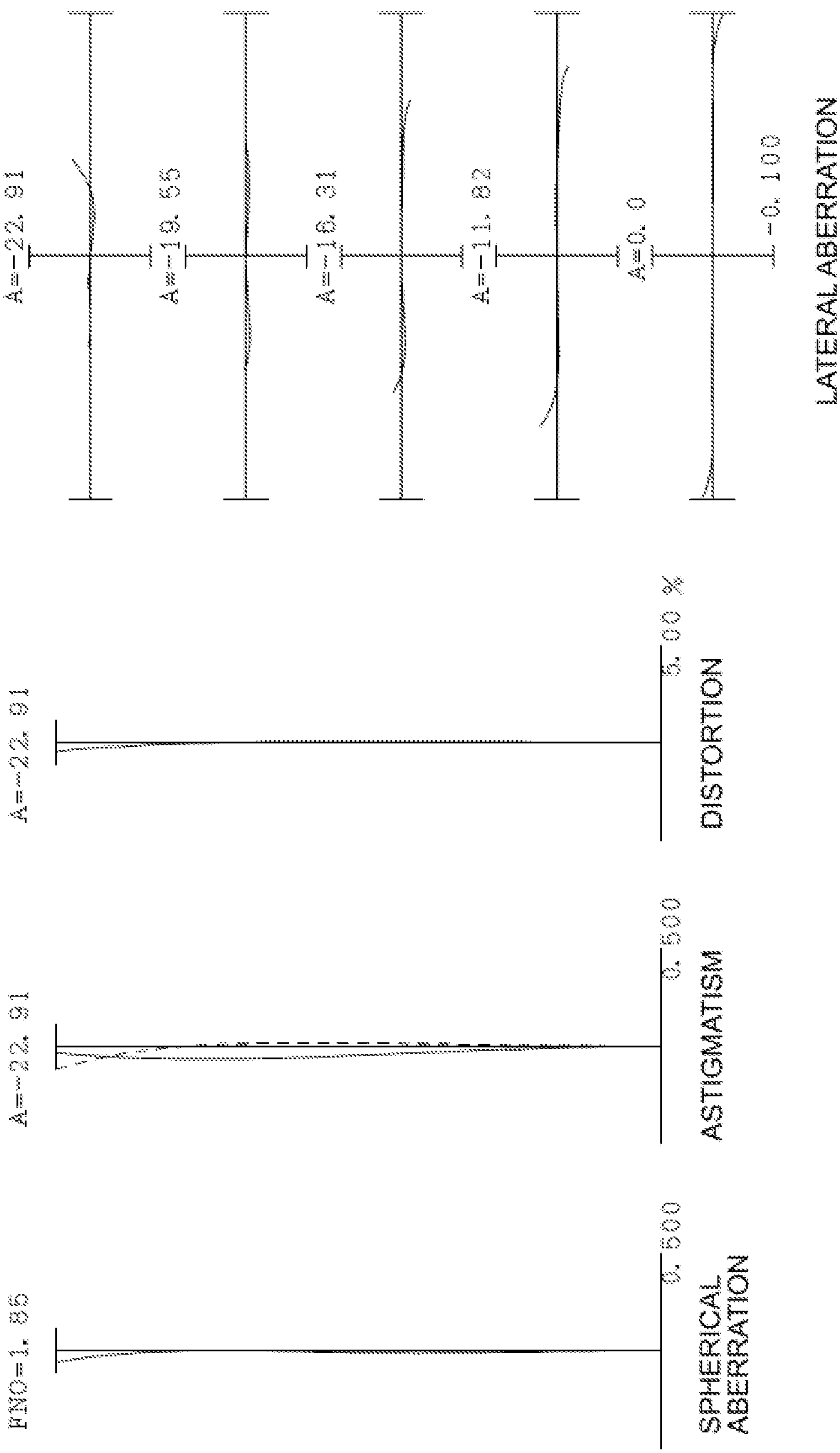

FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=−22. 91
0. 500
ASTIGMATISM
A=−22. 91
5. 00 %
DISTORTION
A=−22. 91
A=−19. 55
A=−16. 31
A=−11. 82
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 16B

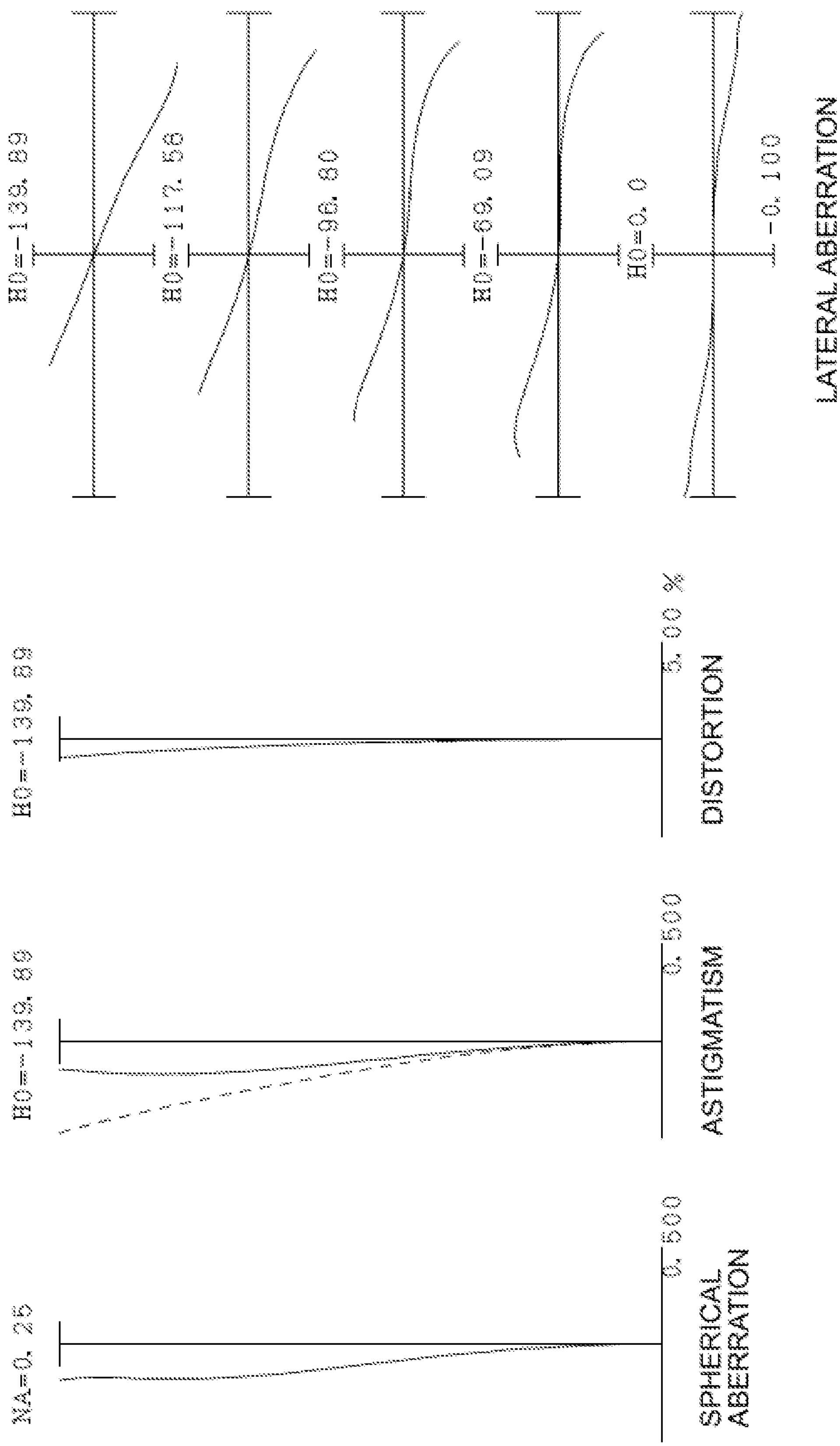

NA=0. 25
0. 500
SPHERICAL ABERRATION
H0=-139. 89
0. 500
ASTIGMATISM
H0=-139. 89
5. 00 %
DISTORTION
H0=-139. 89
H0=-117. 56
H0=-96. 80
H0=-69. 09
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 17

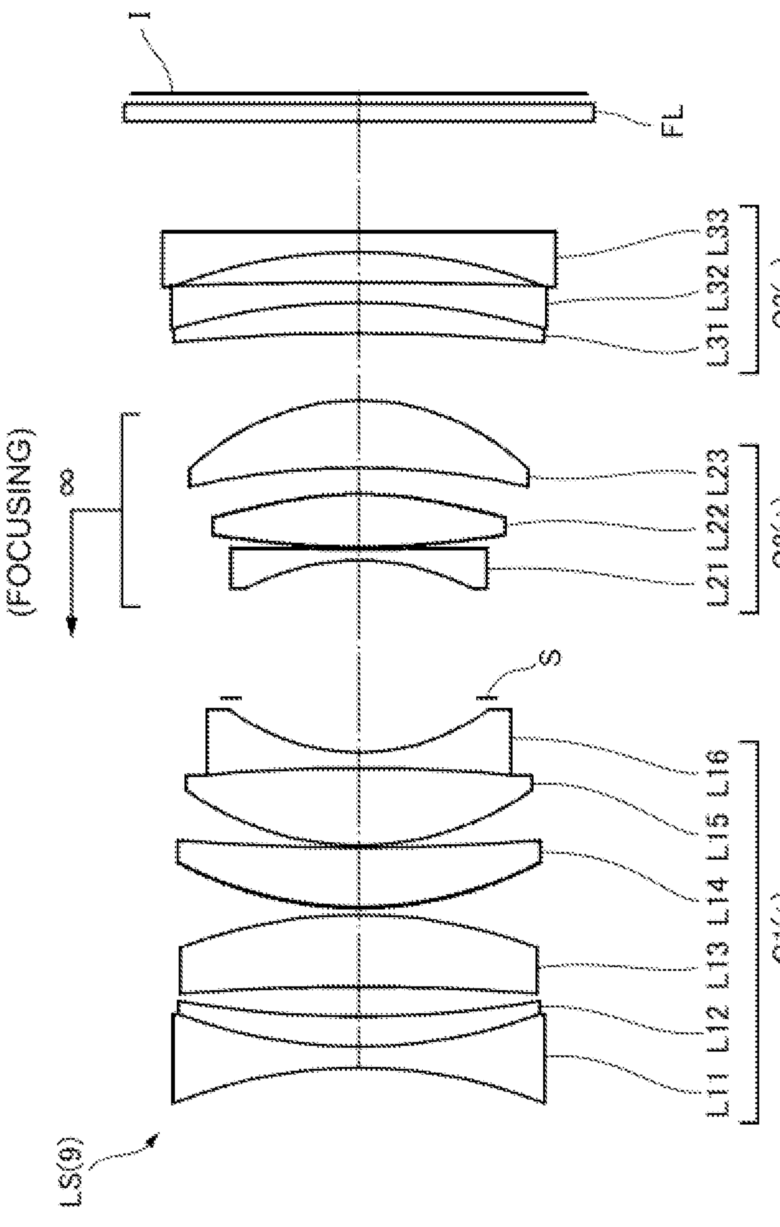
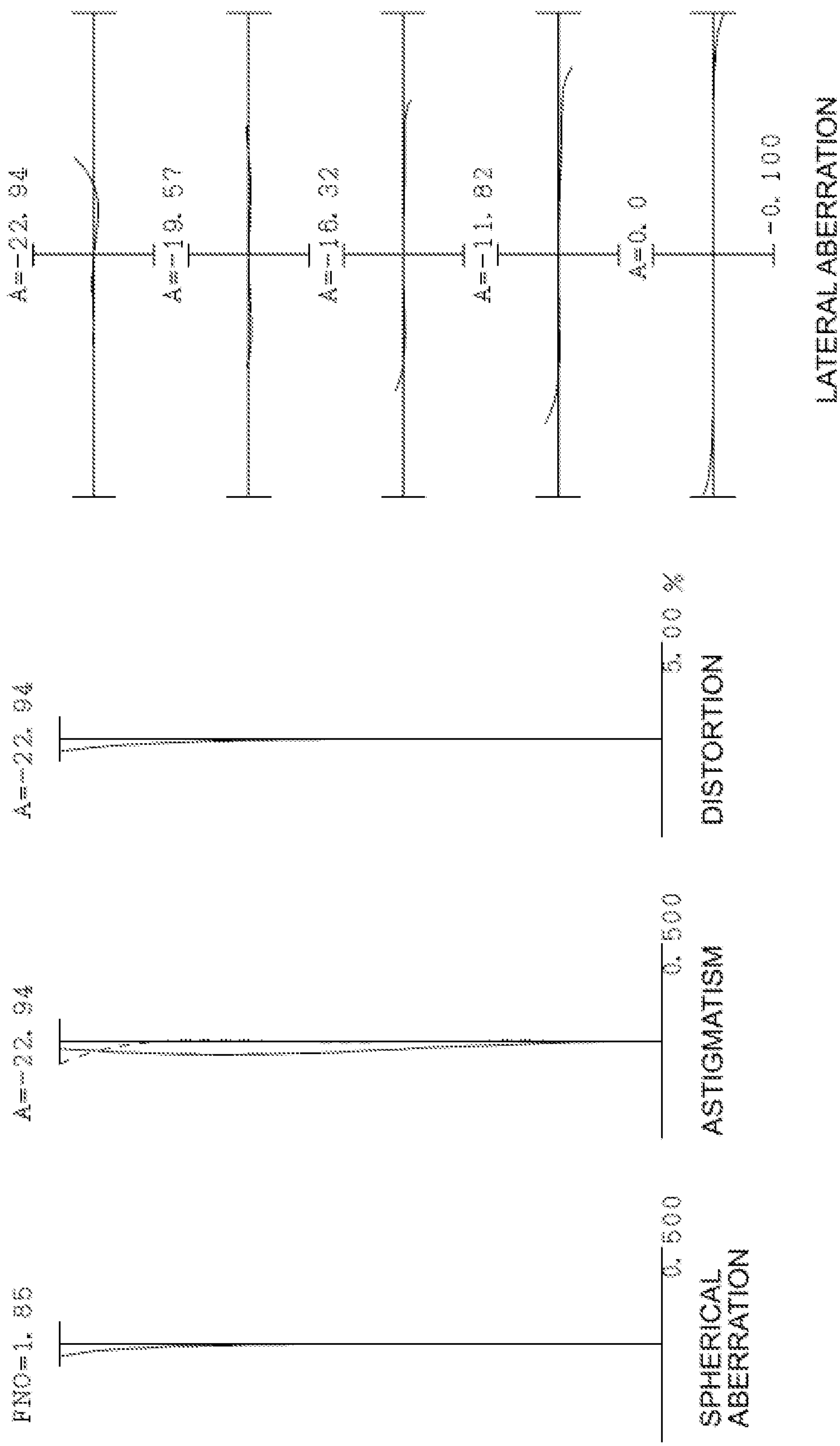

I
FL
L31 L32 L33
G3(−)
(FOCUSING)
∞
L21 L22 L23
G2(+)
S
L11 L12 L13 L14 L15 L16
G1(+)
LS(9)

FIG. 18A



A=−22.94
A=−19.57
A=−16.32
A=−11.82
A=0.0
−0.100
LATERAL ABERRATION
A=−22.94
5.00 %
DISTORTION
A=−22.94
0.500
ASTIGMATISM
FNO=1.85
0.500
SPHERICAL ABERRATION

FIG. 18B

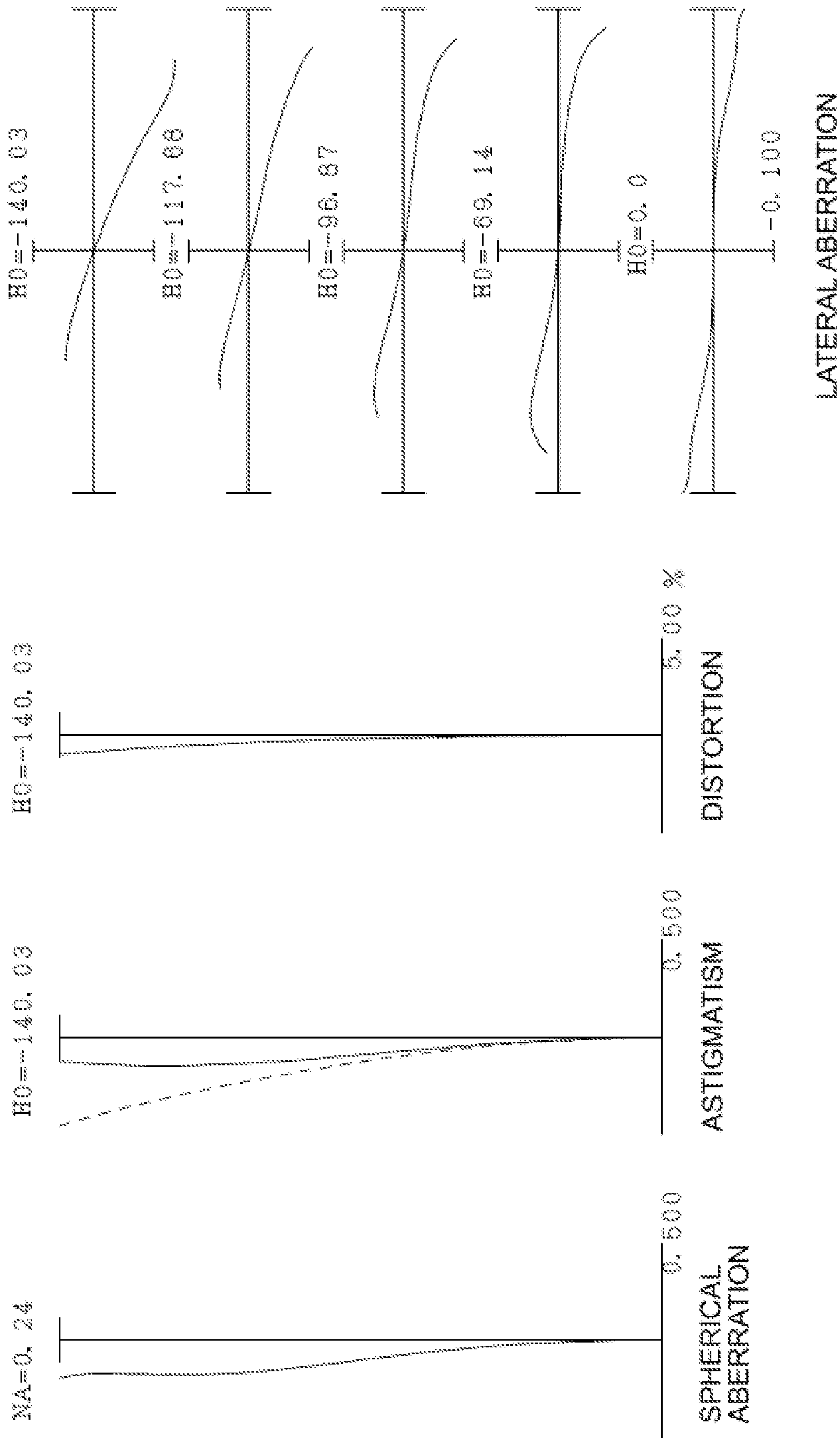

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=-140. 03
0. 500
ASTIGMATISM
H0=-140. 03
5. 00 %
DISTORTION
H0=-140. 03
H0=-117. 66
H0=-96. 87
H0=-69. 14
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 19

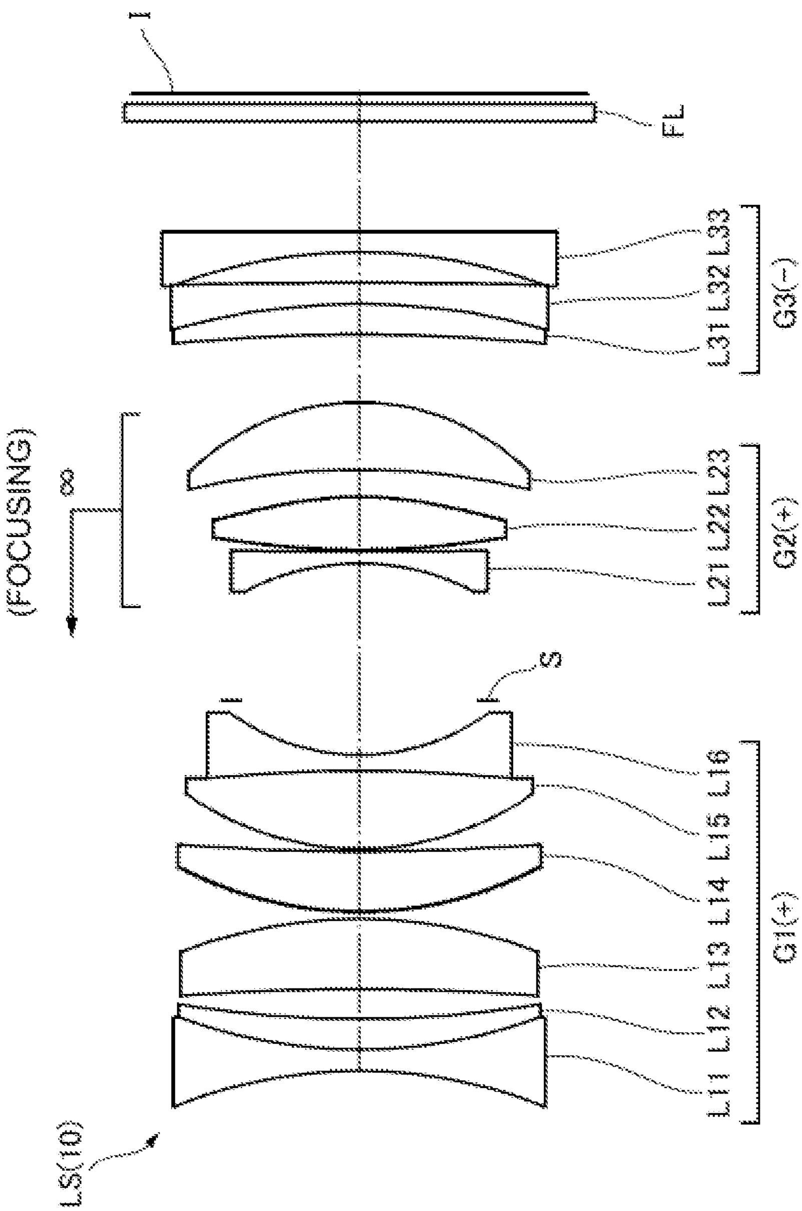
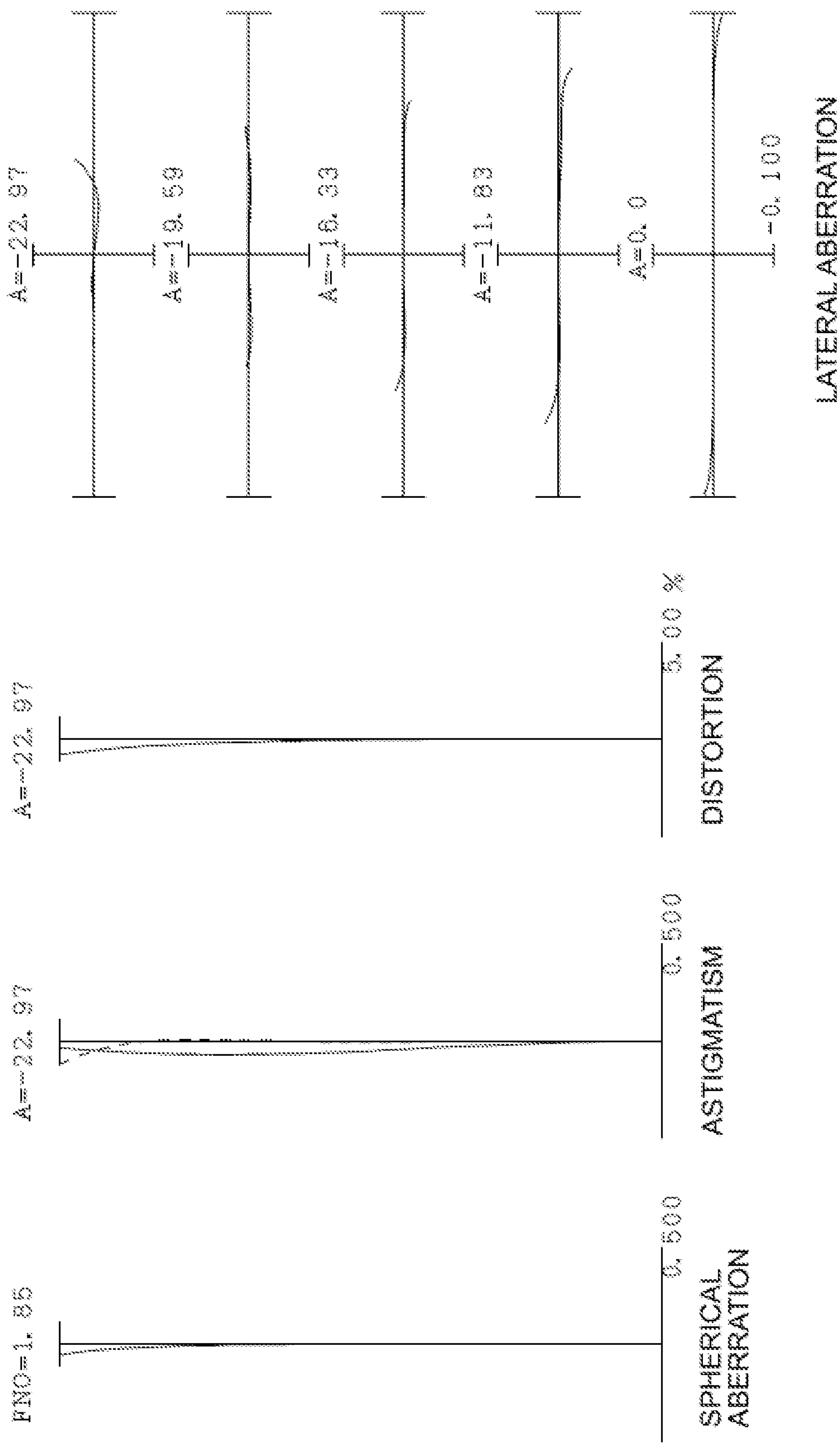

I
FL
L31 L32 L33
G3(−)
L21 L22 L23
G2(+)
(FOCUSING)
∞
S
L11 L12 L13 L14 L15 L16
G1(+)
LS(10)

FIG. 20A



A=-22. 97
A=-19. 59
A=-16. 33
A=-11. 83
A=0. 0
-0. 100
LATERAL ABERRATION
A=-22. 97
5. 00 %
DISTORTION
A=-22. 97
0. 500
ASTIGMATISM
FNO=1. 85
0. 500
SPHERICAL ABERRATION

FIG. 20B

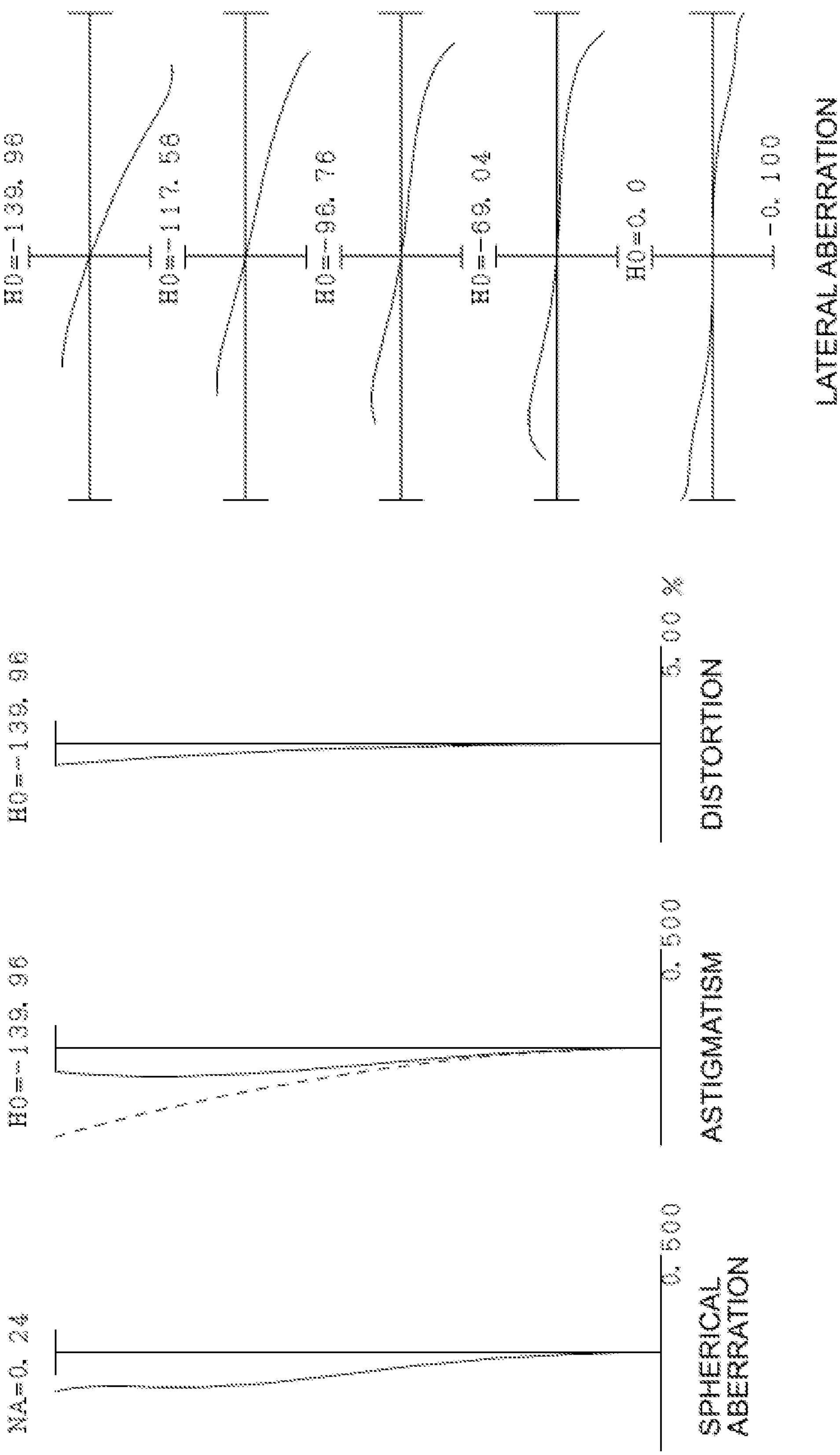

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=-139. 96
0. 500
ASTIGMATISM
H0=-139. 96
5. 00 %
DISTORTION
H0=-139. 96
H0=-117. 58
H0=-96. 76
H0=-69. 04
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 21

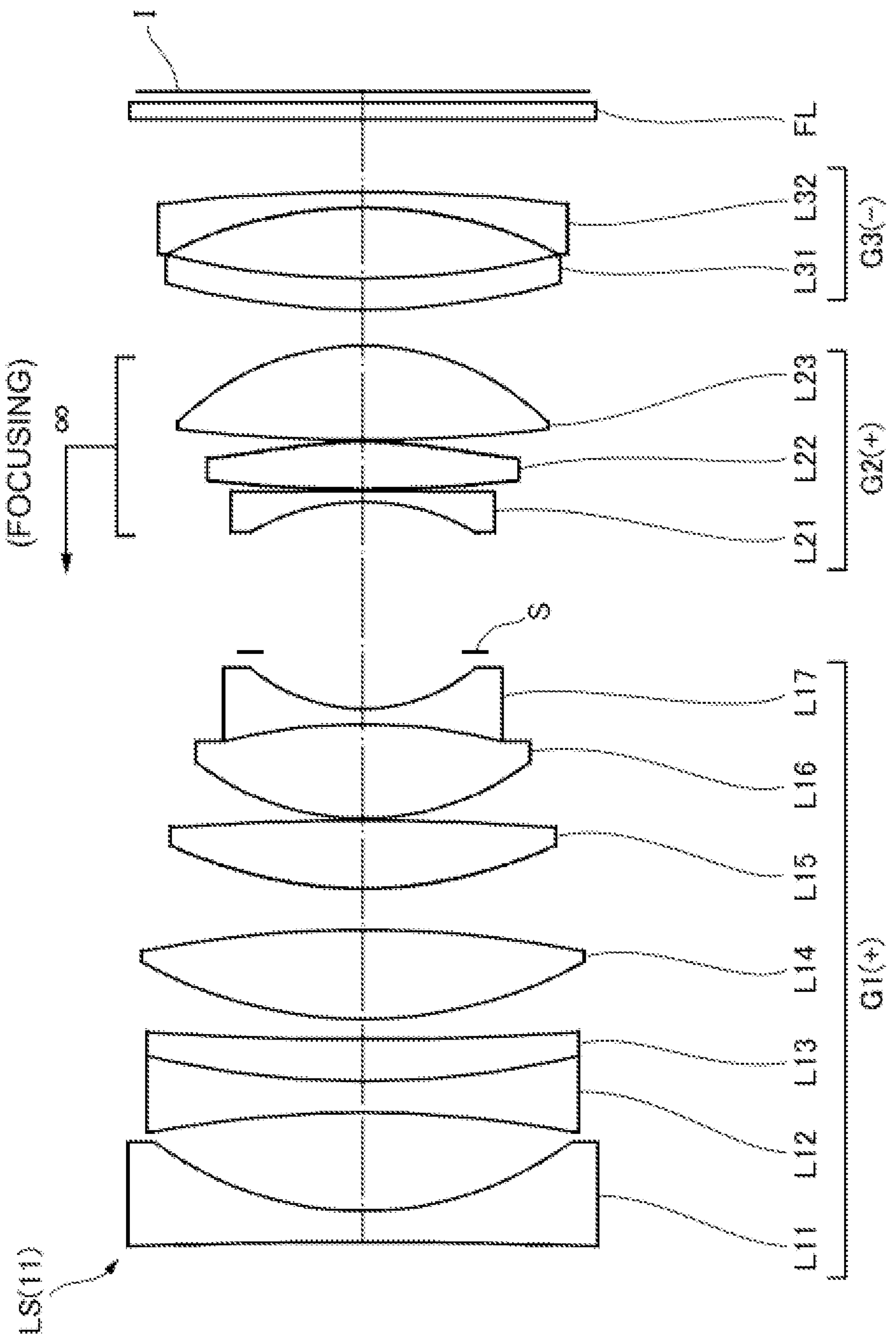

I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(11)

FIG. 22A

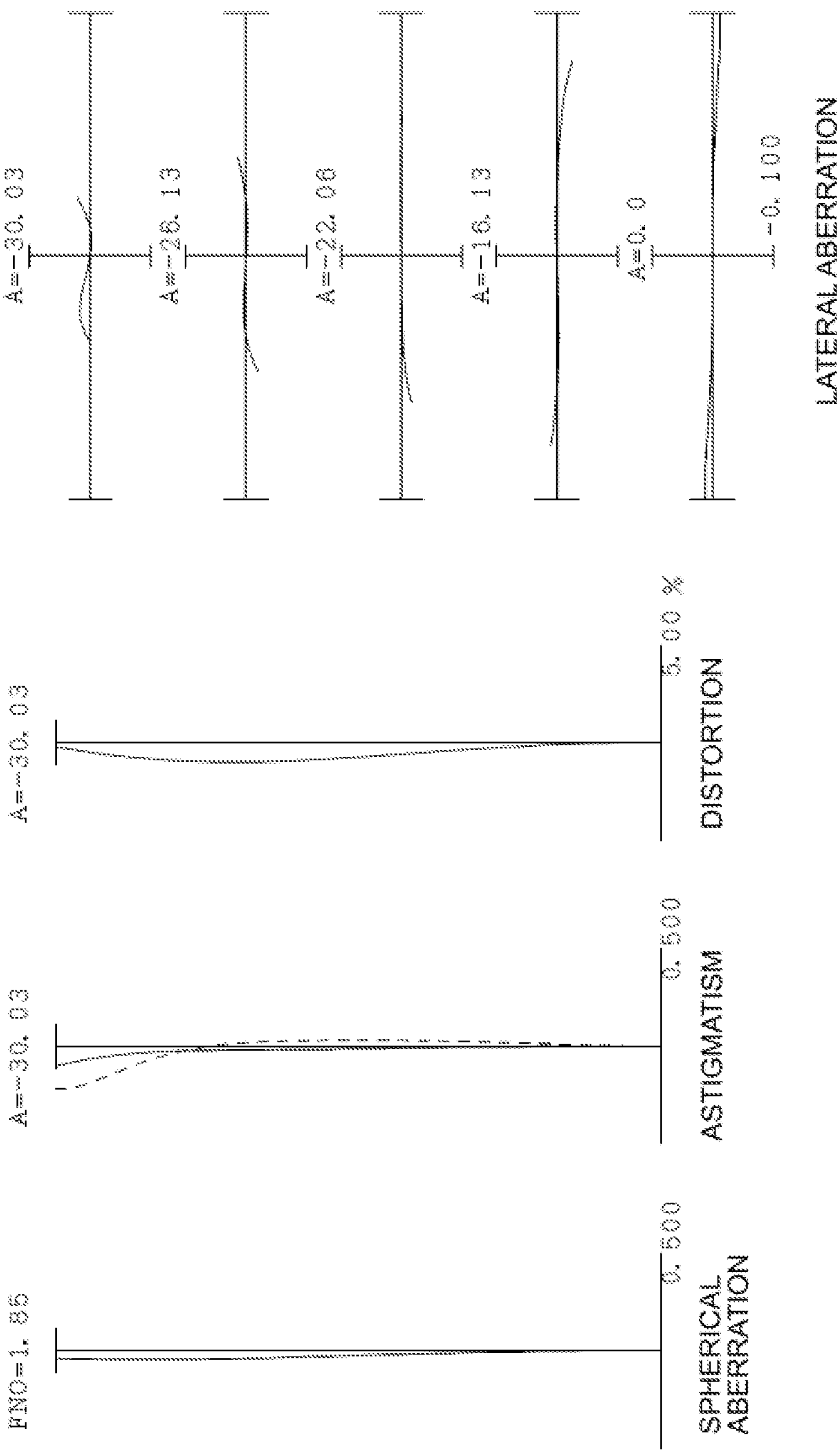
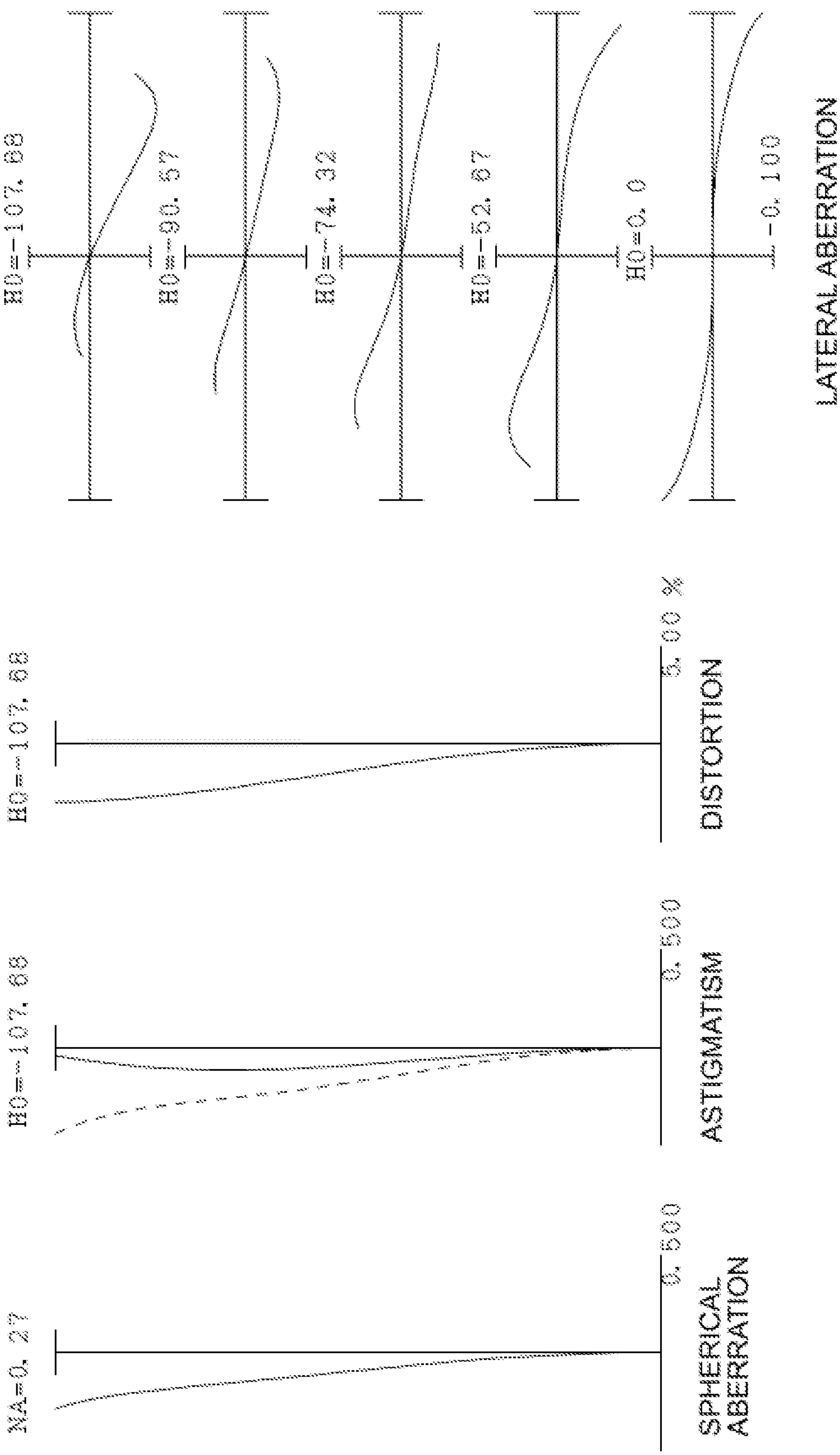
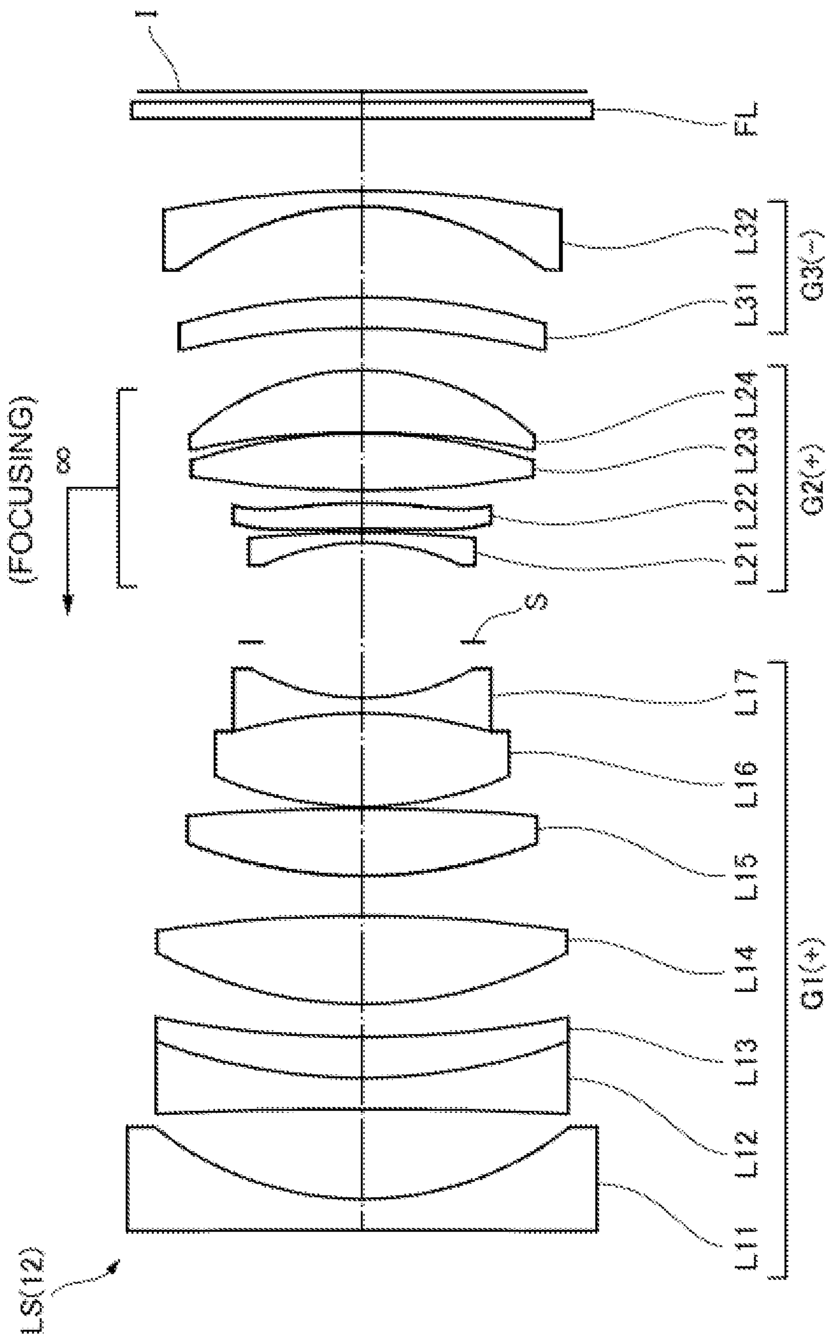

FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=-30. 03
0. 500
ASTIGMATISM
A=-30. 03
5. 00 %
DISTORTION
A=-30. 03
A=-28. 13
A=-22. 06
A=-16. 13
A=0. 0
-0. 100
LATERAL ABERRATION

FIG. 22B



HO=-107.68
HO=-90.57
HO=-74.32
HO=-52.67
HO=0.0
-0.100
LATERAL ABERRATION
HO=-107.68
5.00 %
DISTORTION
HO=-107.68
0.500
ASTIGMATISM
NA=0.27
0.500
SPHERICAL ABERRATION

FIG. 23



(FOCUSING)
∞
I
FL
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(12)

FIG. 24A

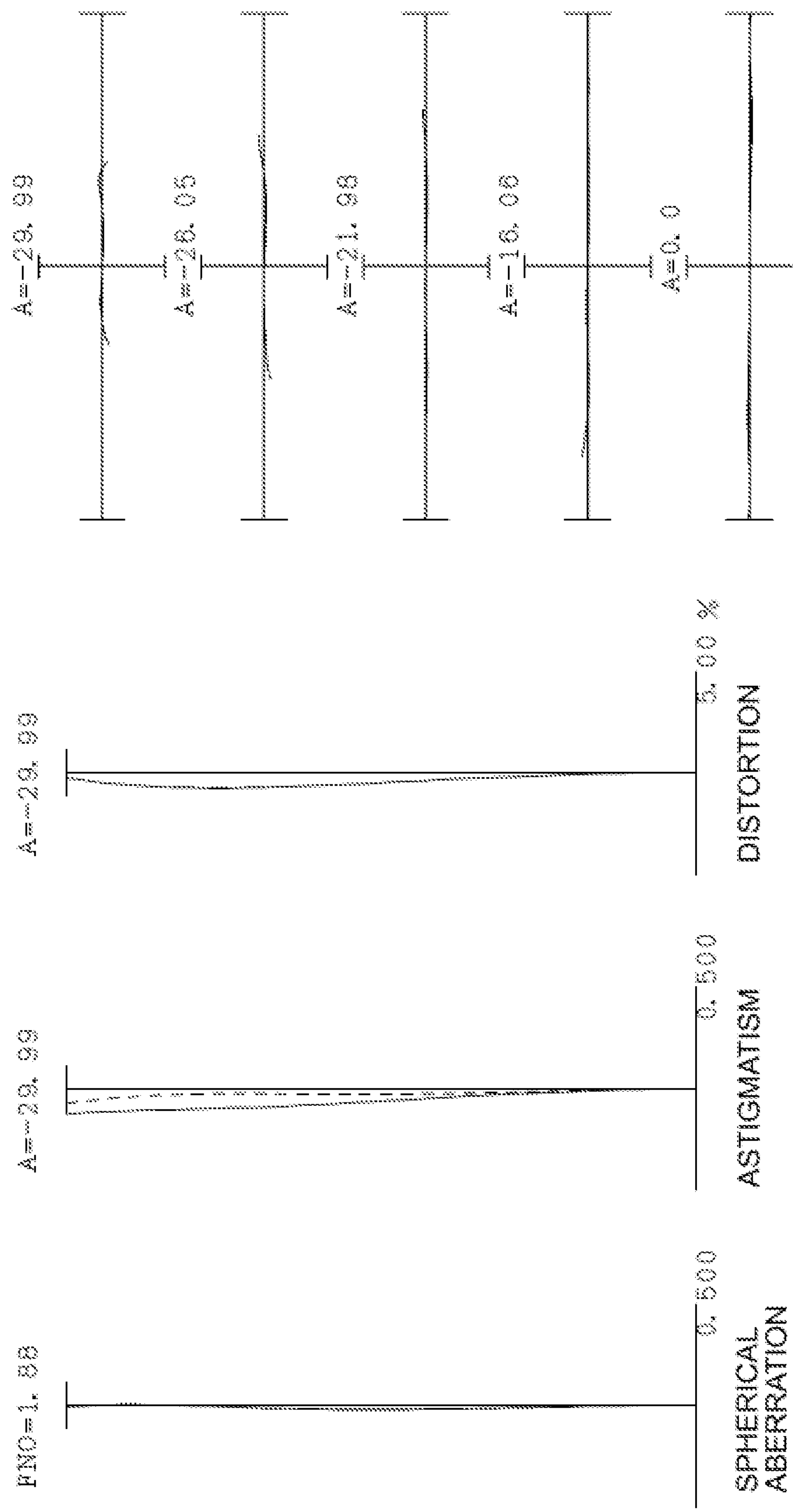

FNO=1.88
0.500
SPHERICAL ABERRATION
A=-29.99
0.500
ASTIGMATISM
A=-29.99
5.00 %
DISTORTION
A=-29.99
A=-28.05
A=-21.98
A=-16.08
A=0.0
-0.100
LATERAL ABERRATION

FIG. 24B

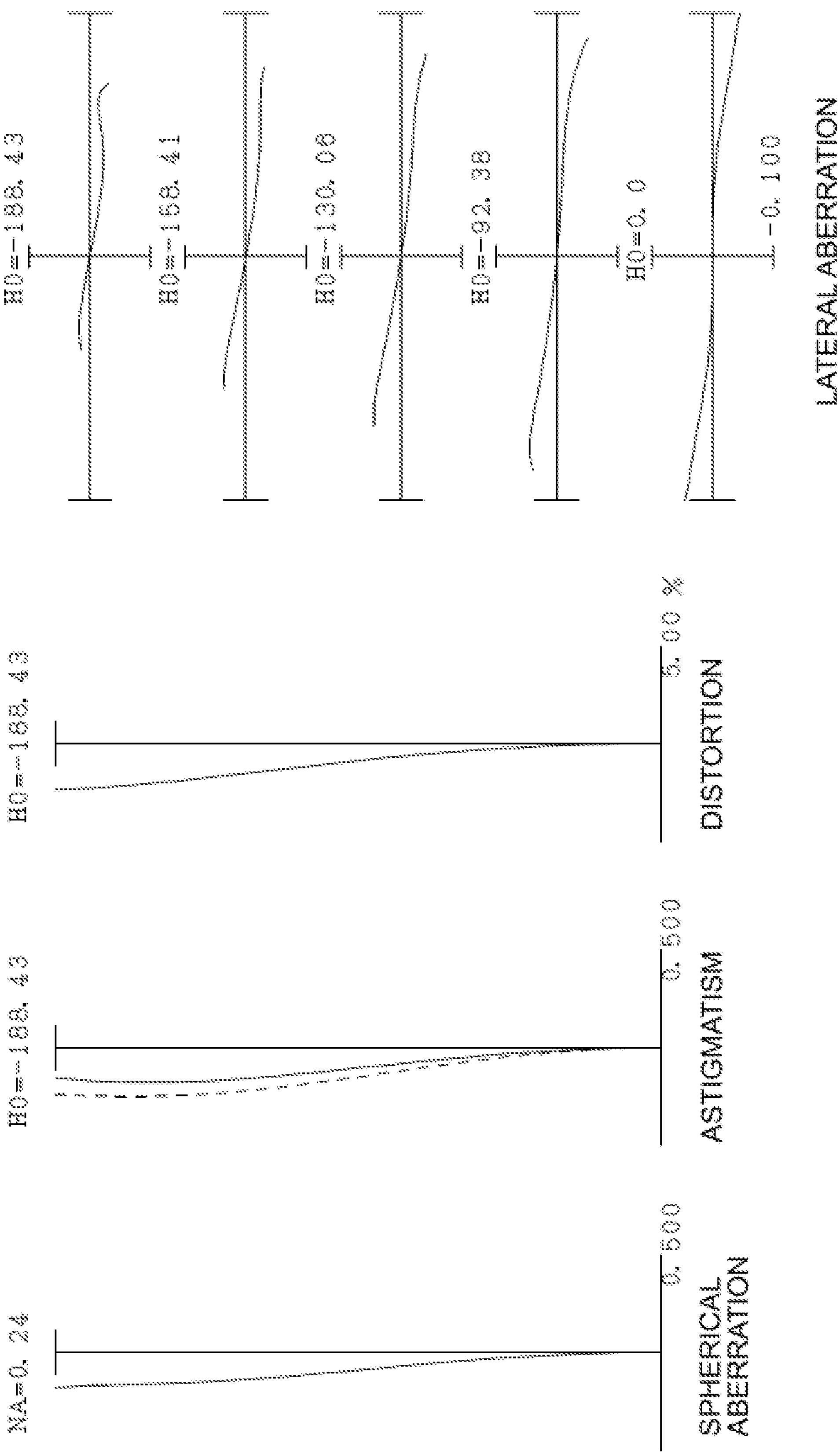

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=−188. 43
0. 500
ASTIGMATISM
H0=−188. 43
5. 00 %
DISTORTION
H0=−188. 43
H0=−158. 41
H0=−130. 08
H0=−92. 38
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 25

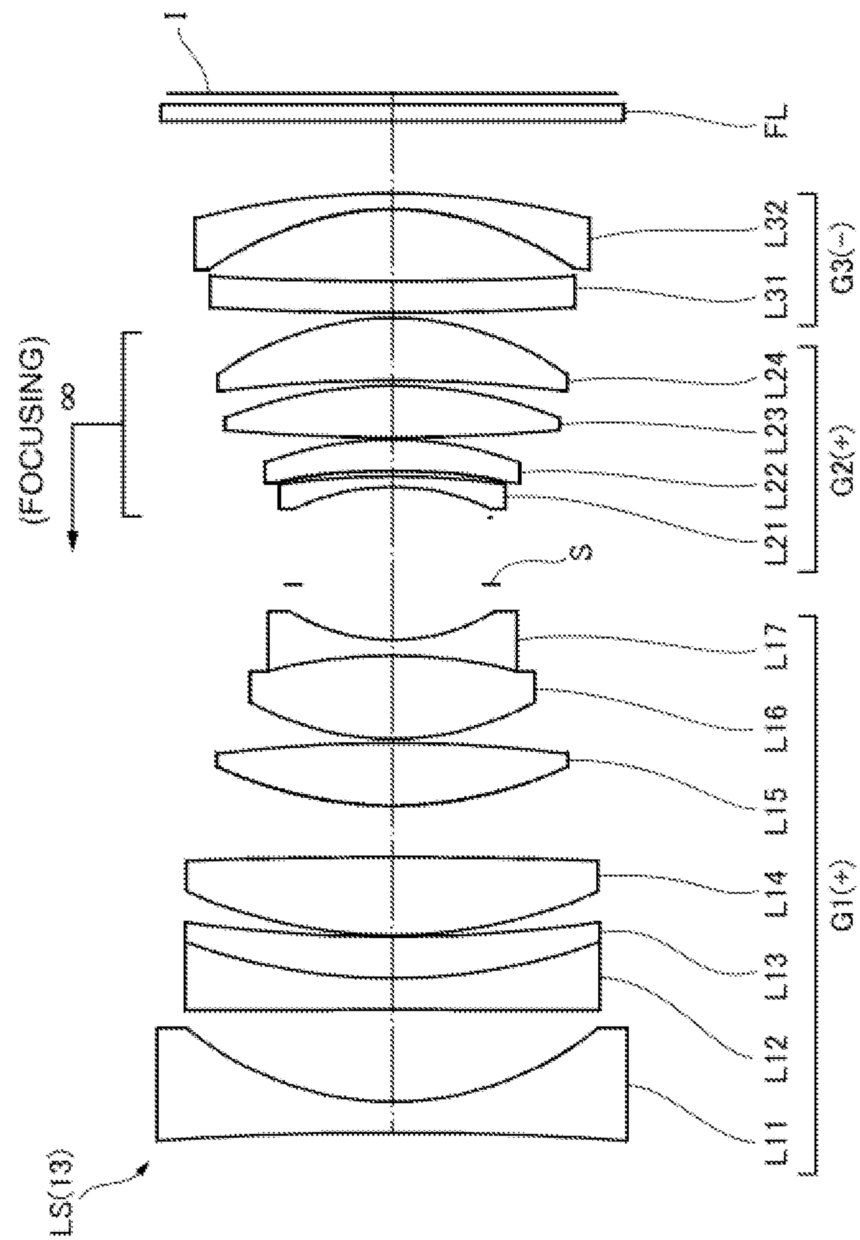
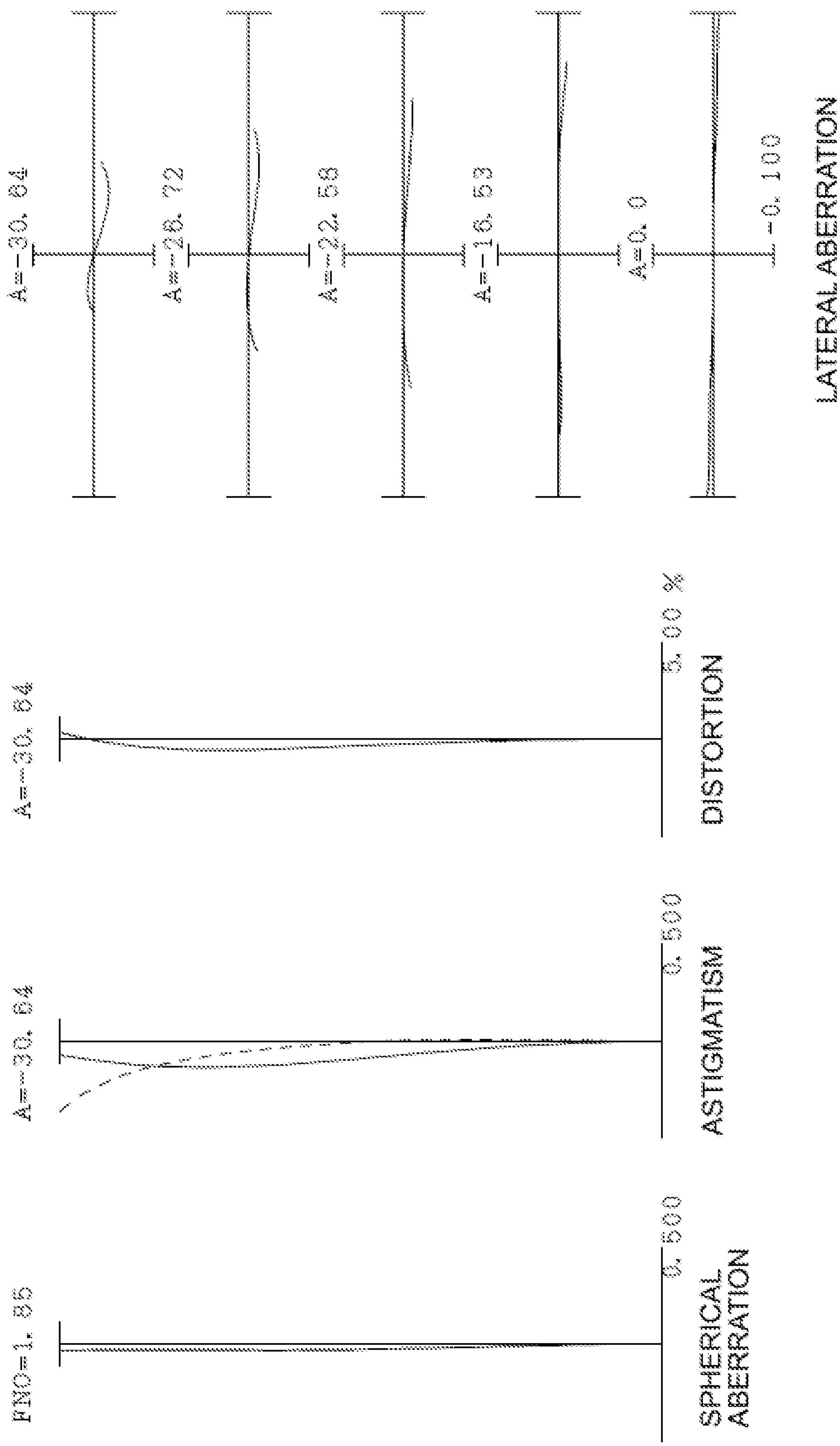

I
FL
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
(FOCUSING)
∞
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(13)

FIG. 26A



FNO=1.85
0.500
SPHERICAL ABERRATION
A=-30.64
0.500
ASTIGMATISM
A=-30.64
5.00 %
DISTORTION
A=-30.64
A=-26.72
A=-22.58
A=-16.53
A=0.0
-0.100
LATERAL ABERRATION

FIG. 26B

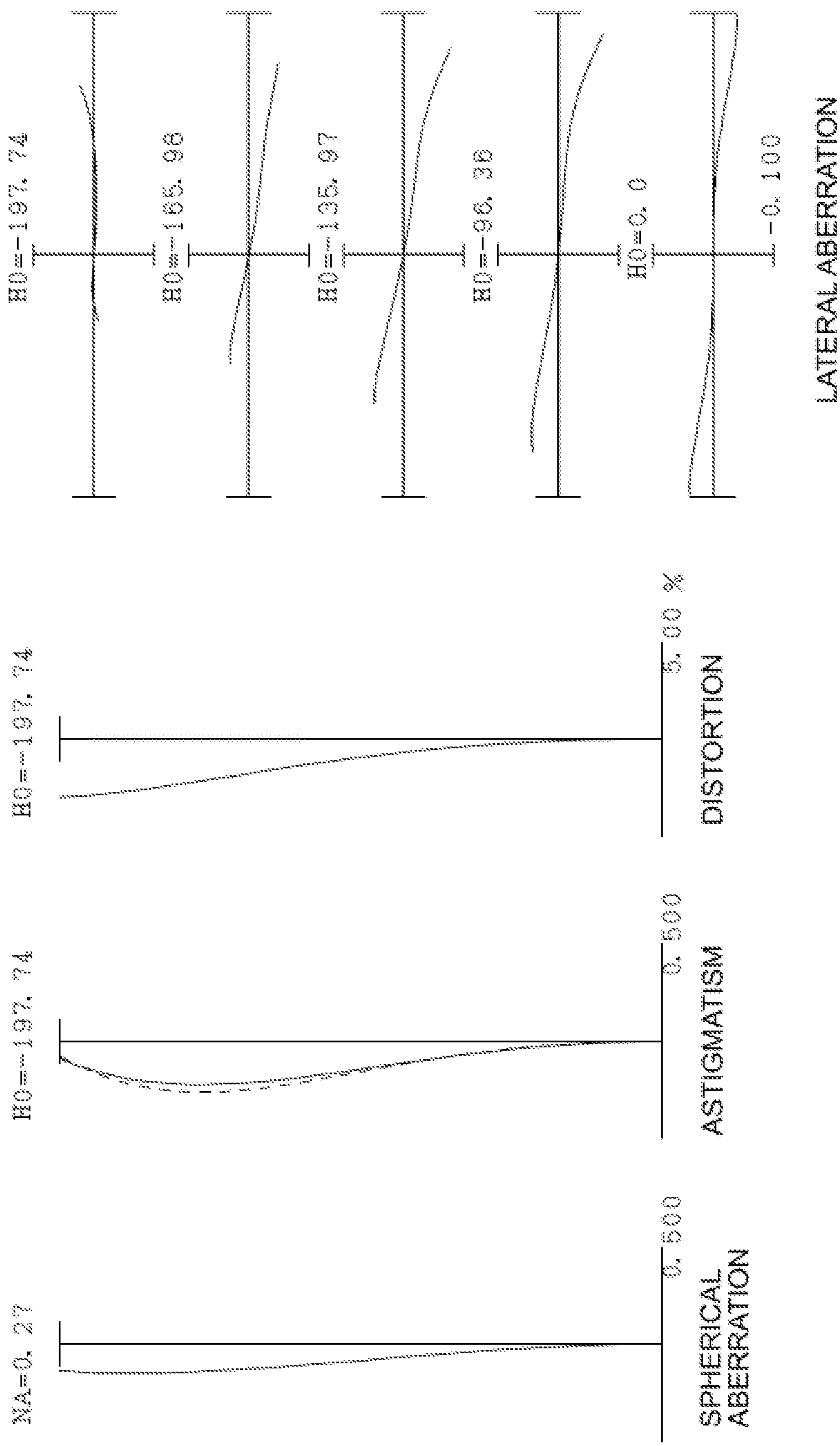
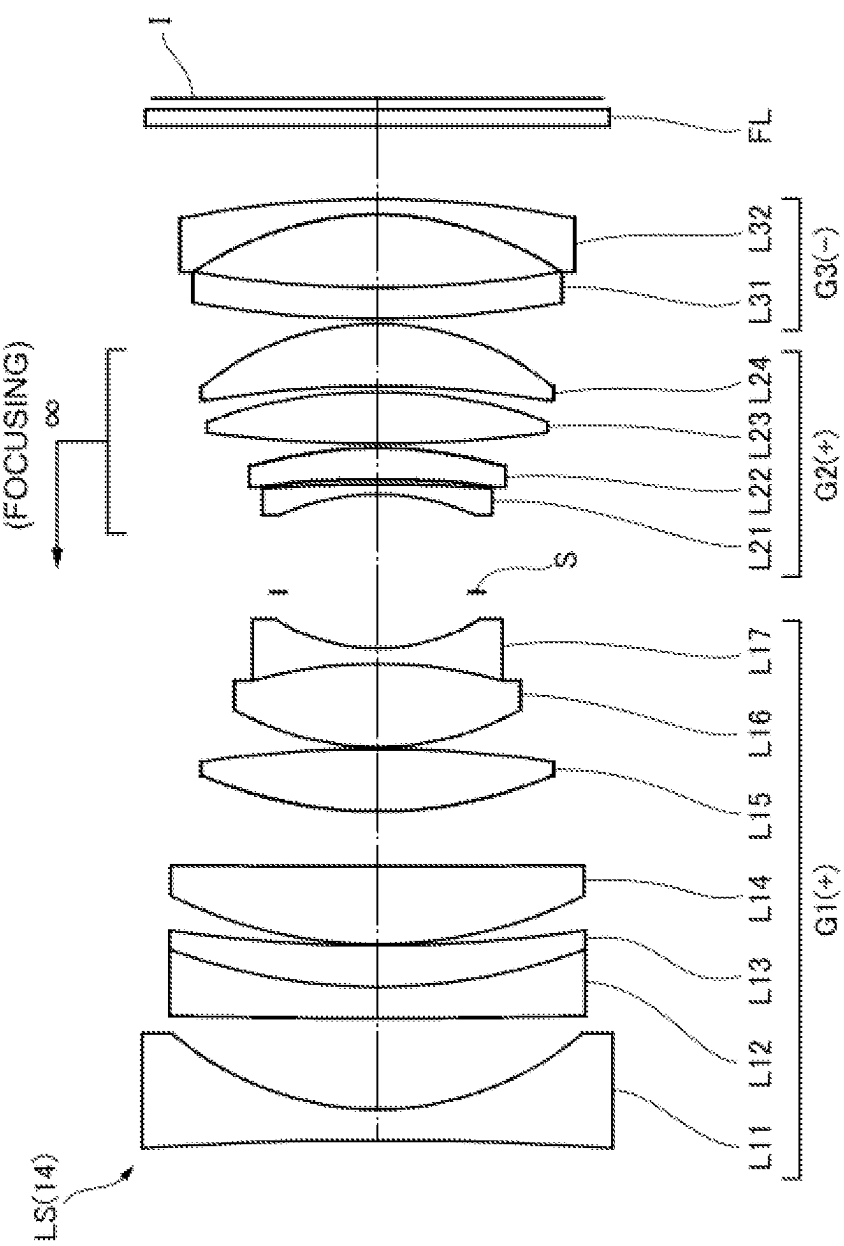

NA=0.27
0.500
SPHERICAL ABERRATION
H0=-197.74
0.500
ASTIGMATISM
H0=-197.74
5.00 %
DISTORTION
H0=-197.74
H0=-165.98
H0=-135.97
H0=-96.36
H0=0.0
-0.100
LATERAL ABERRATION

FIG. 27



I
FL
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
(FOCUSING)
∞
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(14)

FIG. 28A

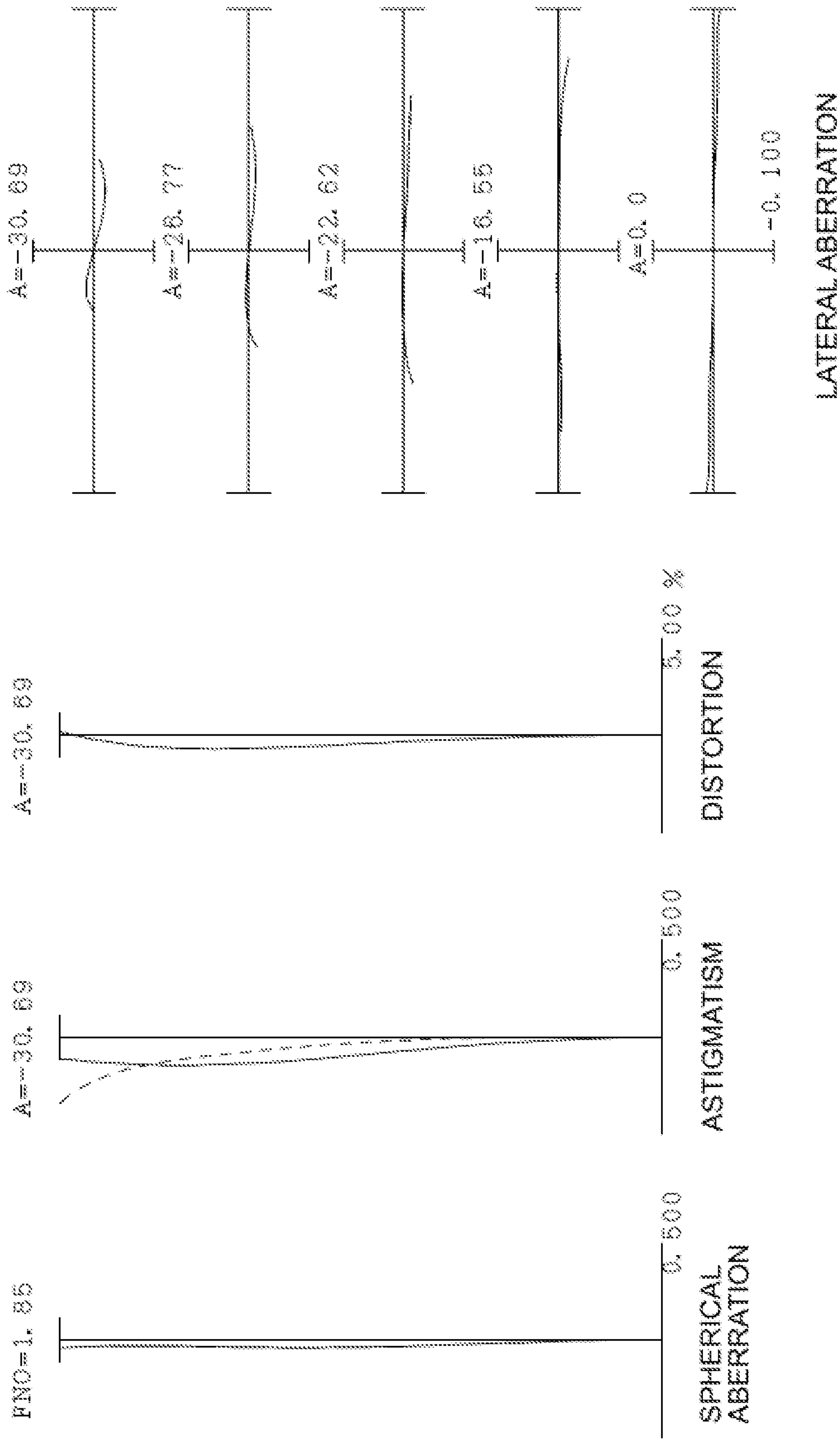

FNO=1.85
0.500
SPHERICAL ABERRATION
A=-30.69
0.500
ASTIGMATISM
A=-30.69
5.00 %
DISTORTION
A=-30.69
A=-28.77
A=-22.62
A=-16.55
A=0.0
-0.100
LATERAL ABERRATION

FIG. 28B

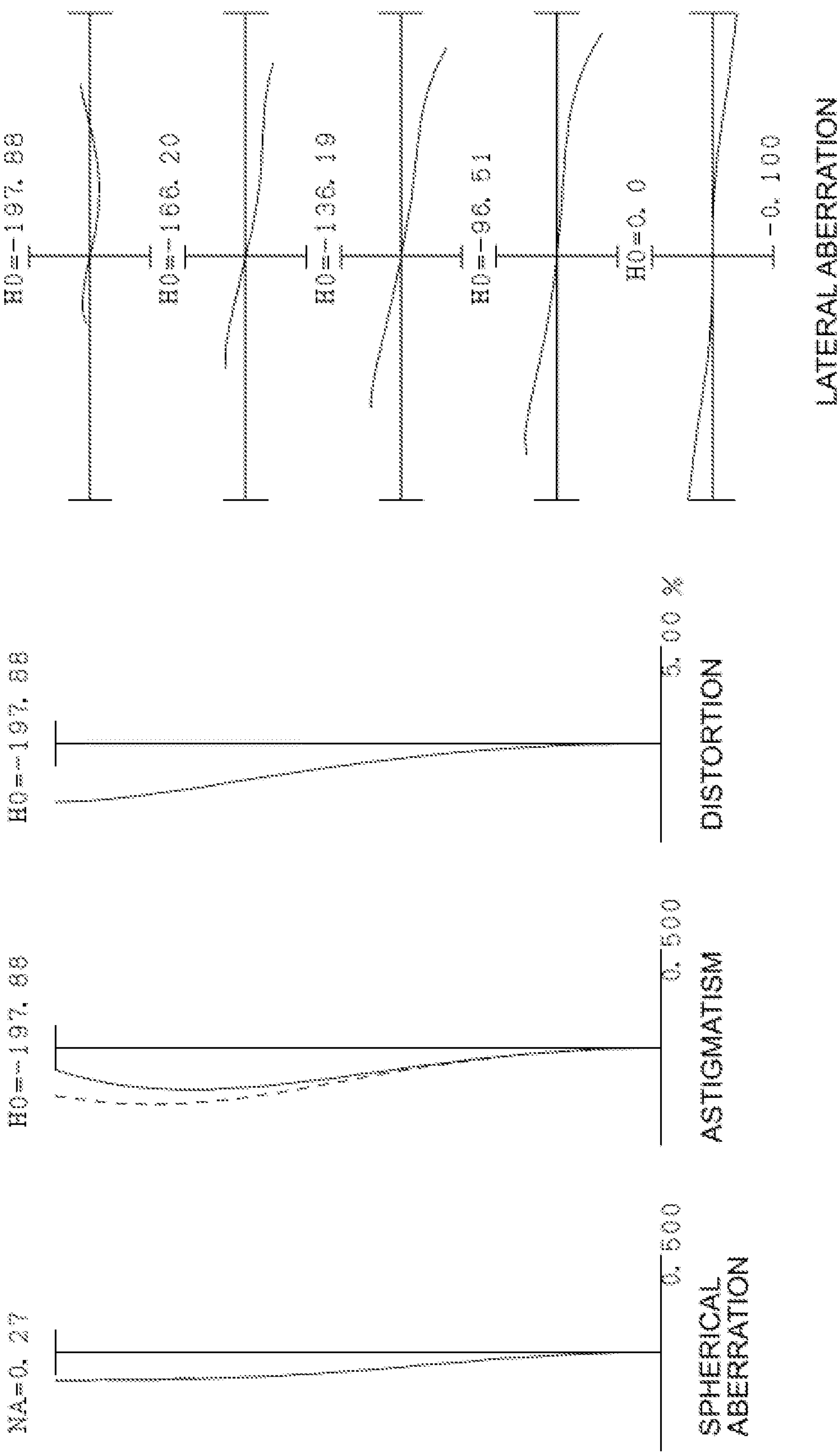

NA=0. 27
0. 500
SPHERICAL ABERRATION
H0=-197. 88
0. 500
ASTIGMATISM
H0=-197. 88
5. 00 %
DISTORTION
H0=-197. 88
H0=-166. 20
H0=-136. 19
H0=-96. 51
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 29

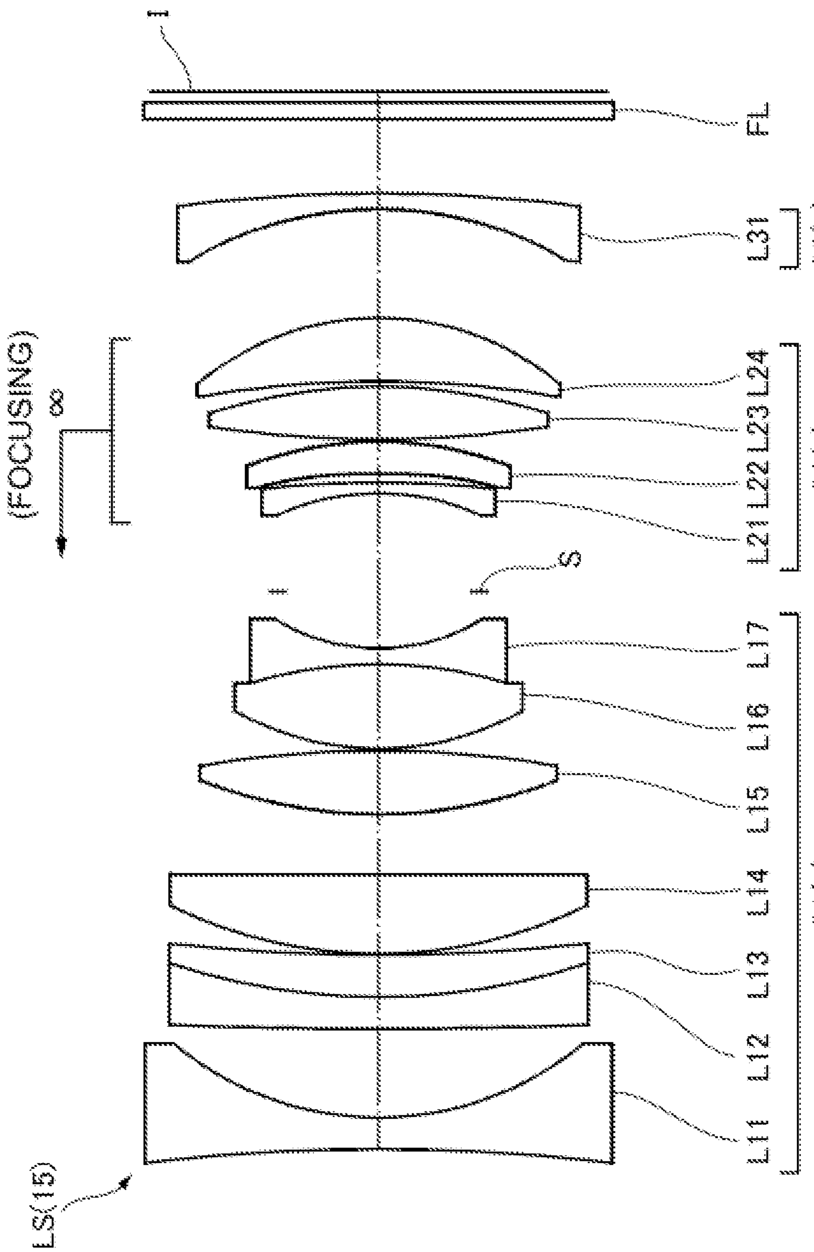

I
FL
L31
G3(−)
(FOCUSING)
∞
L24
L23
L22
L21
G2(+)
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(15)

FIG. 30A

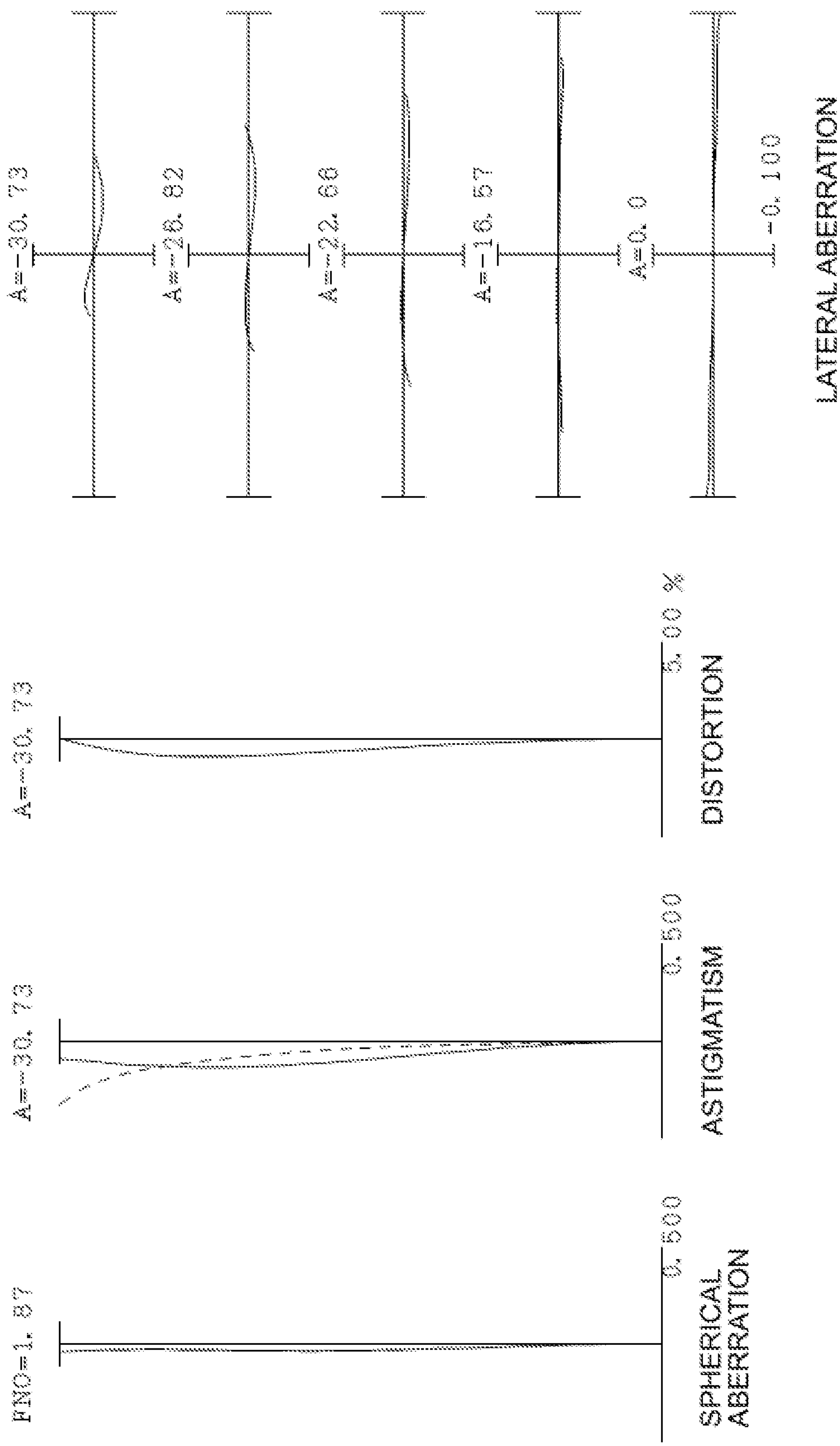
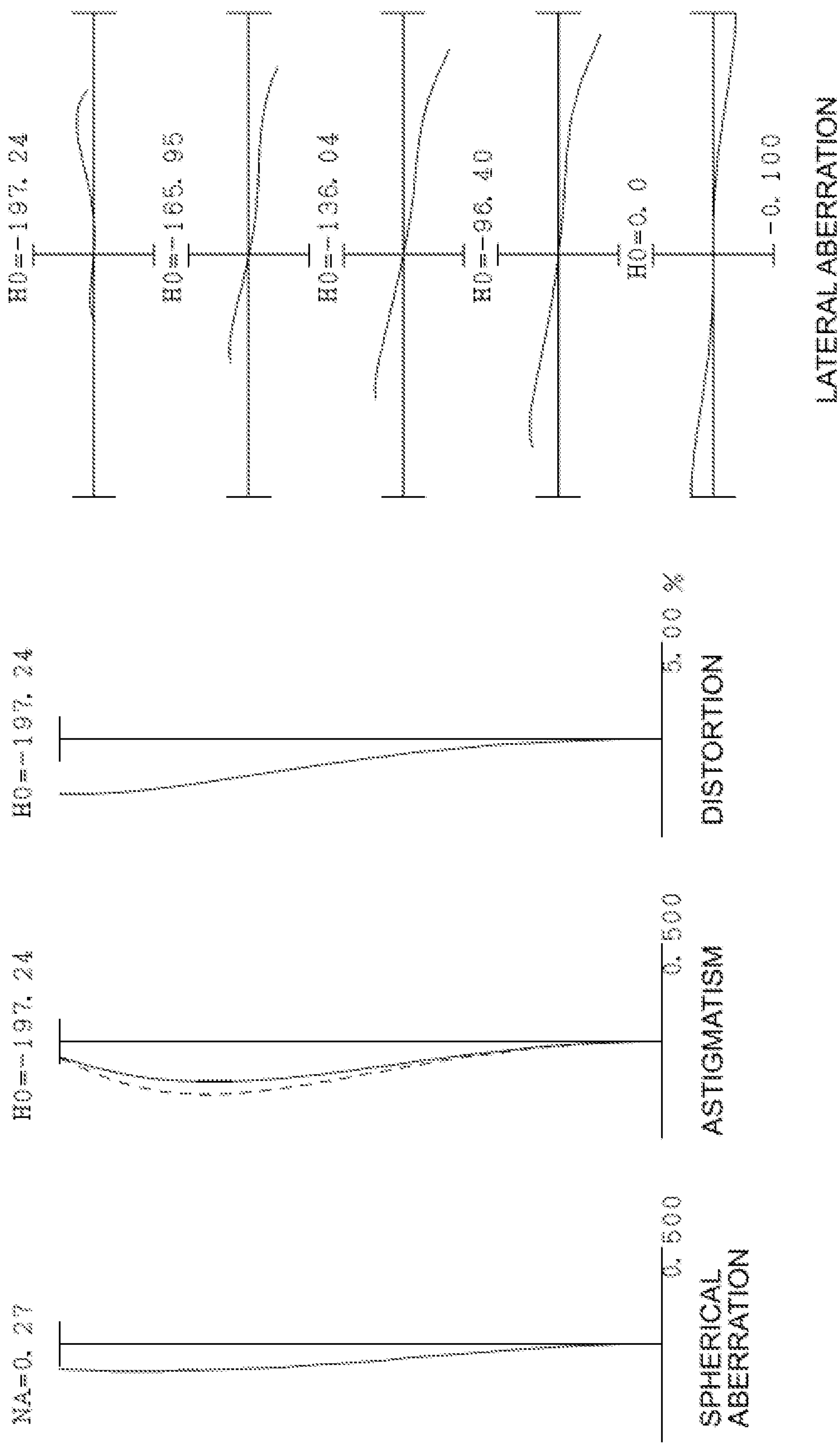

FNO=1. 87
0. 500
SPHERICAL ABERRATION
A=−30. 73
0. 500
ASTIGMATISM
A=−30. 73
5. 00 %
DISTORTION
A=−30. 73
A=−28. 82
A=−22. 66
A=−16. 57
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 30B



H0=-197. 24
H0=-165. 95
H0=-136. 04
H0=-96. 40
H0=0. 0
-0. 100
LATERAL ABERRATION
H0=-197. 24
5. 00 %
DISTORTION
H0=-197. 24
0. 500
ASTIGMATISM
NA=0. 27
0. 500
SPHERICAL ABERRATION

FIG. 31

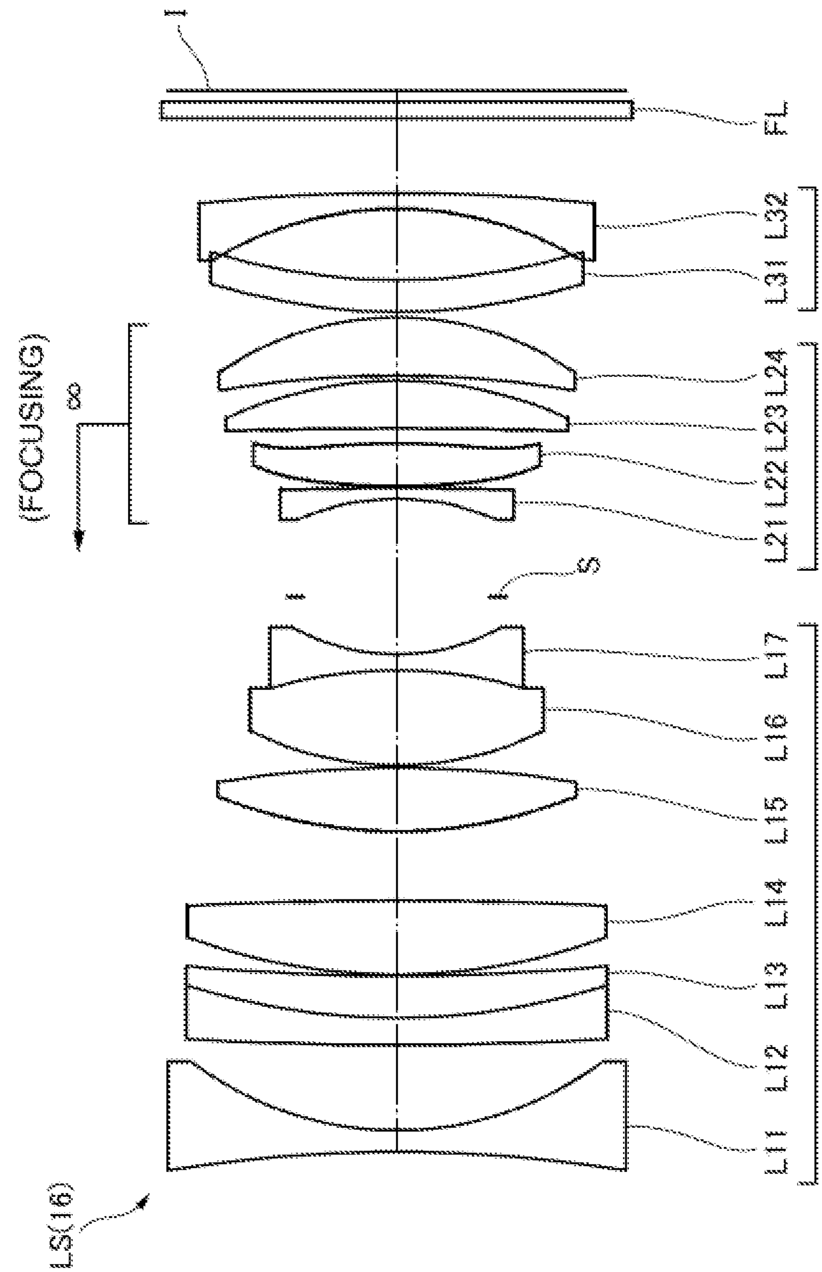
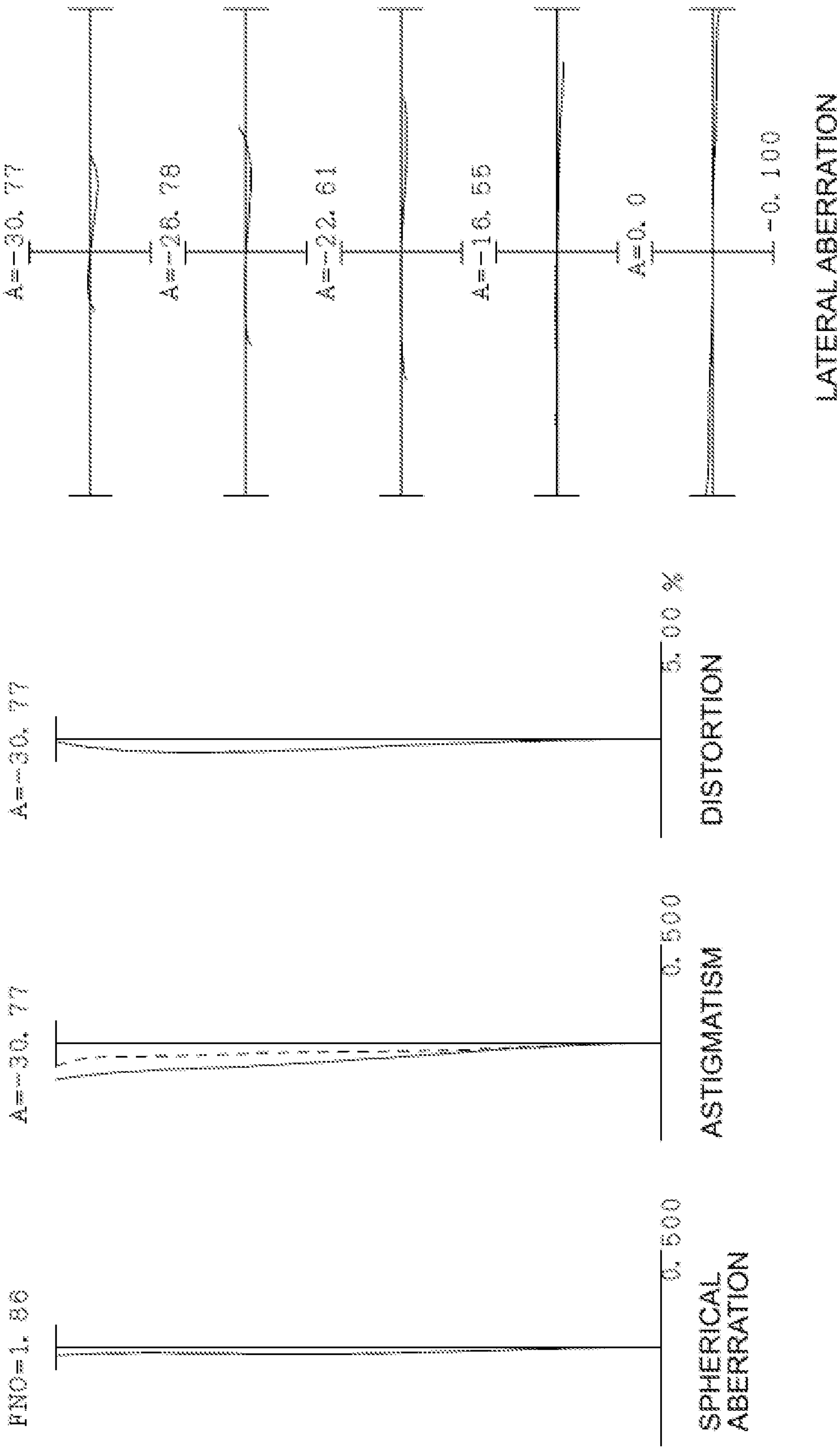

I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L24
L23
L22
L21
G2(+)
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(16)

FIG. 32A



FNO=1. 86
0. 500
SPHERICAL ABERRATION
A=−30. 77
0. 500
ASTIGMATISM
A=−30. 77
5. 00 %
DISTORTION
A=−30. 77
A=−28. 78
A=−22. 61
A=−16. 55
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 32B

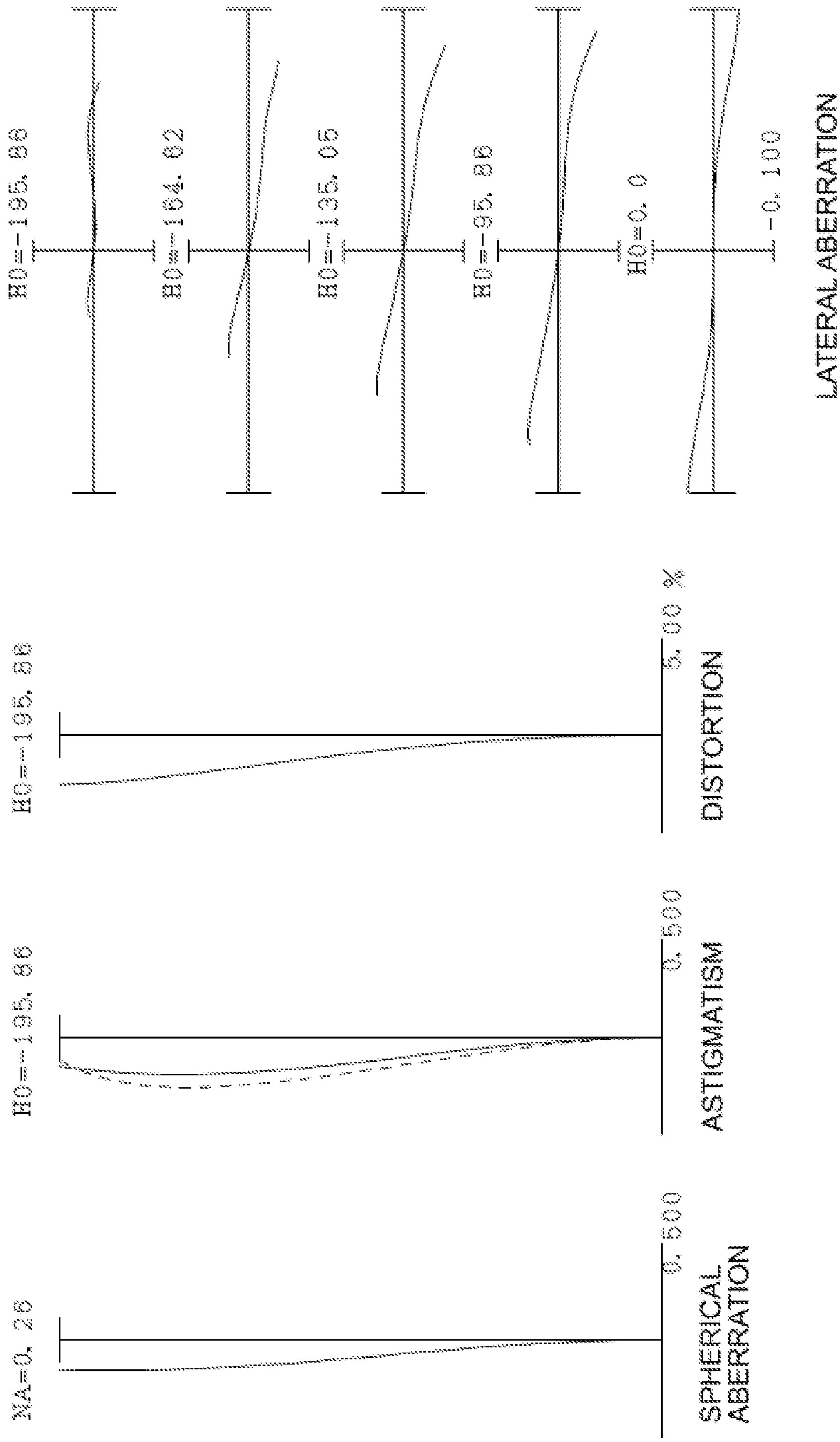
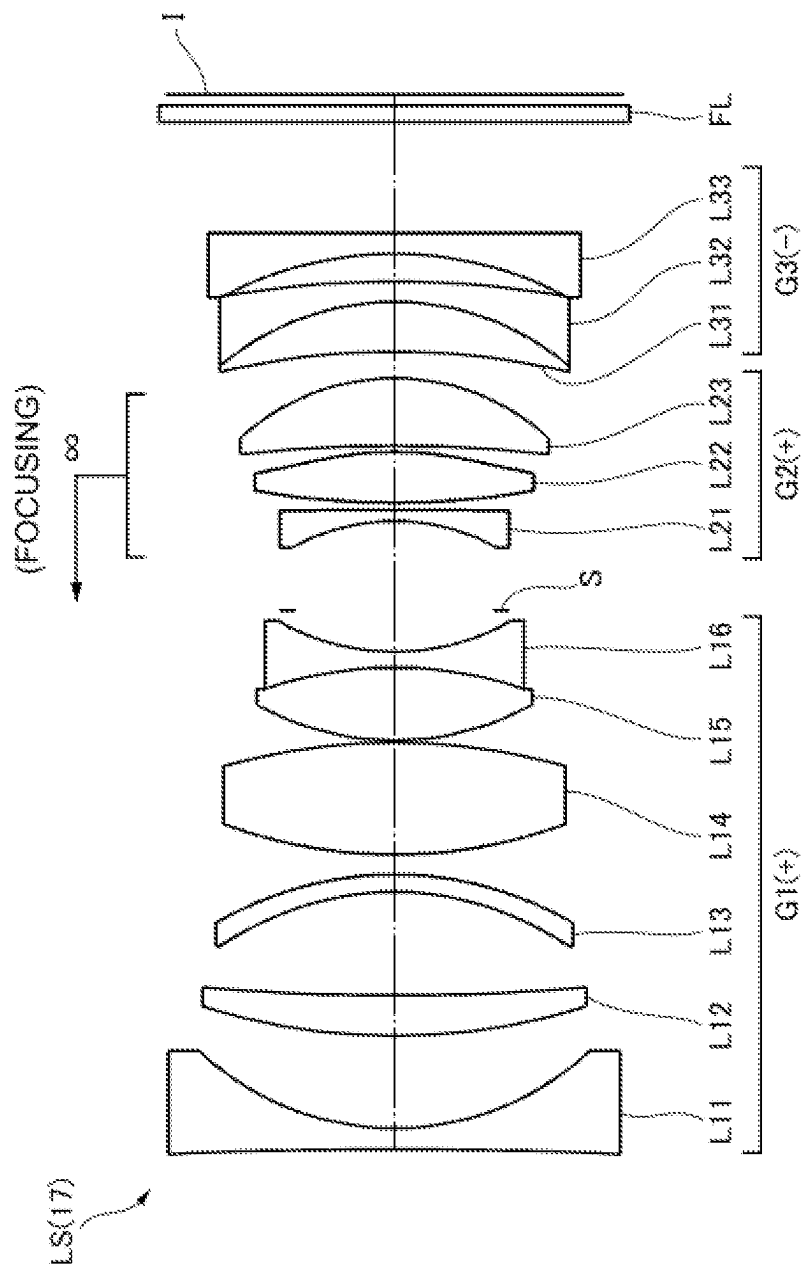

NA=0. 26
0. 500
SPHERICAL ABERRATION
H0=-195. 86
0. 500
ASTIGMATISM
H0=-195. 86
5. 00 %
DISTORTION
H0=-195. 86
H0=-164. 62
H0=-135. 05
H0=-95. 86
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 33



I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(17)

FIG. 34A

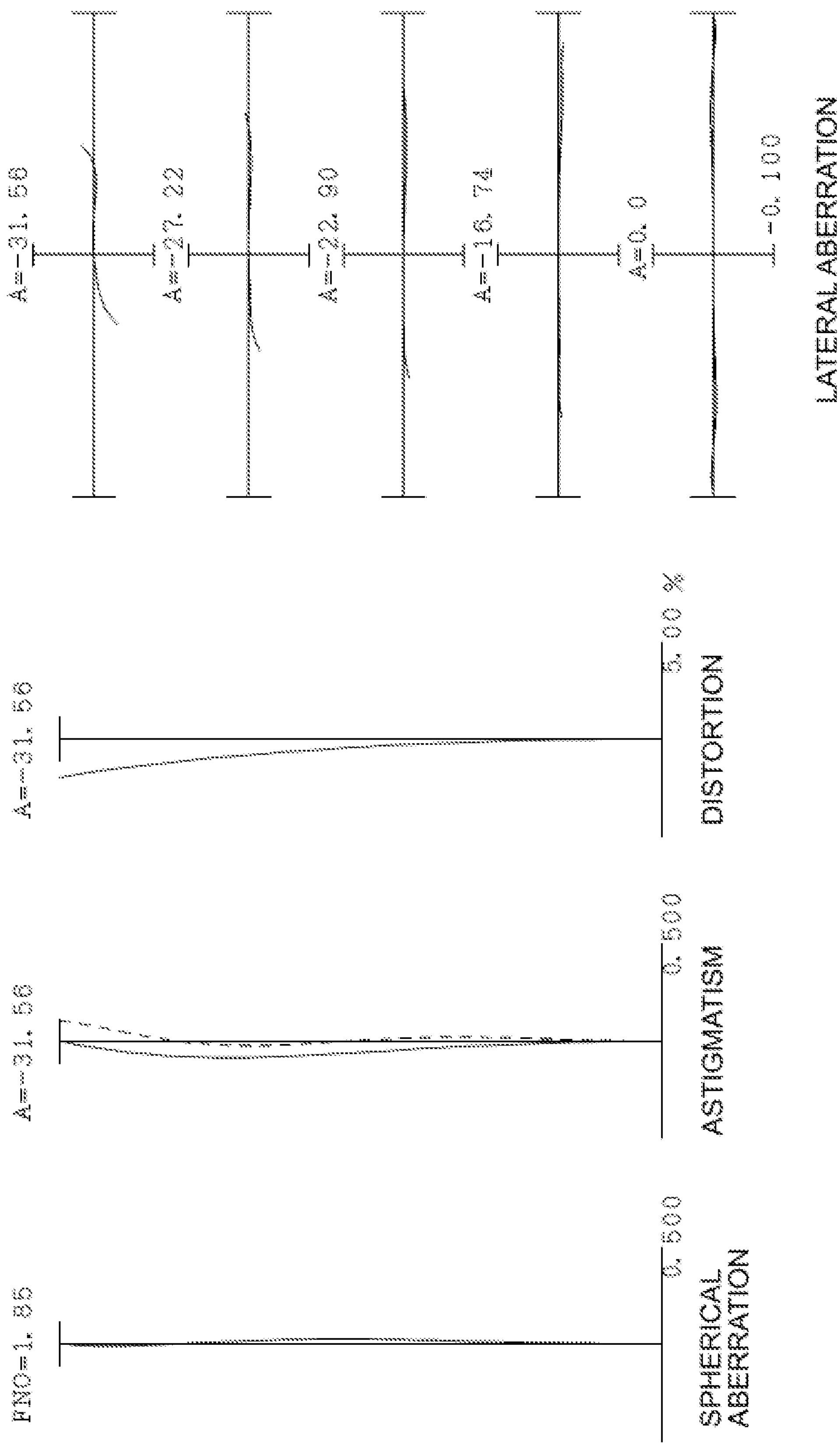

FNO=1.85
0.500
SPHERICAL ABERRATION
A=-31.56
0.500
ASTIGMATISM
A=-31.56
5.00 %
DISTORTION
A=-31.56
A=-27.22
A=-22.90
A=-16.74
A=0.0
-0.100
LATERAL ABERRATION

FIG. 34B

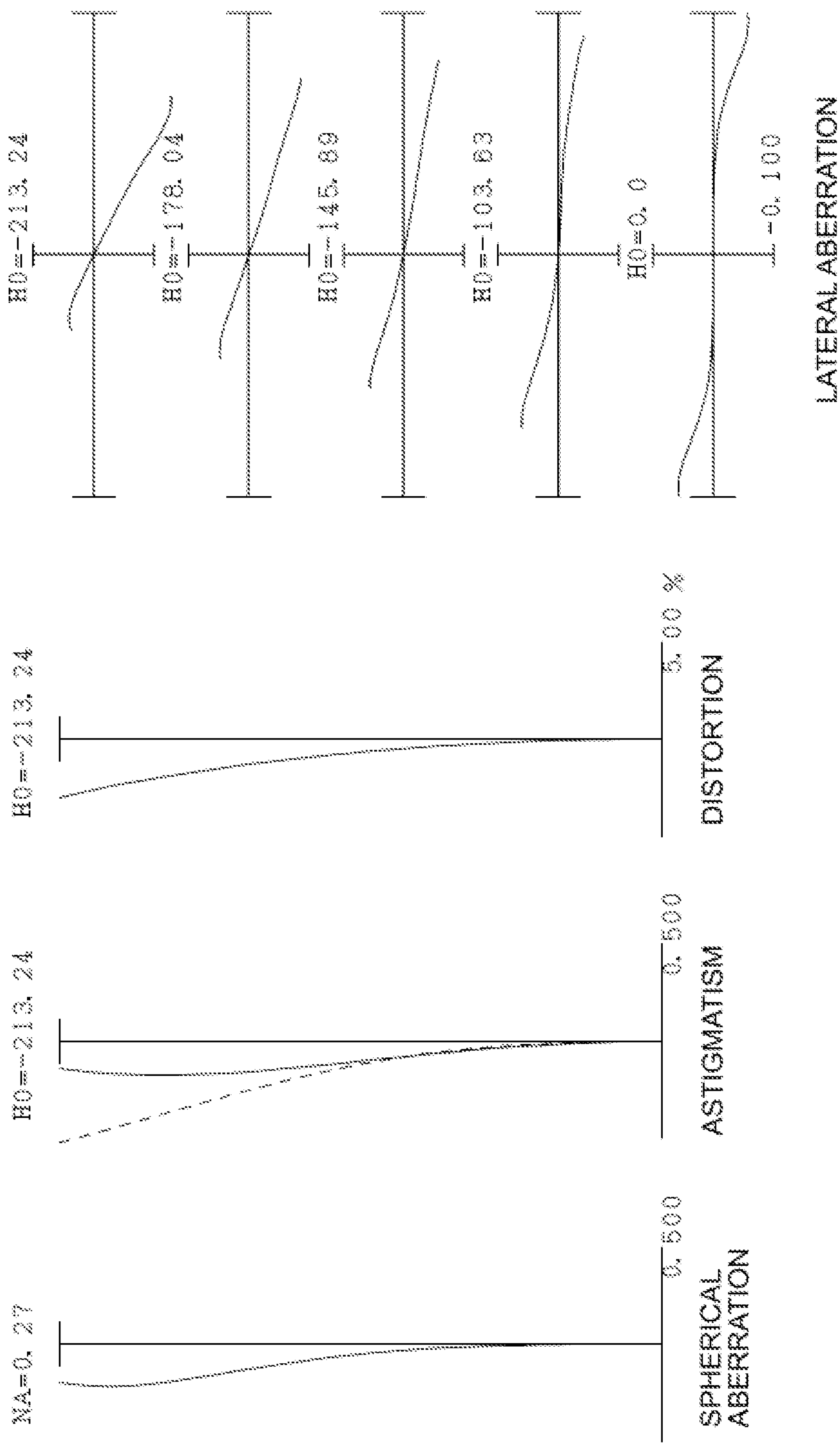

NA=0. 27
0. 500
SPHERICAL ABERRATION
H0=−213. 24
0. 500
ASTIGMATISM
H0=−213. 24
5. 00 %
DISTORTION
H0=−213. 24
H0=−178. 04
H0=−145. 89
H0=−103. 63
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 35

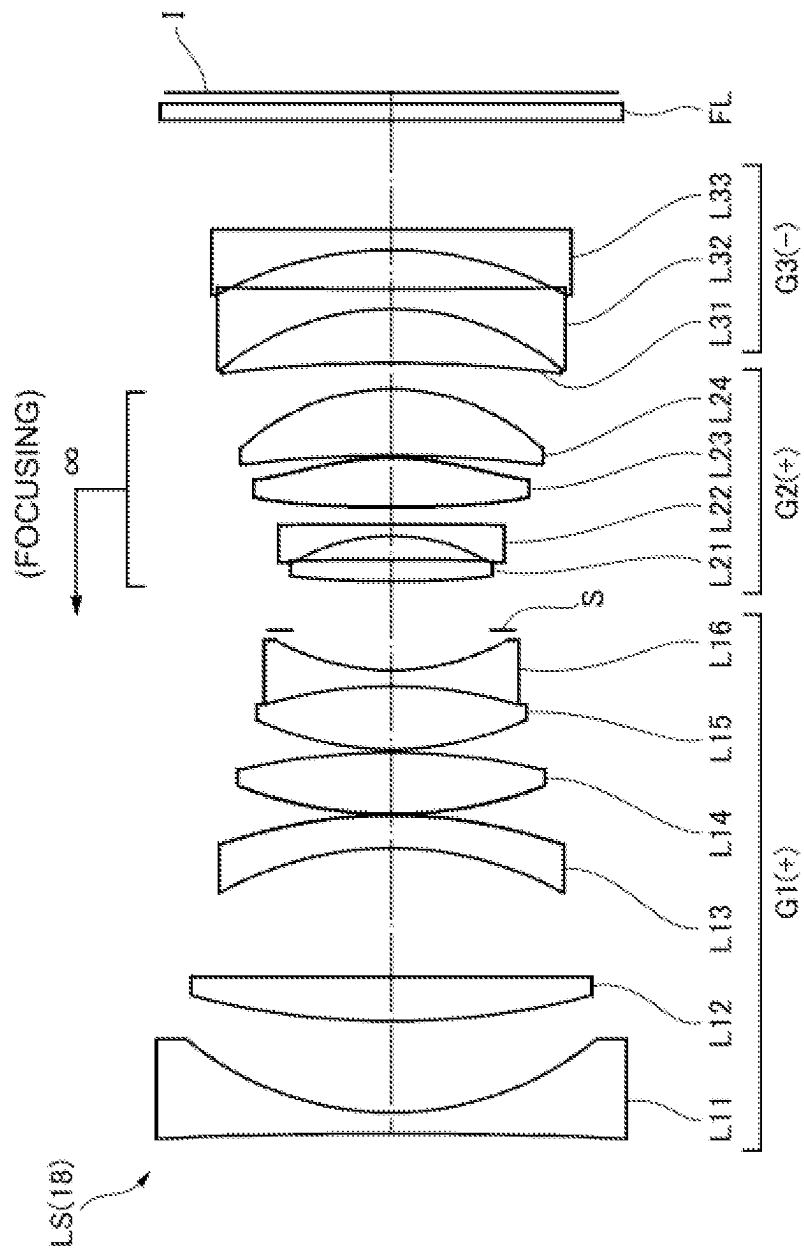
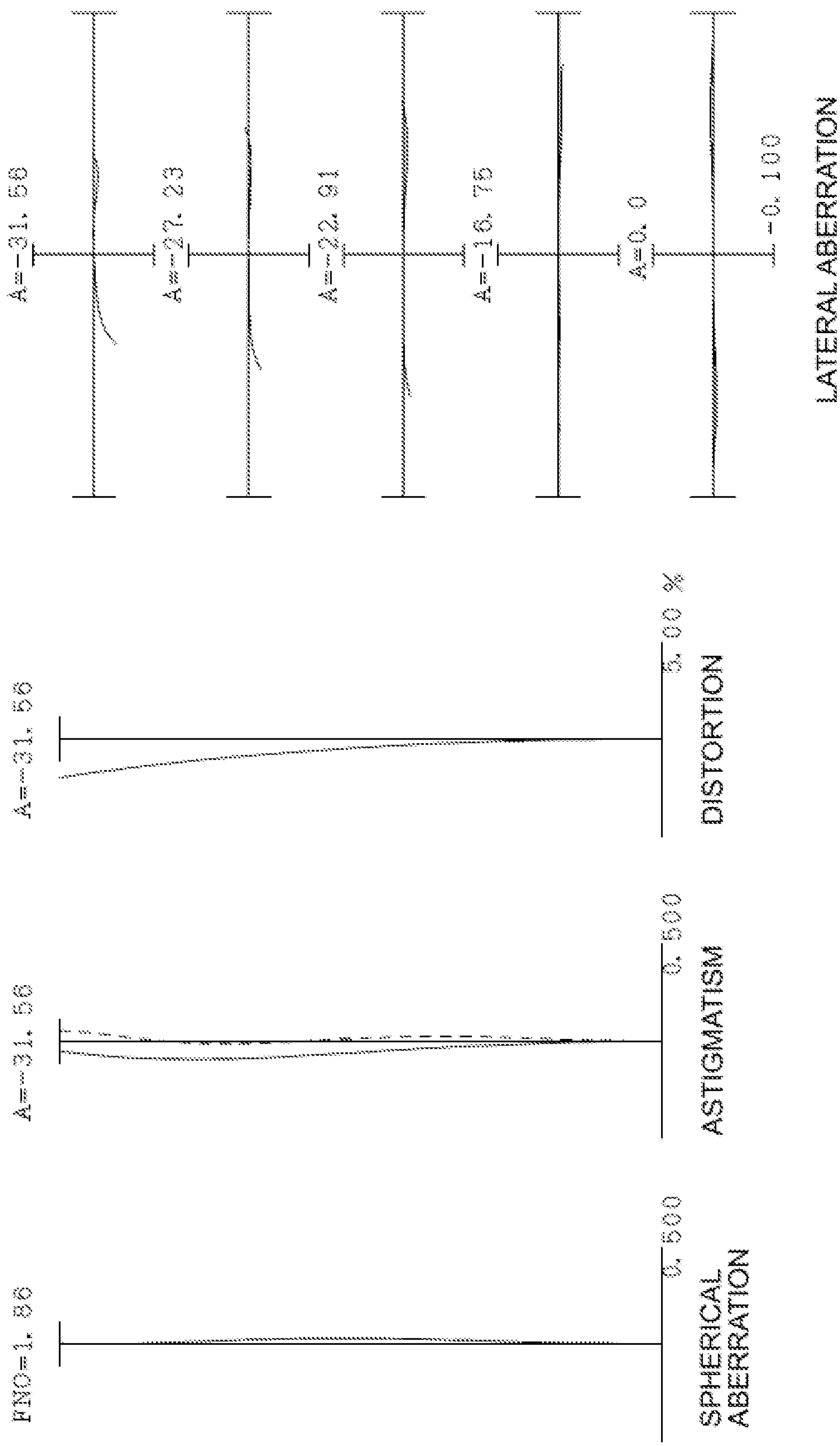

(FOCUSING)
∞
I
FL
L33
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(18)

FIG. 36A



FNO=1.86
0.500
SPHERICAL ABERRATION
A=-31.56
0.500
ASTIGMATISM
A=-31.56
5.00 %
DISTORTION
A=-31.56
A=-27.23
A=-22.91
A=-16.75
A=0.0
-0.100
LATERAL ABERRATION

FIG. 36B

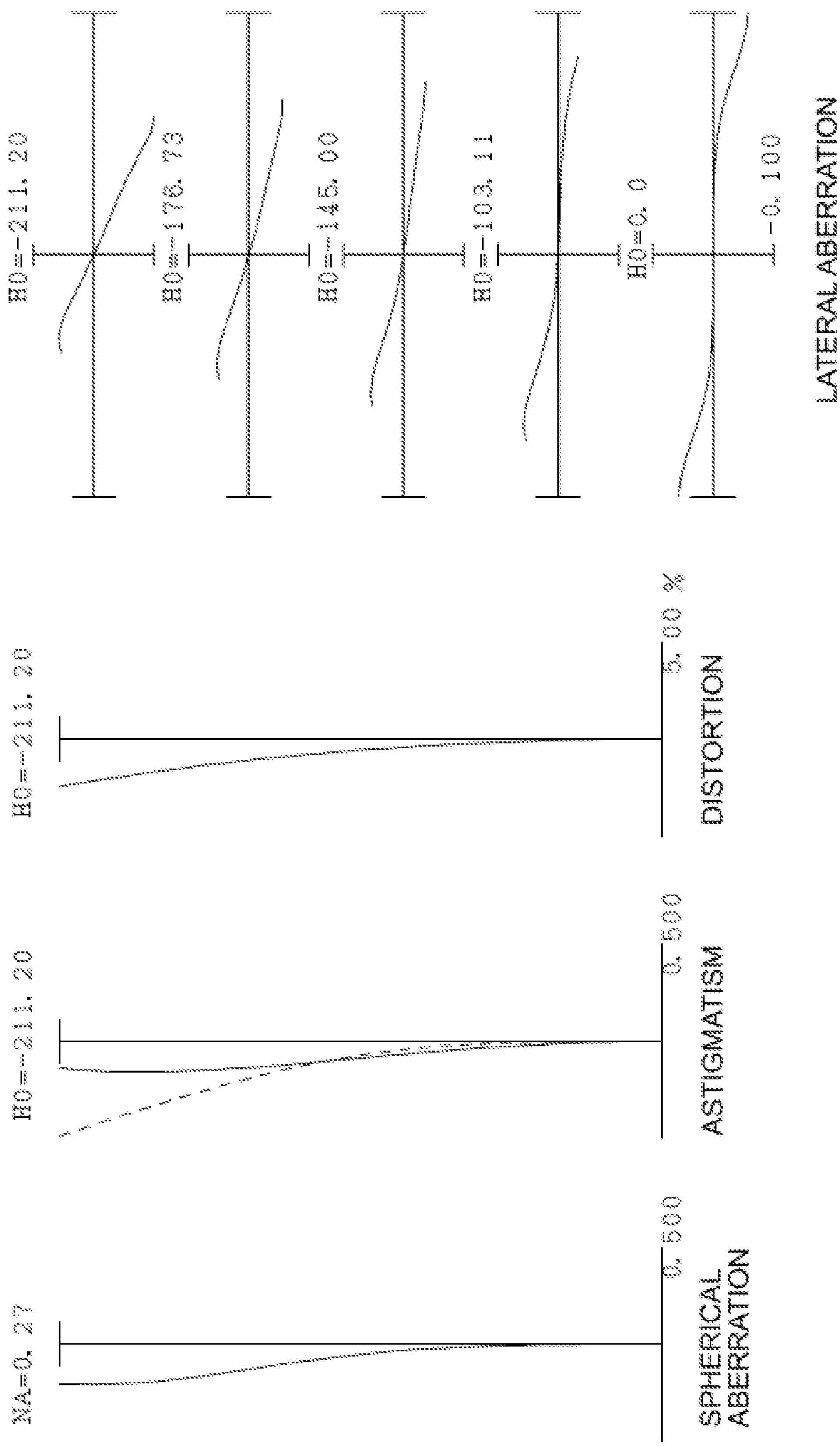
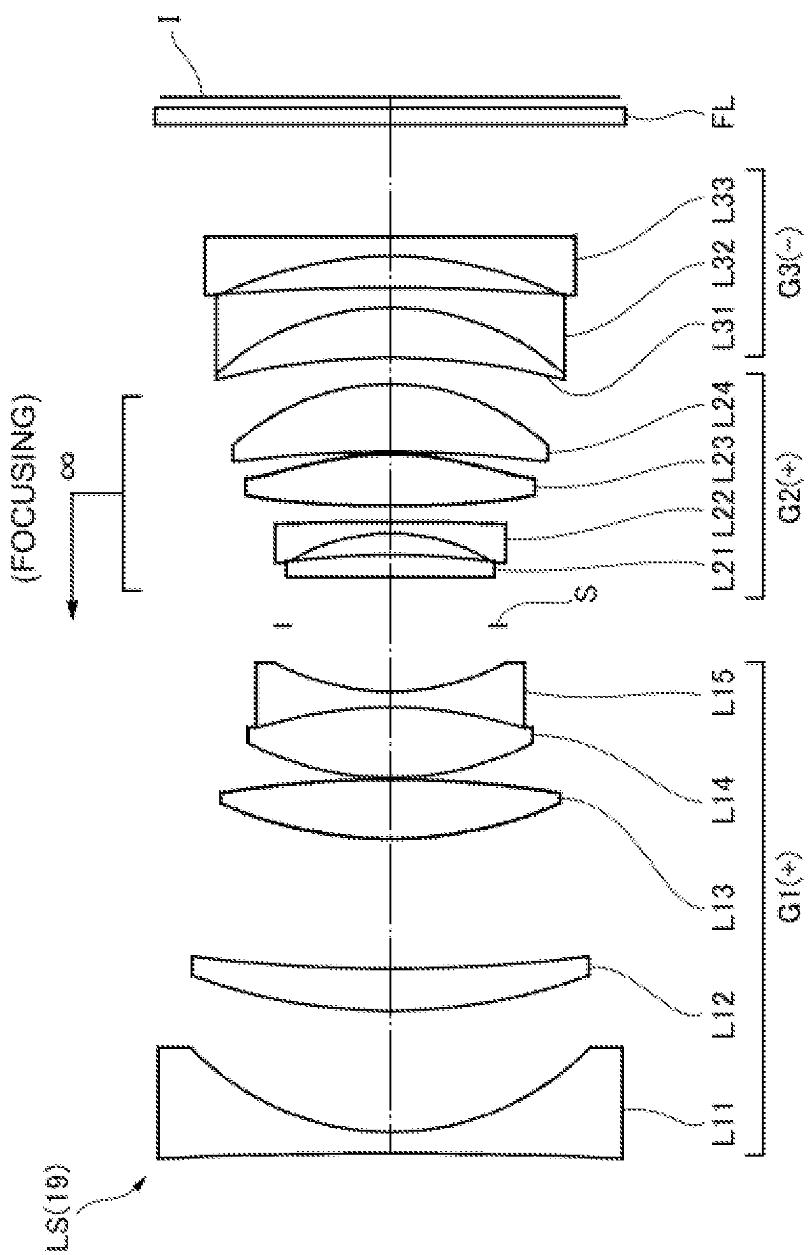

H0=−211.20
H0=−176.73
H0=−145.00
H0=−103.11
H0=0.0
−0.100
LATERAL ABERRATION
H0=−211.20
5.00 %
DISTORTION
H0=−211.20
0.500
ASTIGMATISM
NA=0.27
0.500
SPHERICAL ABERRATION

FIG. 37



I
FL
L33
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
(FOCUSING)
∞
S
L15
L14
L13
L12
L11
G1(+)
LS(19)

FIG. 38A

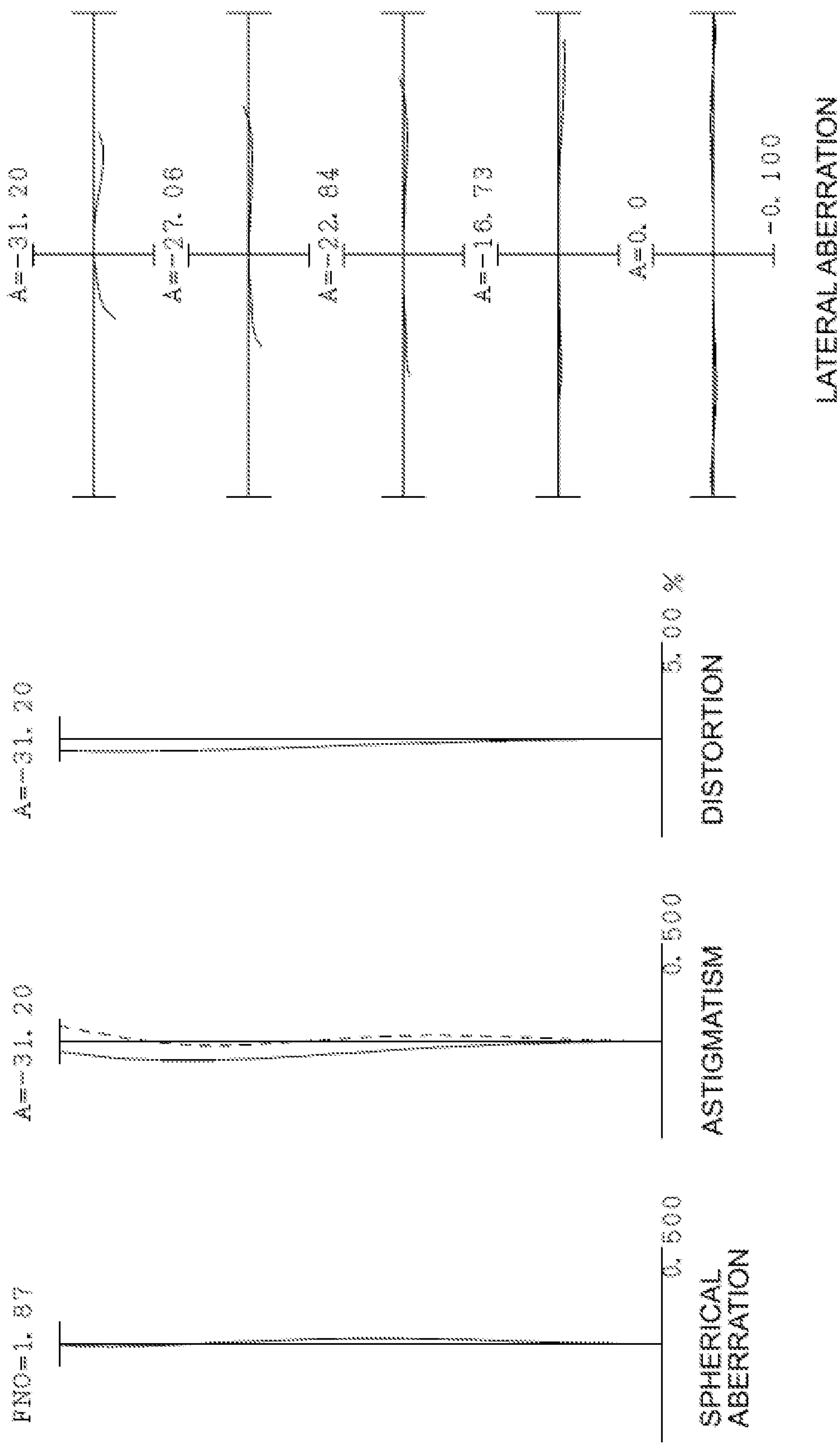

FNO=1.87
0.500
SPHERICAL ABERRATION
A=-31.20
0.500
ASTIGMATISM
A=-31.20
5.00 %
DISTORTION
A=-31.20
A=-27.06
A=-22.84
A=-16.73
A=0.0
-0.100
LATERAL ABERRATION

FIG. 38B

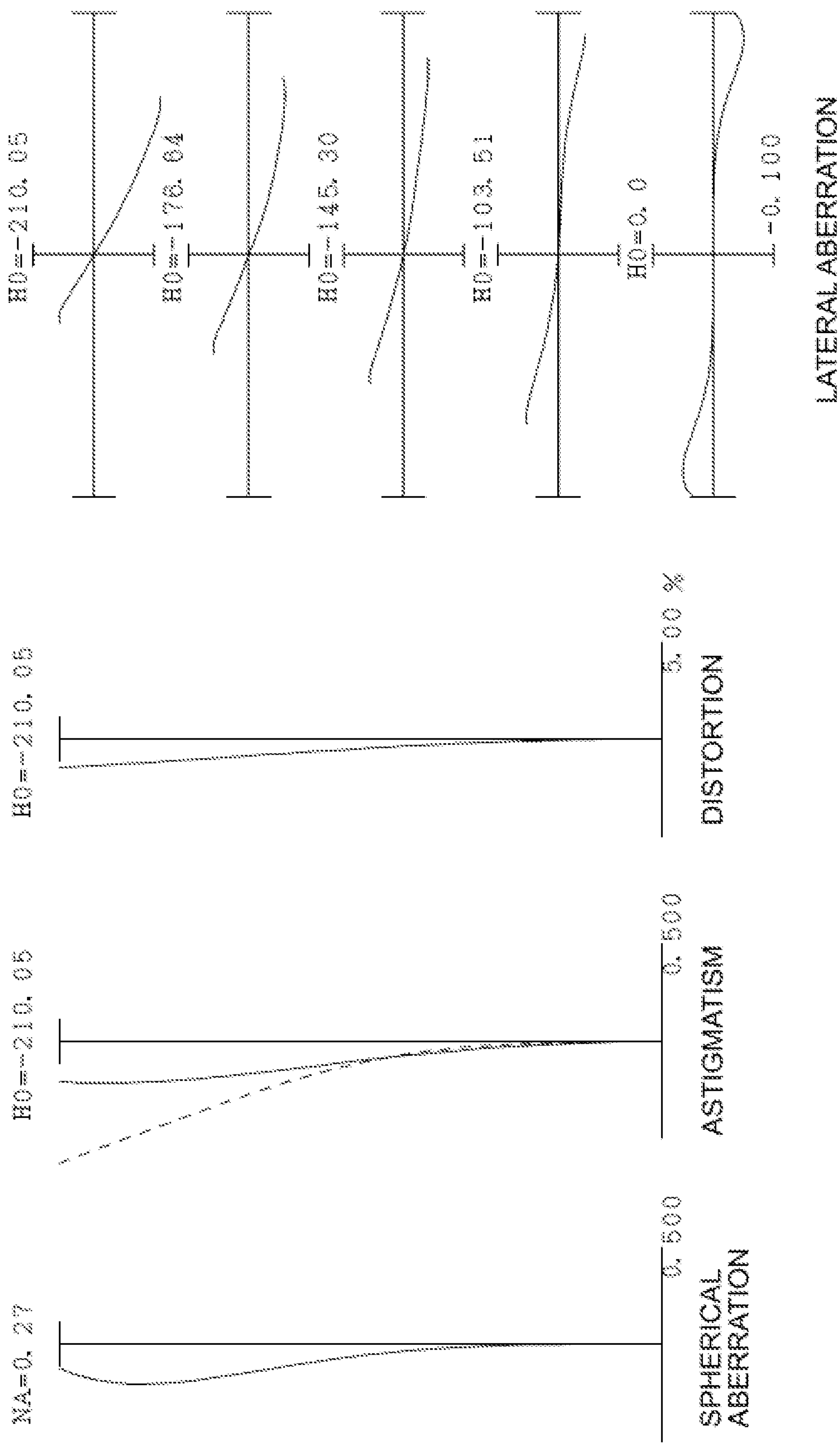

NA=0. 27
0. 500
SPHERICAL ABERRATION
H0=-210. 05
0. 500
ASTIGMATISM
H0=-210. 05
5. 00 %
DISTORTION
H0=-210. 05
H0=-176. 04
H0=-145. 30
H0=-103. 51
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 39

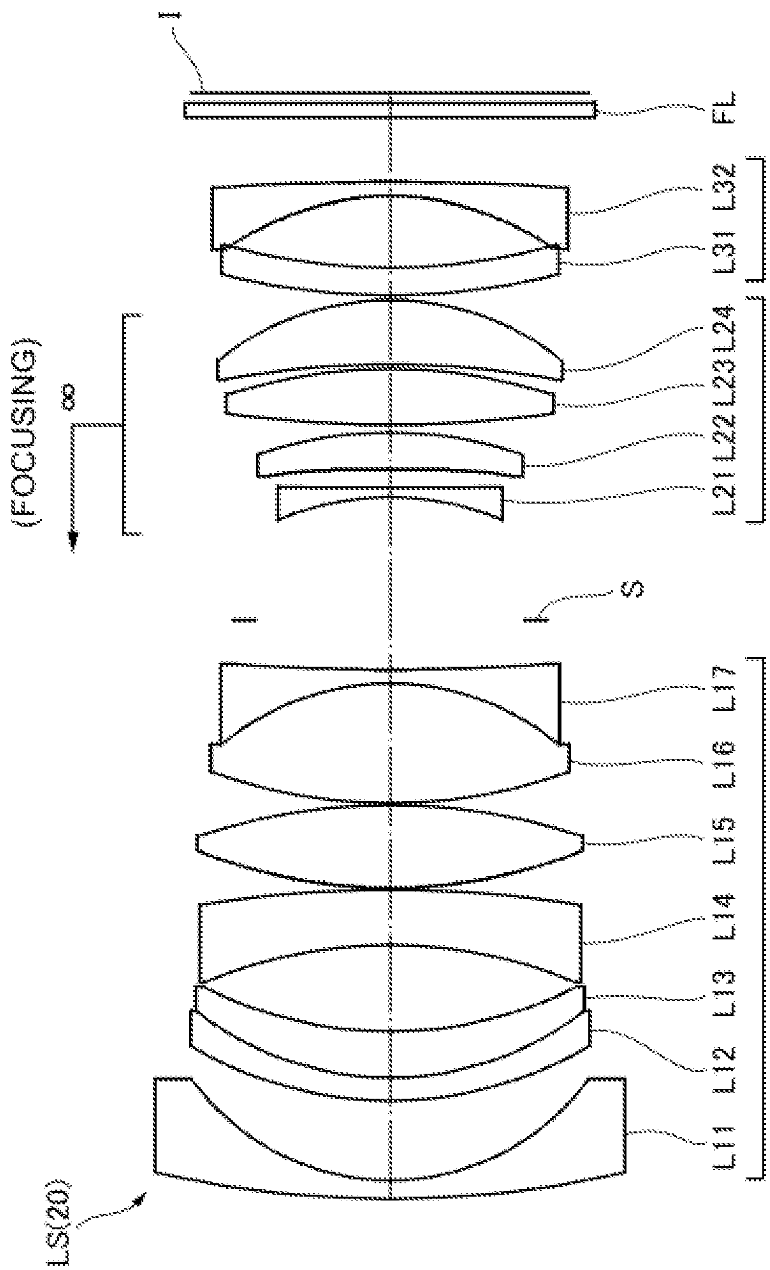

I
FL
L32
L31
G3(−)
L24
L23
L22
L21
G2(+)
(FOCUSING)
∞
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(20)

FIG. 40A

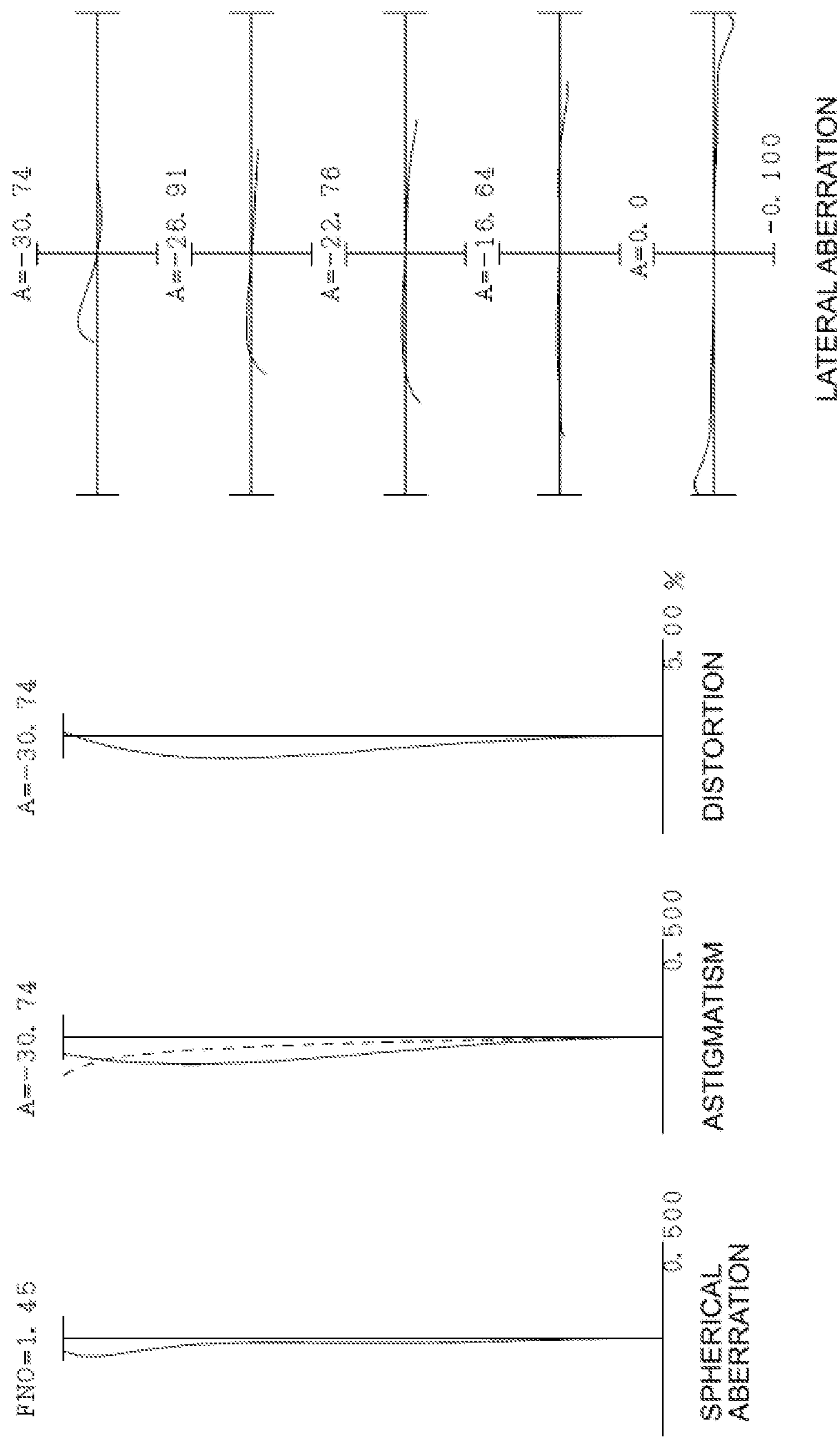

A=-30. 74
A=-28. 91
A=-22. 76
A=-16. 64
A=0. 0
-0. 100
LATERAL ABERRATION
A=-30. 74
5. 00 %
DISTORTION
A=-30. 74
0. 500
ASTIGMATISM
FNO=1. 45
0. 500
SPHERICAL ABERRATION

FIG. 40B

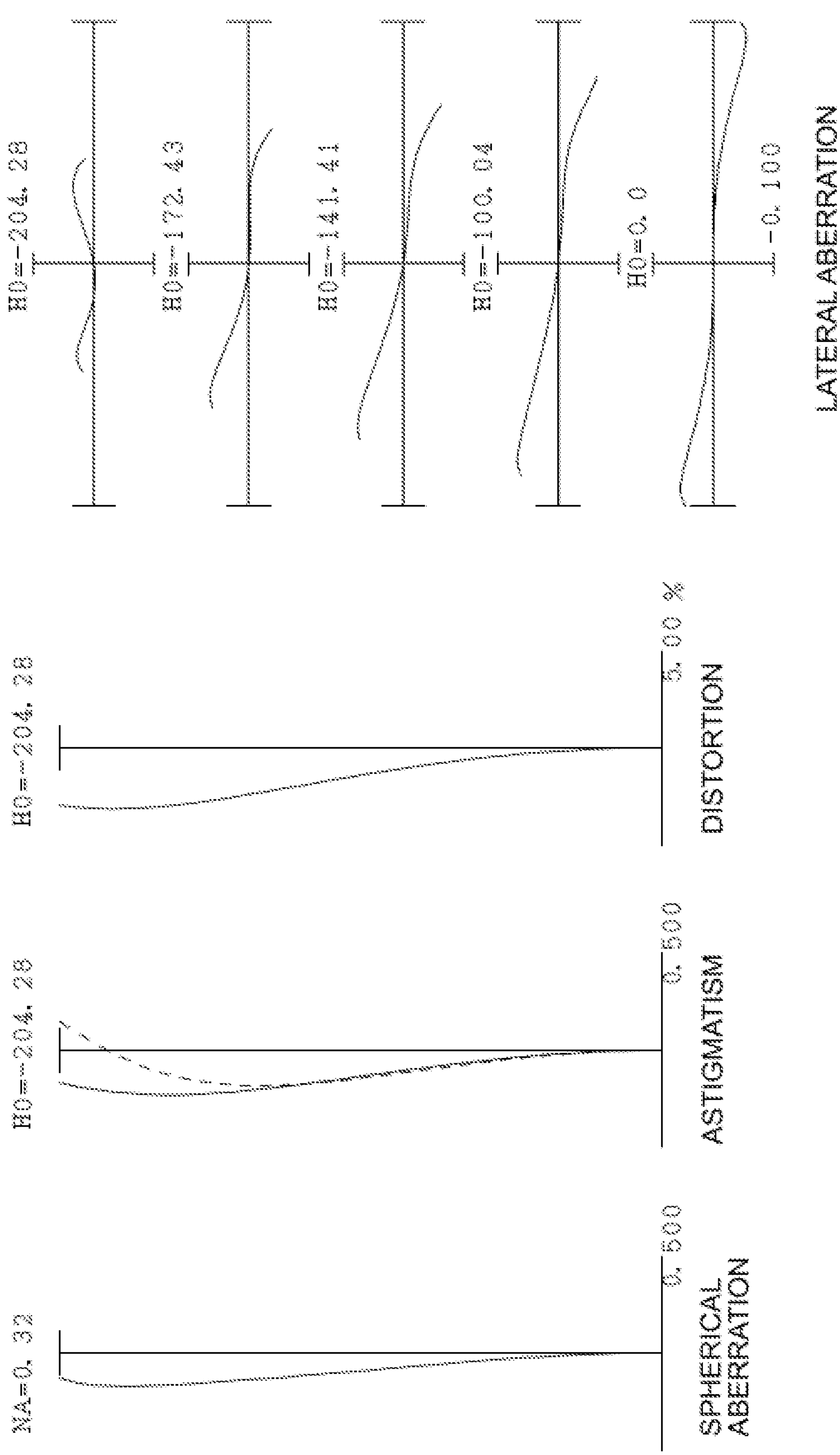
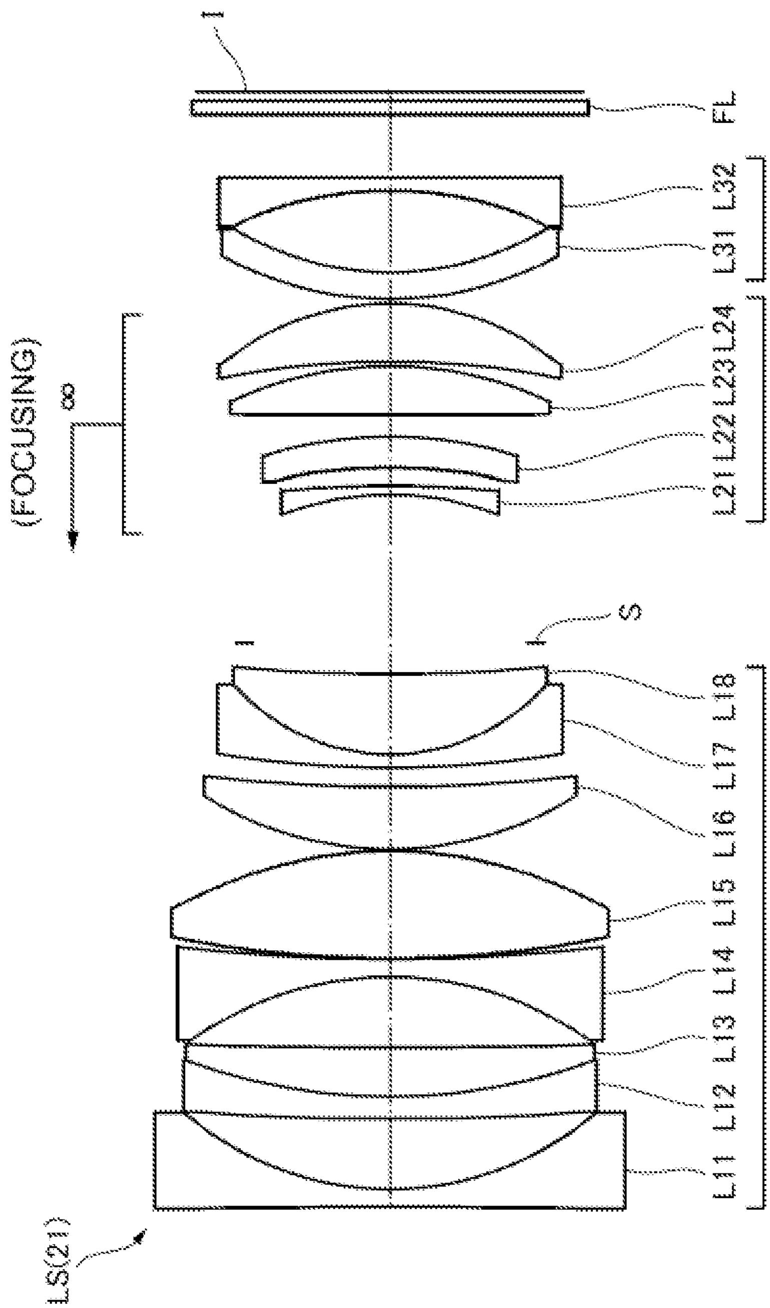

NA=0. 32
0. 500
SPHERICAL ABERRATION
H0=-204. 28
0. 500
ASTIGMATISM
H0=-204. 28
5. 00 %
DISTORTION
H0=-204. 28
H0=-172. 43
H0=-141. 41
H0=-100. 04
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 41



I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L24
L23
L22
L21
G2(+)
S
L18
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(21)

FIG. 42A

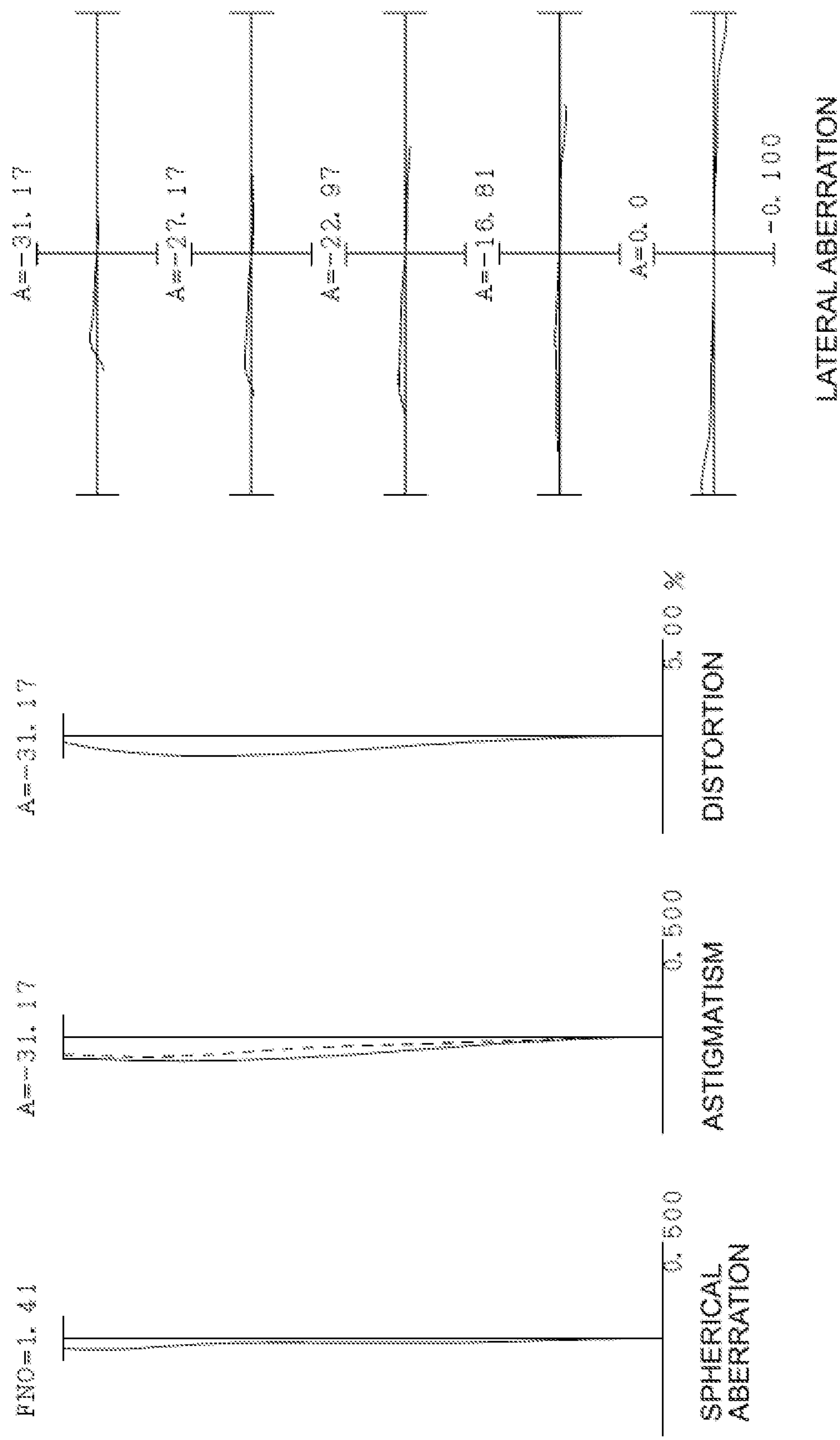

FNO=1. 41
0. 500
SPHERICAL ABERRATION
A=−31. 17
0. 500
ASTIGMATISM
A=−31. 17
5. 00 %
DISTORTION
A=−31. 17
A=−27. 17
A=−22. 97
A=−16. 81
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 42B

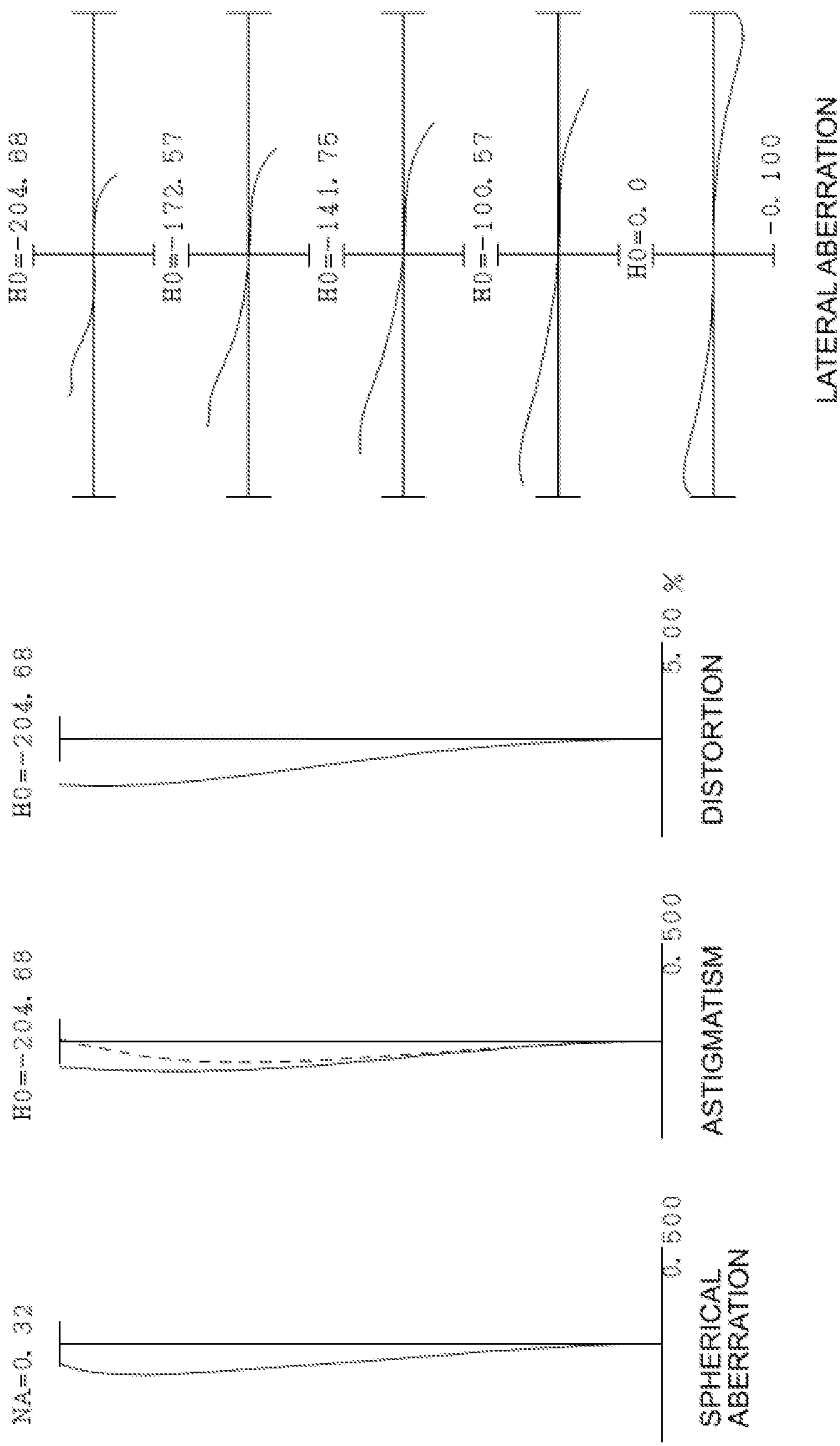
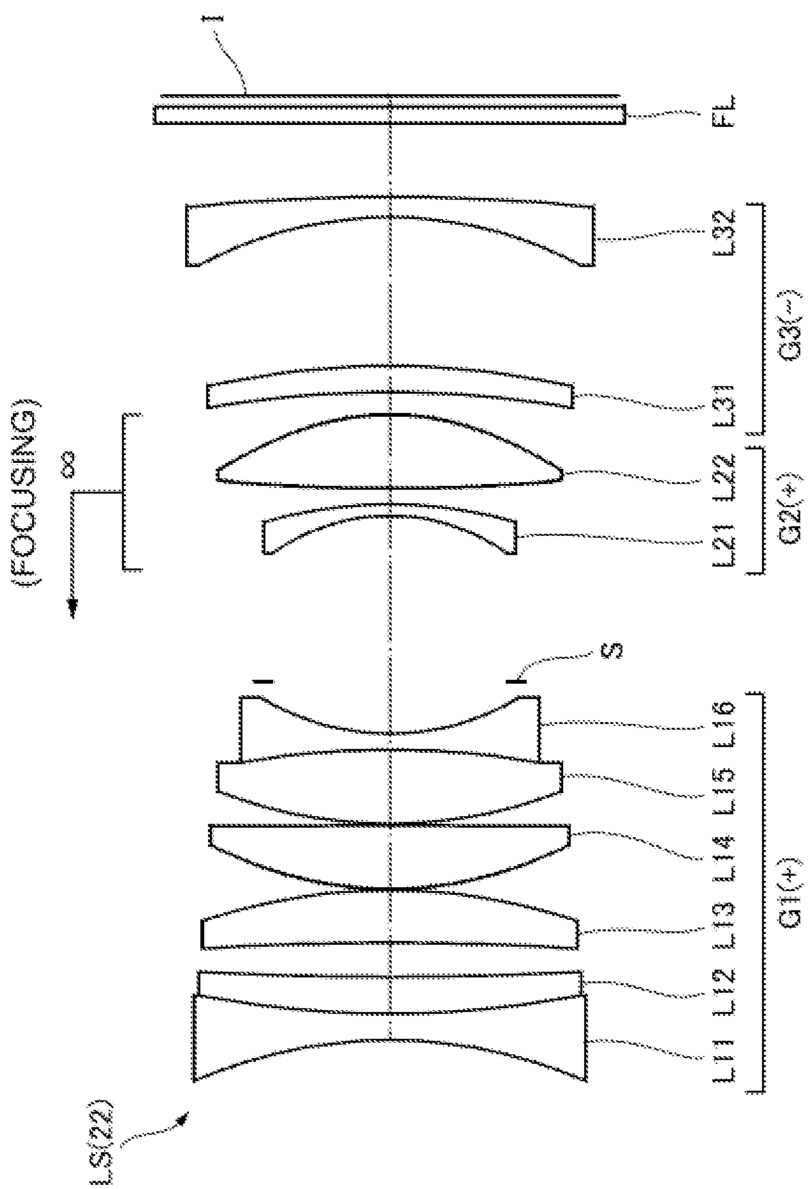
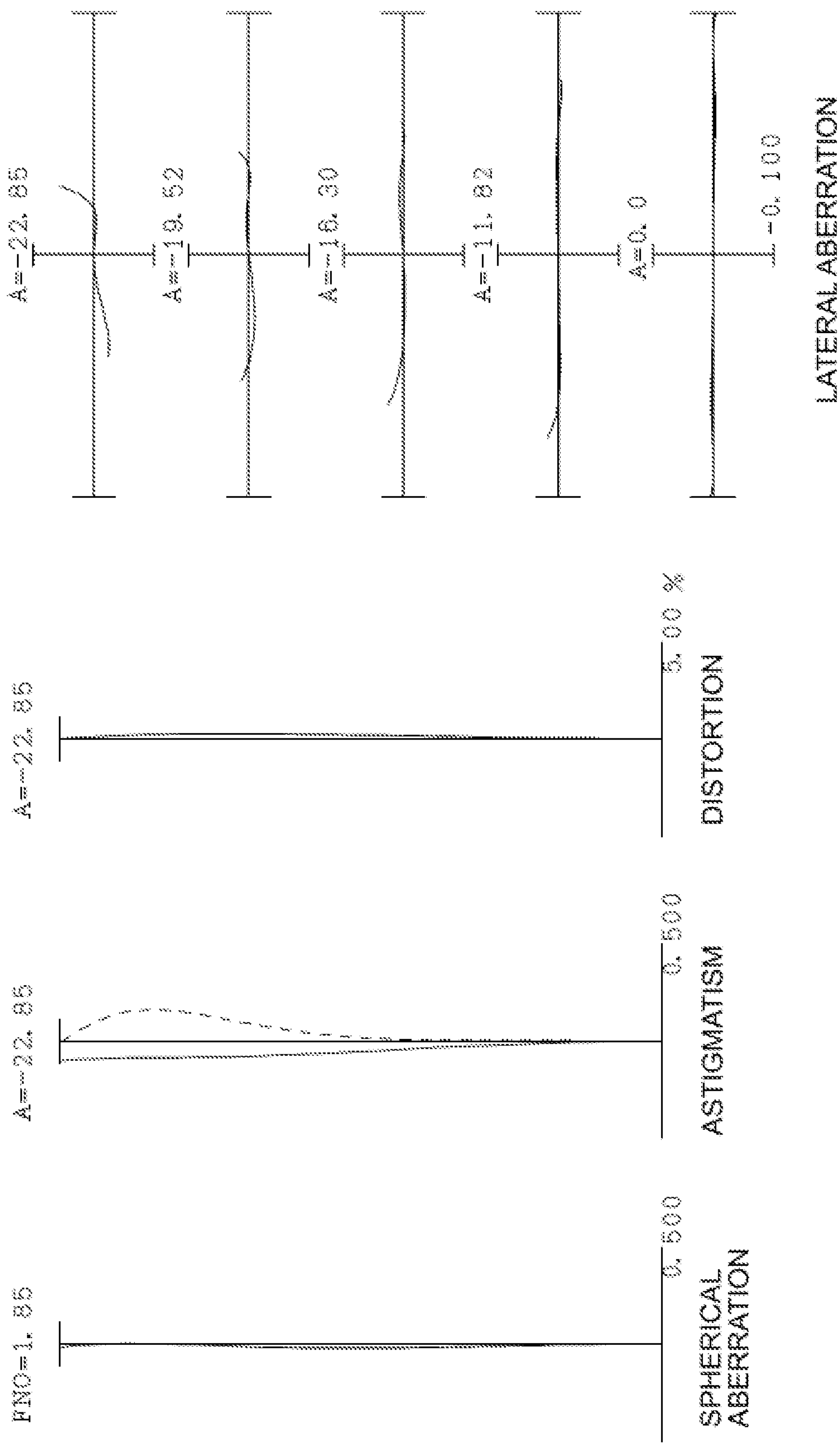

H0=-204.68
H0=-172.57
H0=-141.75
H0=-100.57
H0=0.0
-0.100
LATERAL ABERRATION
H0=-204.68
5.00 %
DISTORTION
H0=-204.68
0.500
ASTIGMATISM
NA=0.32
0.500
SPHERICAL ABERRATION

FIG. 43



(FOCUSING)
∞
I
FL
L32
G3(−)
L31
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(22)

FIG. 44A



FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=−22. 85
0. 500
ASTIGMATISM
A=−22. 85
5. 00 %
DISTORTION
A=−22. 85
A=−19. 52
A=−16. 30
A=−11. 82
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 44B

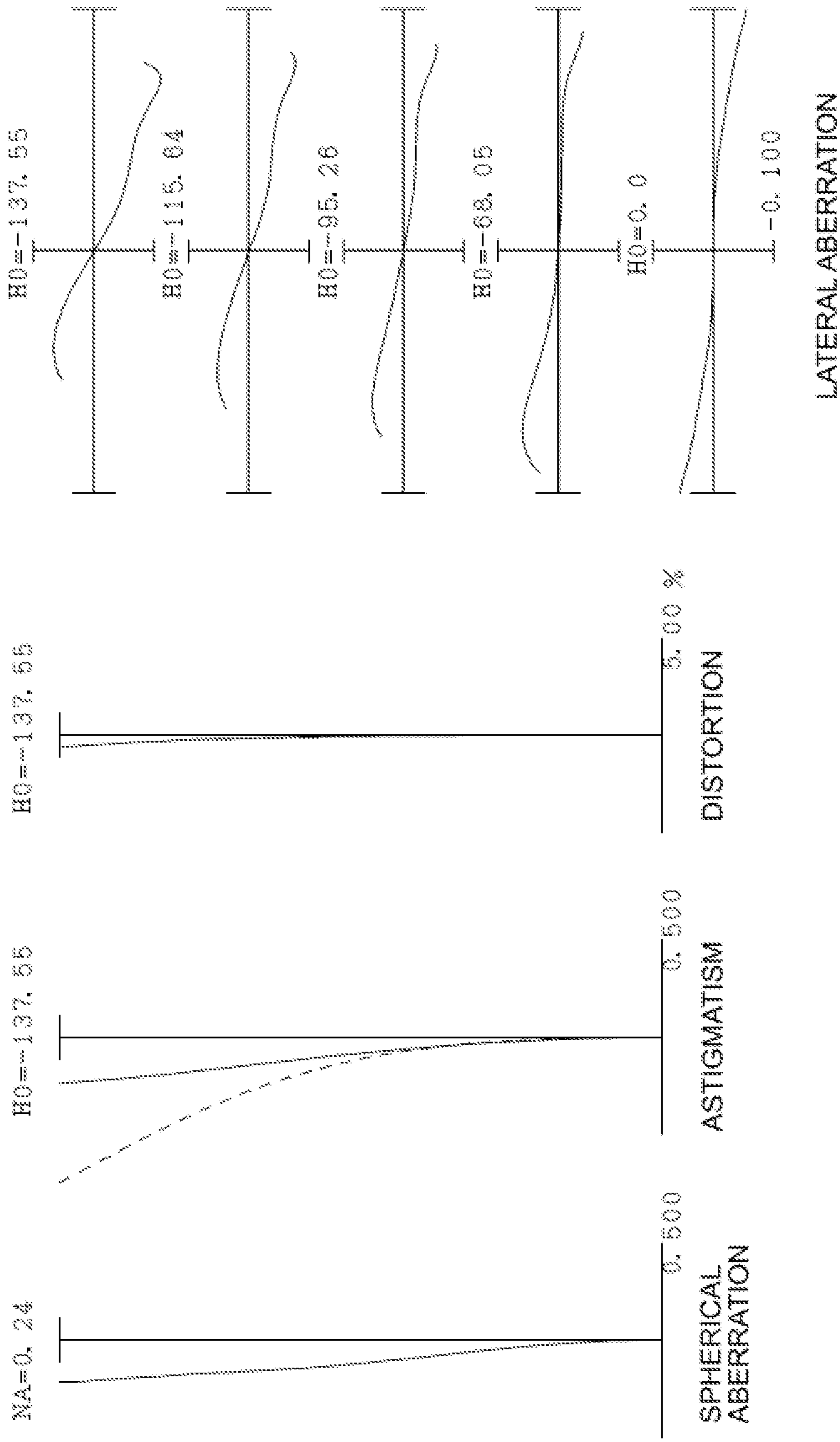

H0=-137. 55
H0=-115. 04
H0=-95. 26
H0=-68. 05
H0=0. 0
-0. 100
LATERAL ABERRATION
H0=-137. 55
5. 00 %
DISTORTION
H0=-137. 55
0. 500
ASTIGMATISM
NA=0. 24
0. 500
SPHERICAL ABERRATION

FIG. 45

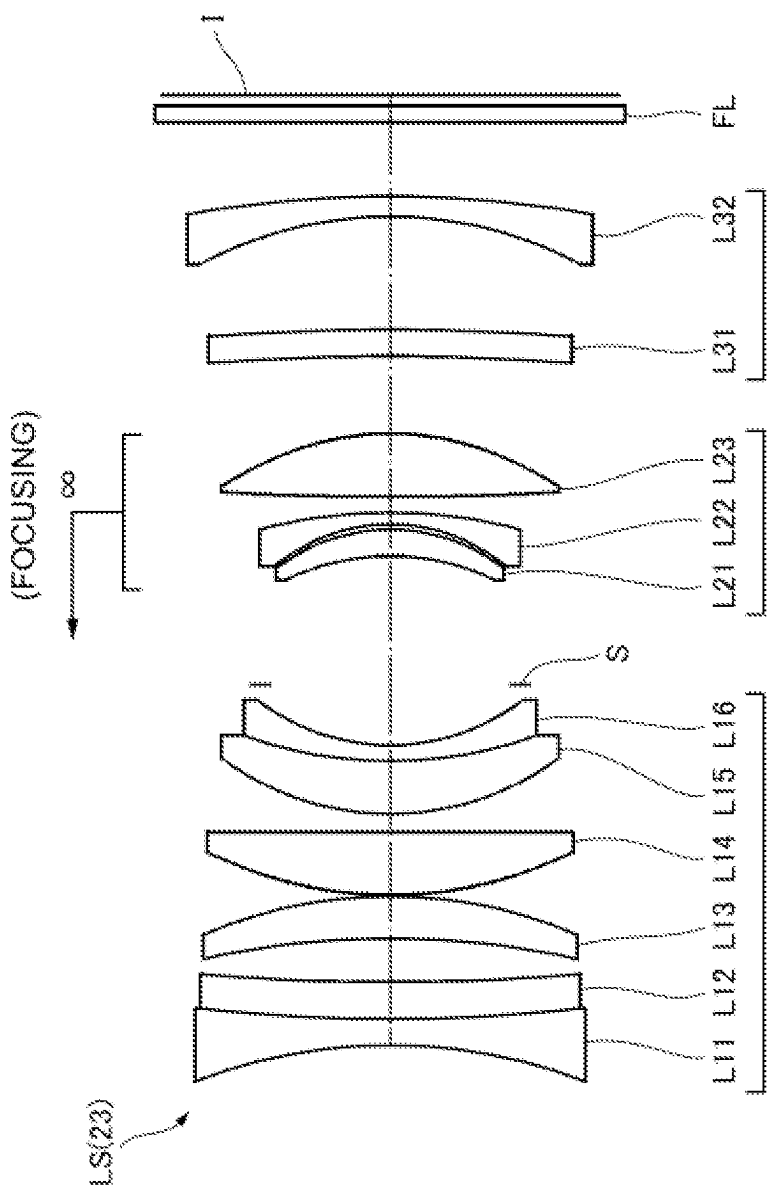
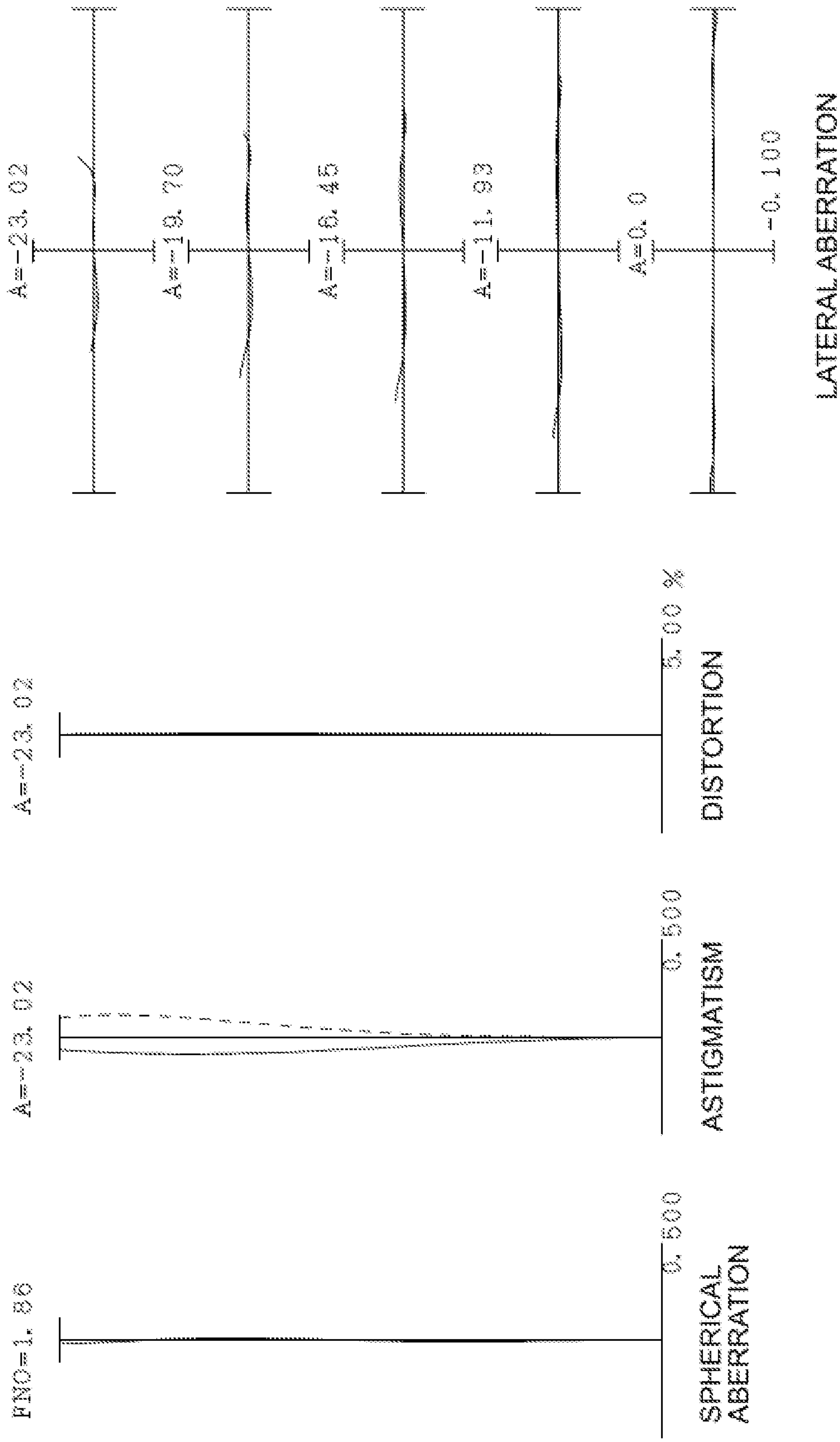

I
FL
L32
G3(−)
L31
(FOCUSING)
∞
L23
L22
G2(+)
L21
S
L16
L15
L14
G1(+)
L13
L12
L11
LS(23)

FIG. 46A


FNO=1.86
0.500
SPHERICAL ABERRATION
A=-23.02
0.500
ASTIGMATISM
A=-23.02
5.00 %
DISTORTION
A=-23.02
A=-19.70
A=-16.45
A=-11.93
A=0.0
-0.100
LATERAL ABERRATION

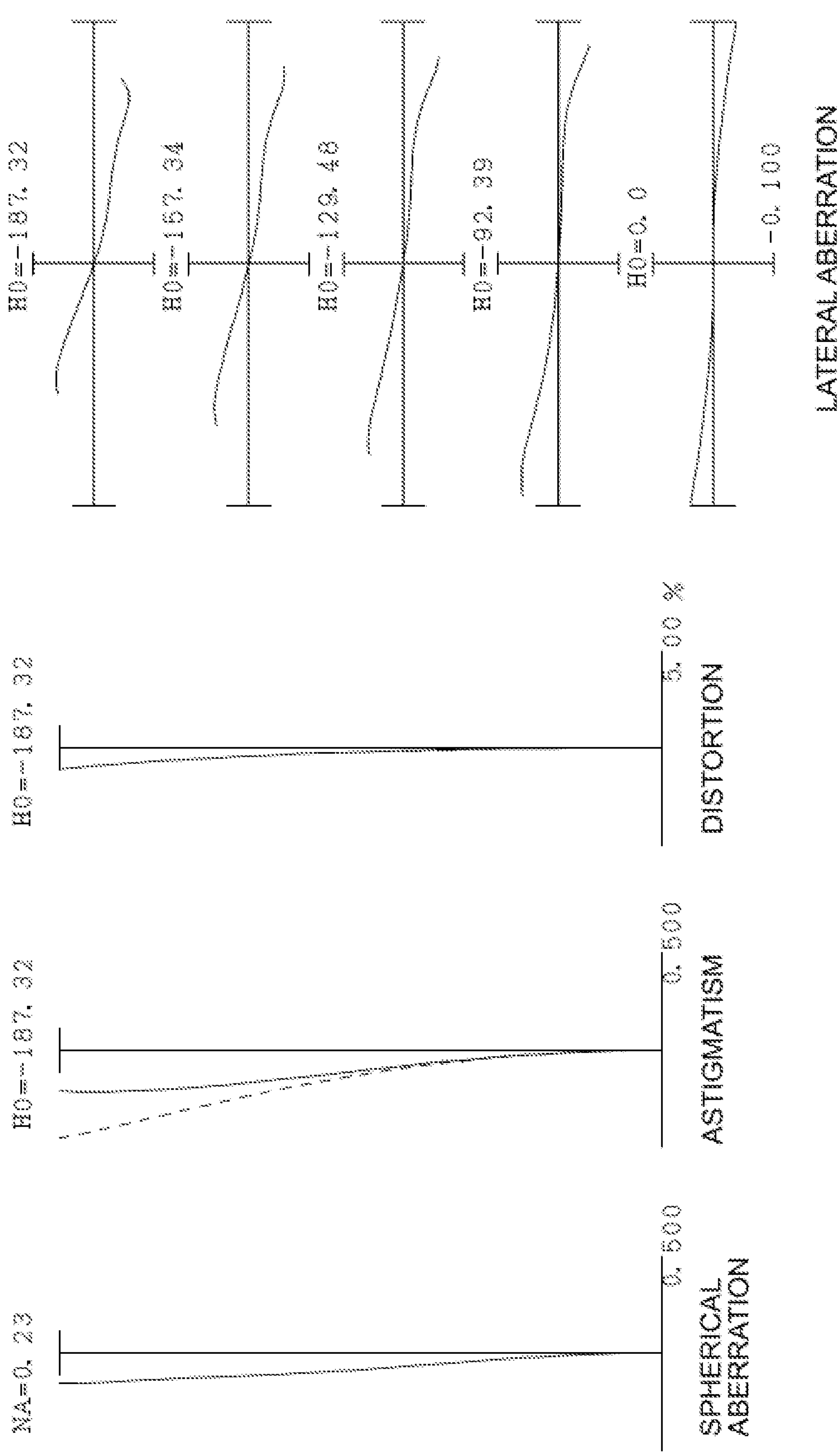

NA=0. 23
0. 500
SPHERICAL ABERRATION
H0=−187. 32
0. 500
ASTIGMATISM
H0=−187. 32
5. 00 %
DISTORTION
H0=−187. 32
H0=−157. 34
H0=−129. 48
H0=−92. 39
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 46B

FIG. 47

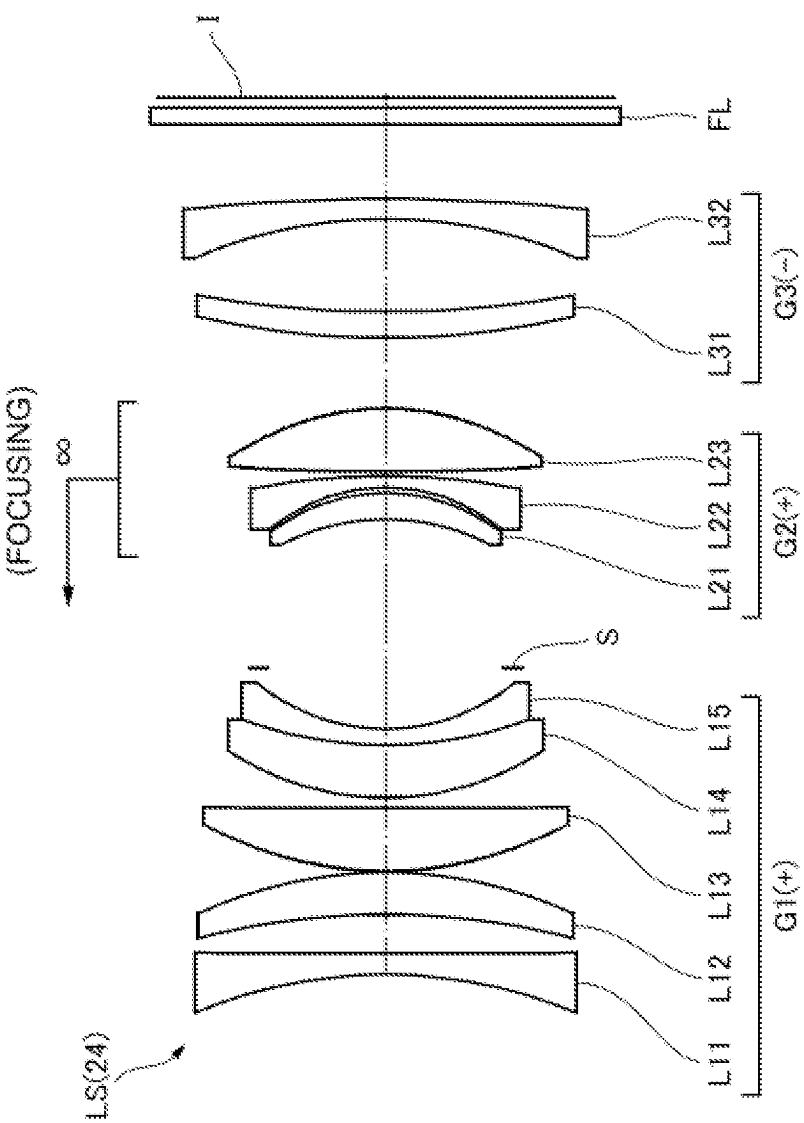

I
FL
L32
G3(−)
L31
(FOCUSING)
∞
L23
L22
G2(+)
L21
S
L15
L14
L13
G1(+)
L12
L11
LS(24)

FIG. 48A

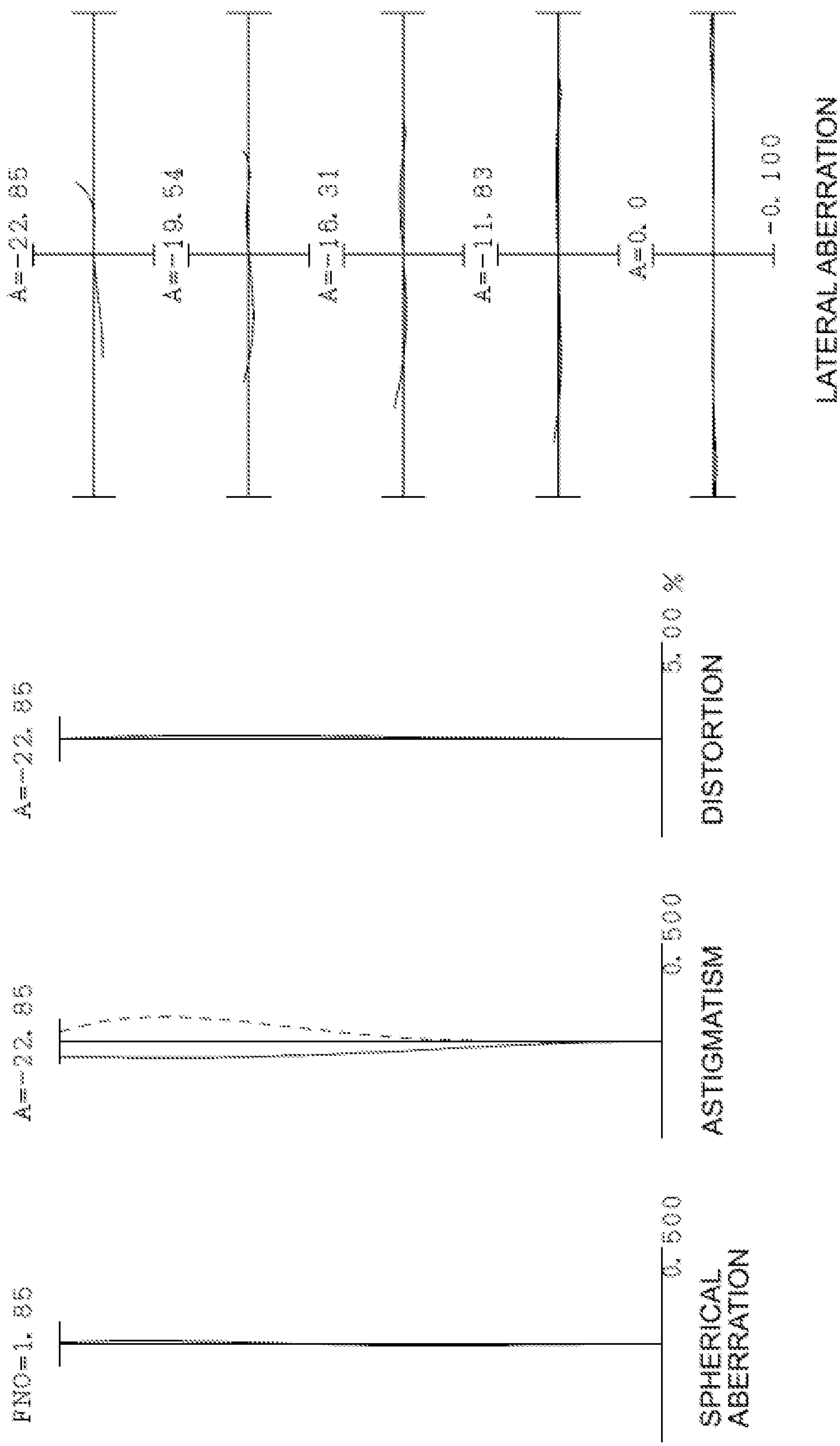

FNO=1.85
0.500
SPHERICAL ABERRATION
A=-22.85
0.500
ASTIGMATISM
A=-22.85
5.00 %
DISTORTION
A=-22.85
A=-19.54
A=-16.31
A=-11.83
A=0.0
-0.100
LATERAL ABERRATION

FIG. 48B

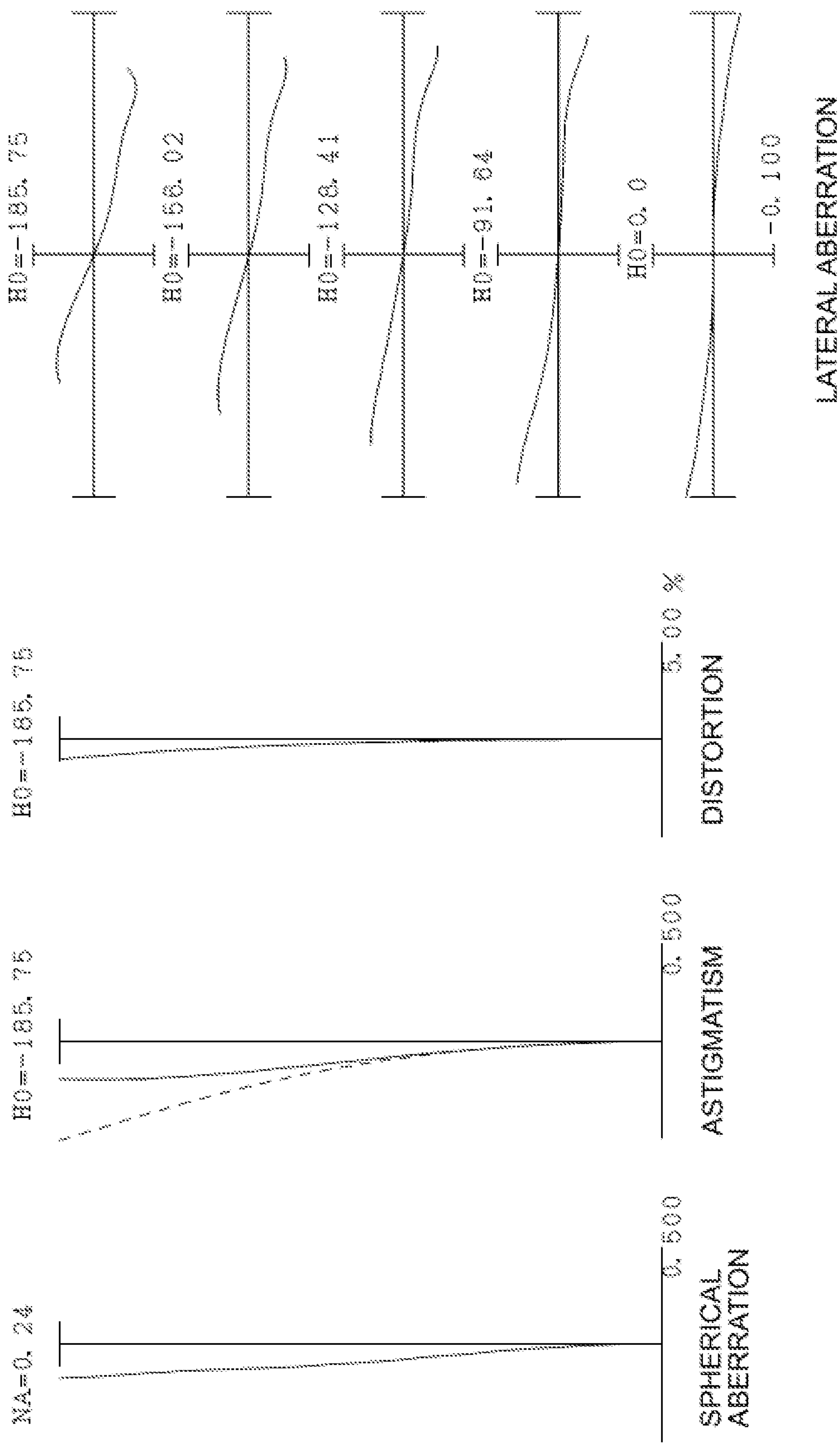

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=−185. 75
0. 500
ASTIGMATISM
H0=−185. 75
5. 00 %
DISTORTION
H0=−185. 75
H0=−156. 02
H0=−128. 41
H0=−91. 84
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 49

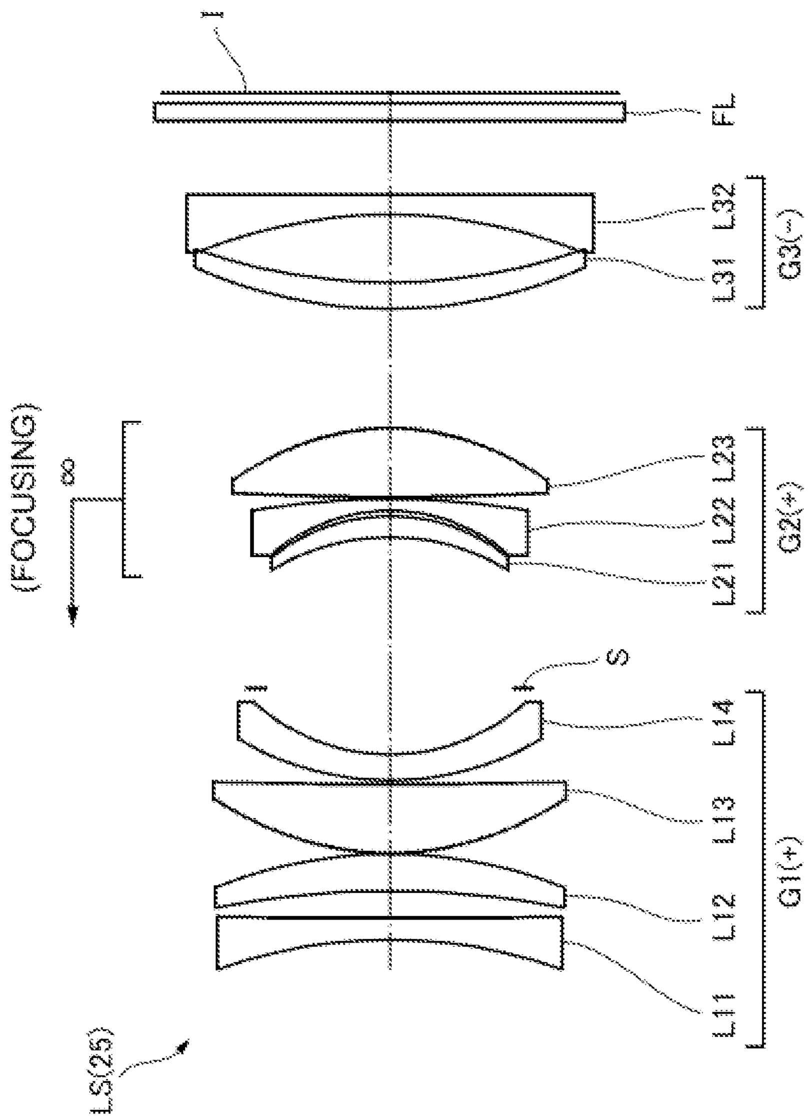


FIG. 50A

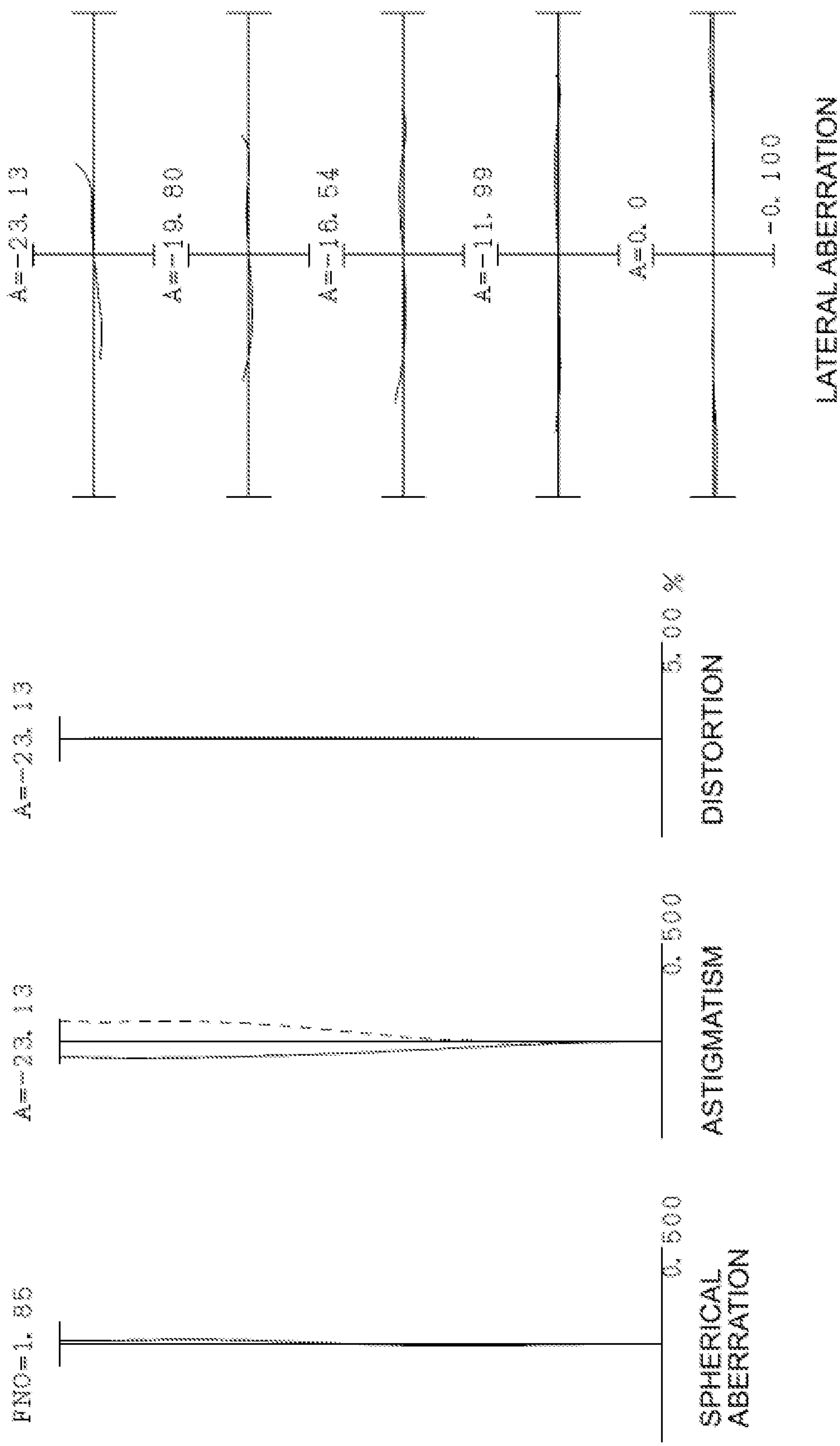

FNO=1.85
0.500
SPHERICAL ABERRATION
A=−23.13
0.500
ASTIGMATISM
A=−23.13
5.00 %
DISTORTION
A=−23.13
A=−19.80
A=−16.54
A=−11.99
A=0.0
−0.100
LATERAL ABERRATION

FIG. 50B

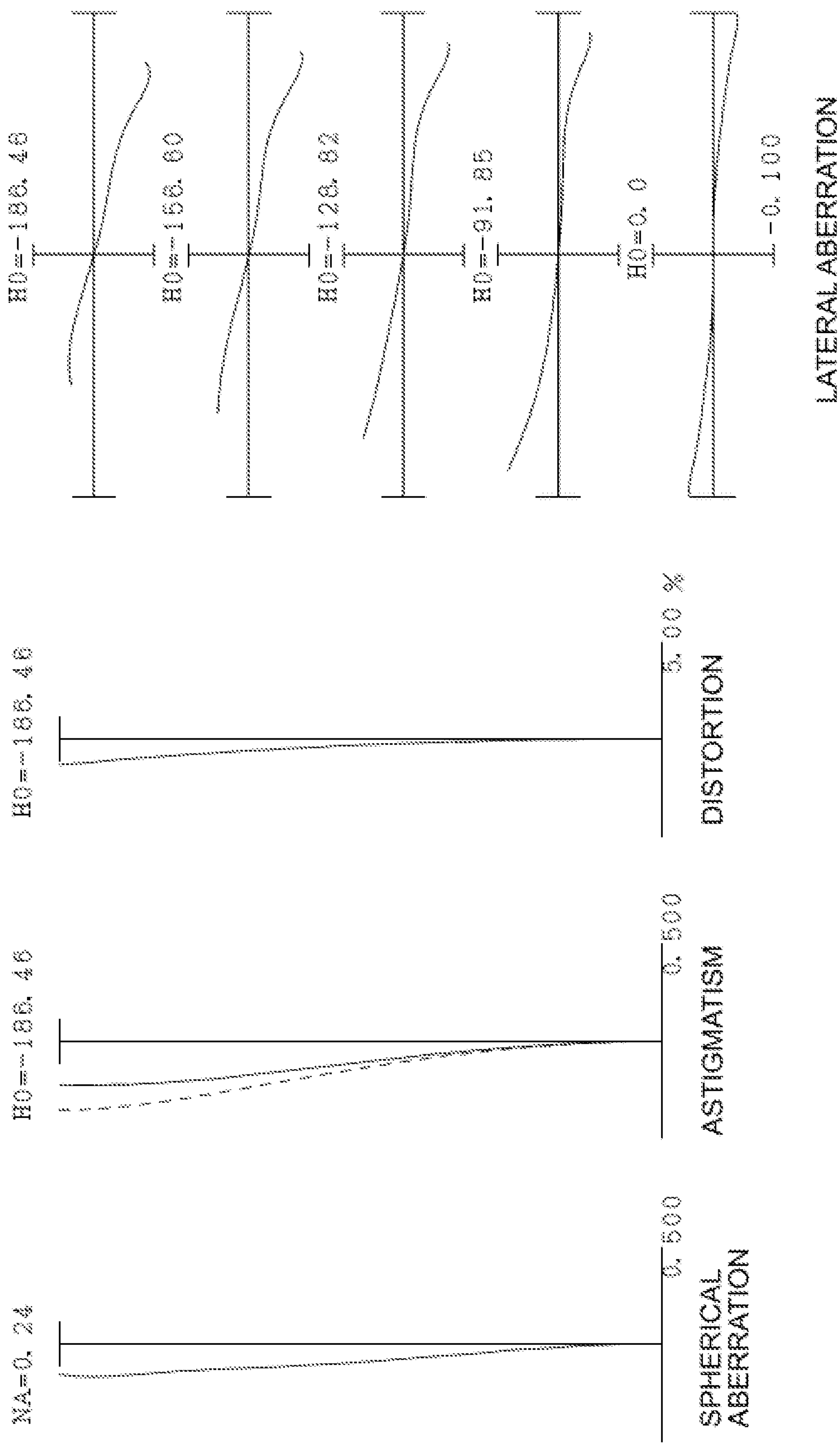

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=-186. 46
0. 500
ASTIGMATISM
H0=-186. 46
5. 00 %
DISTORTION
H0=-186. 46
H0=-156. 60
H0=-128. 82
H0=-91. 85
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 51

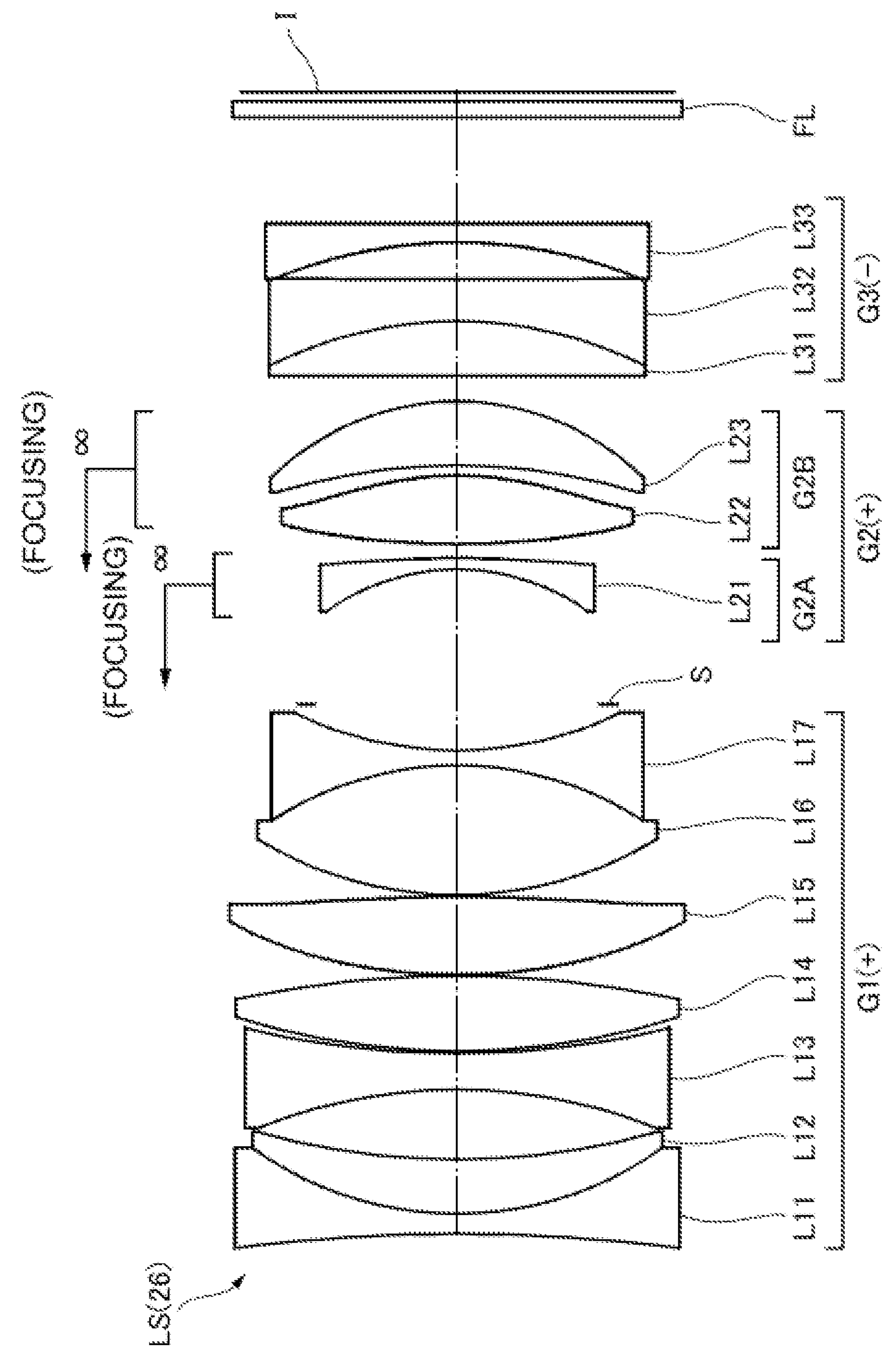

I
FL
L33
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
G2B
G2(+)
L21
G2A
(FOCUSING)
∞
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(26)

FIG. 52A

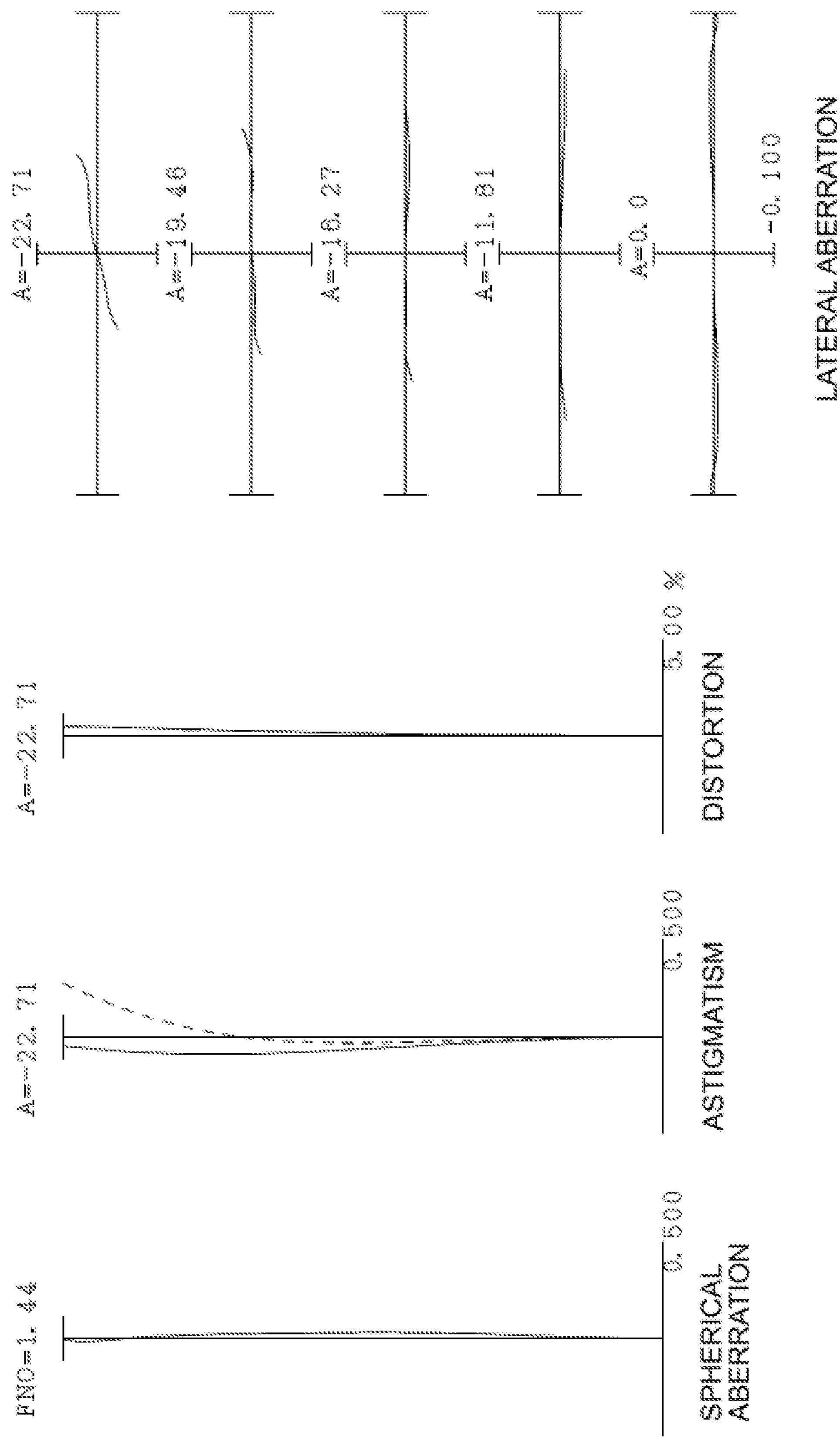

FNO=1.44
0.500
SPHERICAL ABERRATION
A=−22.71
0.500
ASTIGMATISM
A=−22.71
5.00 %
DISTORTION
A=−22.71
A=−19.46
A=−16.27
A=−11.81
A=0.0
−0.100
LATERAL ABERRATION

FIG. 52B

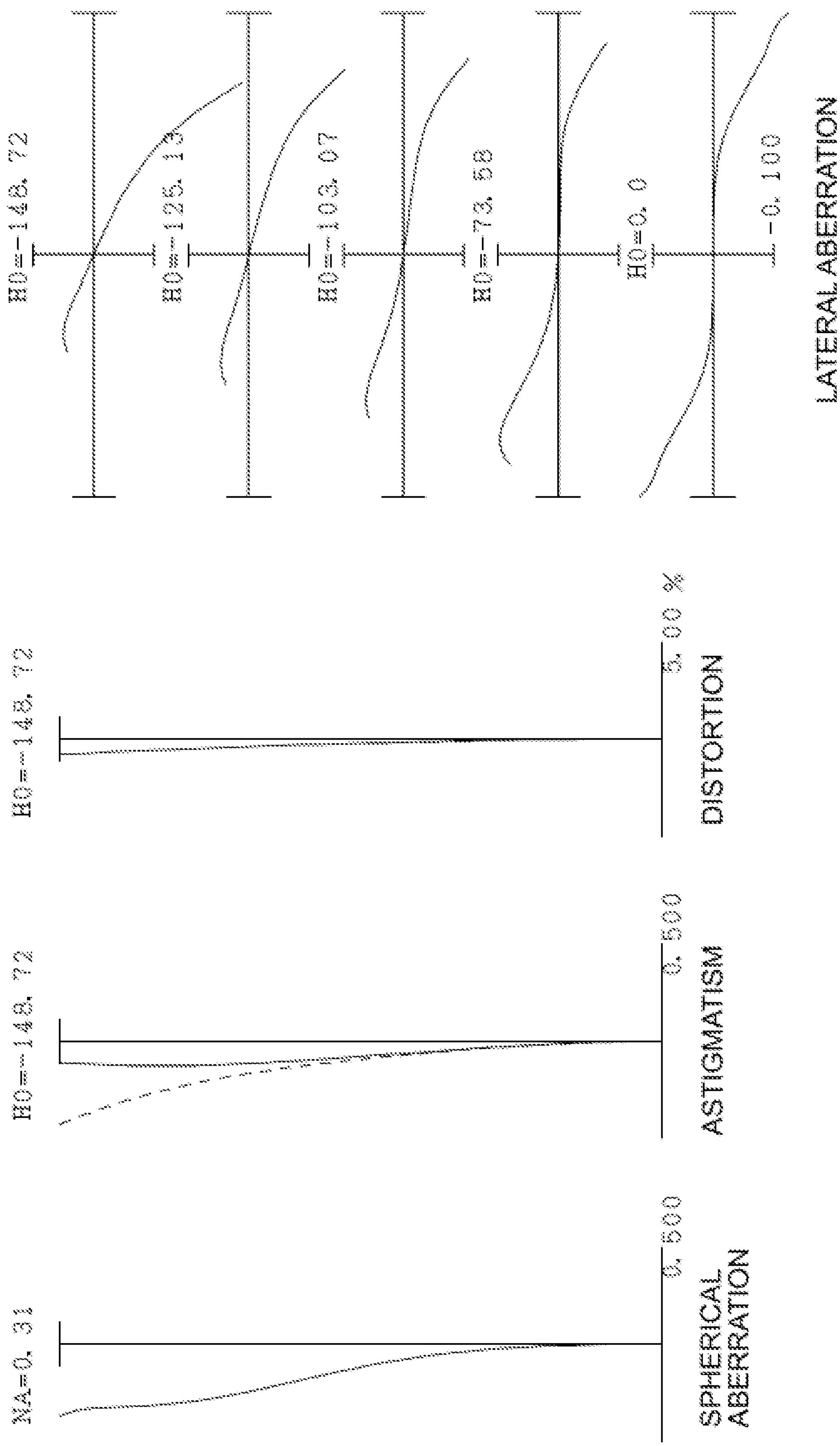
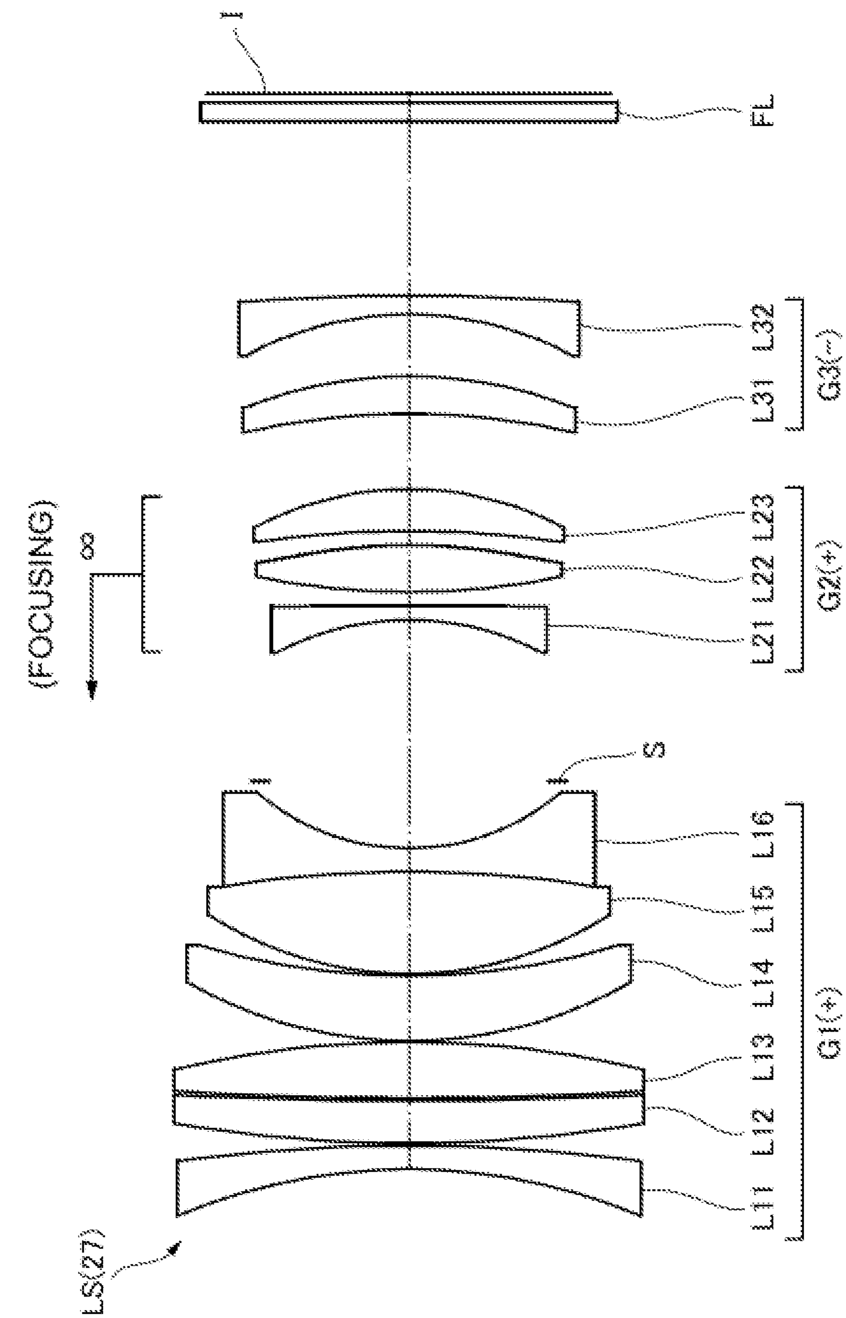

NA=0. 31
0. 500
SPHERICAL ABERRATION
H0=-148. 72
0. 500
ASTIGMATISM
H0=-148. 72
5. 00 %
DISTORTION
H0=-148. 72
H0=-125. 13
H0=-103. 07
H0=-73. 58
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 53



I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(27)

FIG. 54A

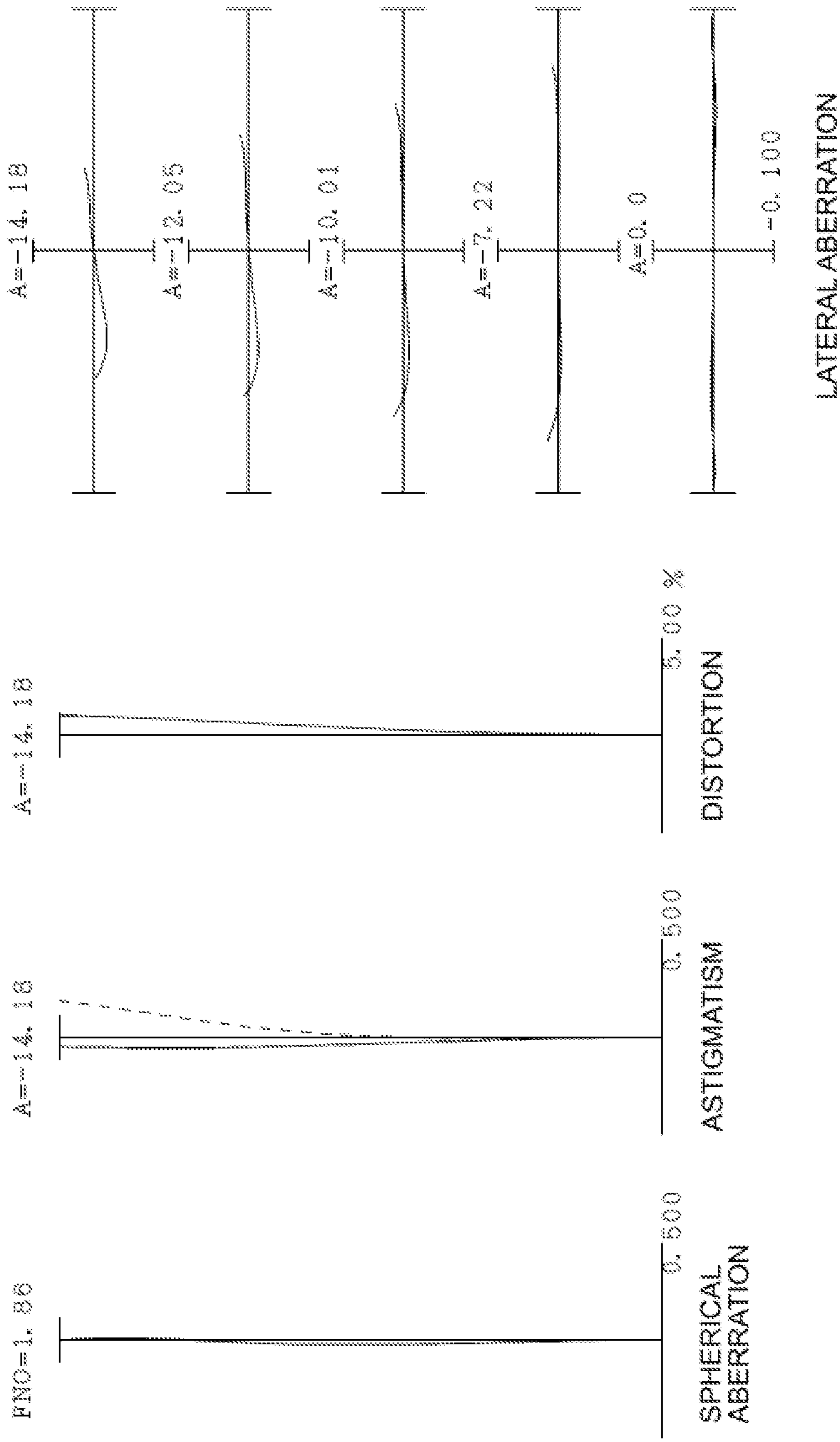
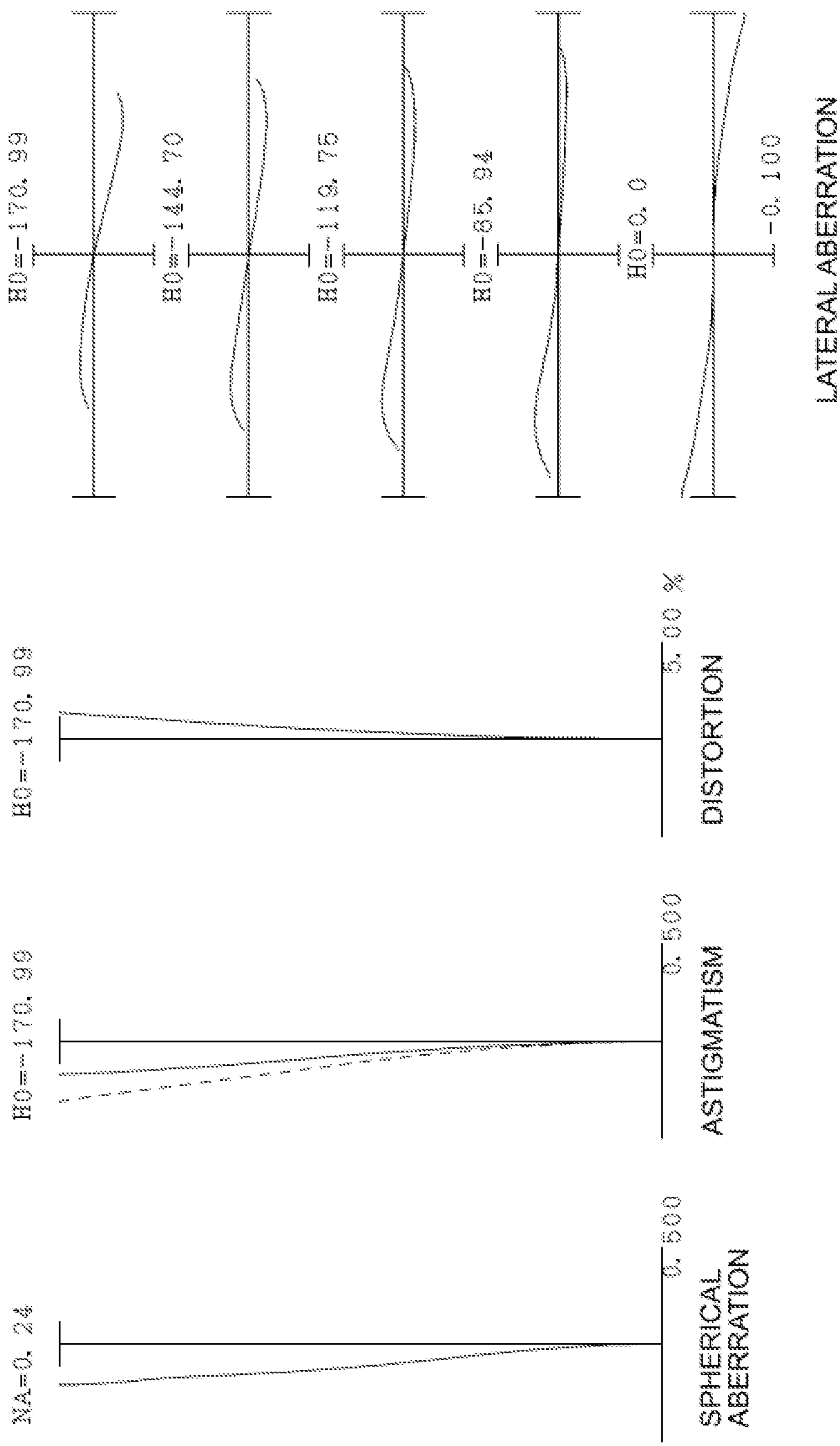
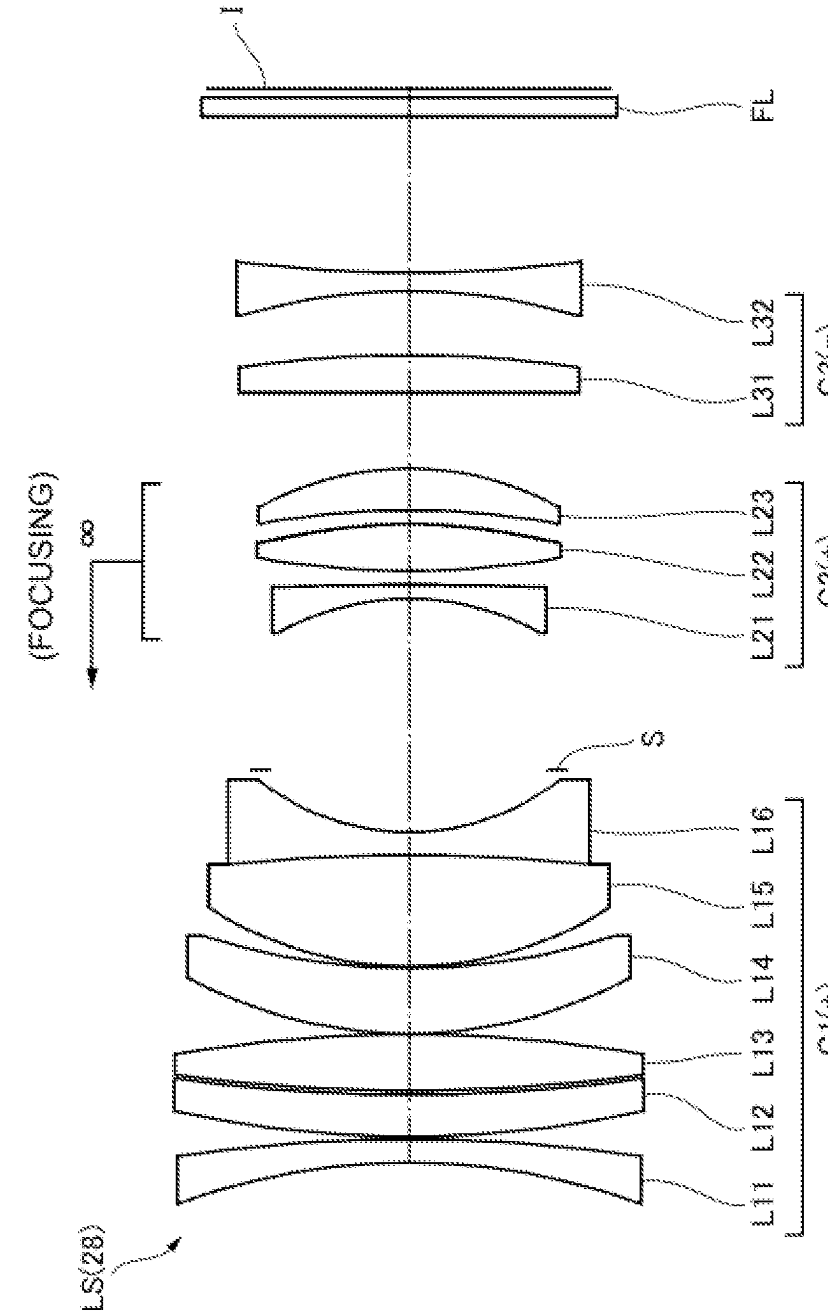

FNO=1. 86
0. 500
SPHERICAL ABERRATION
A=−14. 18
0. 500
ASTIGMATISM
A=−14. 18
5. 00 %
DISTORTION
A=−14. 18
A=−12. 05
A=−10. 01
A=−7. 22
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 54B



NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=-170. 99
0. 500
ASTIGMATISM
H0=-170. 99
5. 00 %
DISTORTION
H0=-170. 99
H0=-144. 70
H0=-119. 75
H0=-85. 94
H0=0. 0
-0. 100
LATERAL ABERRATION



(FOCUSING)
∞
I
FL
L32
L31
G3(−)
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(28)

FIG. 55

FIG. 56A

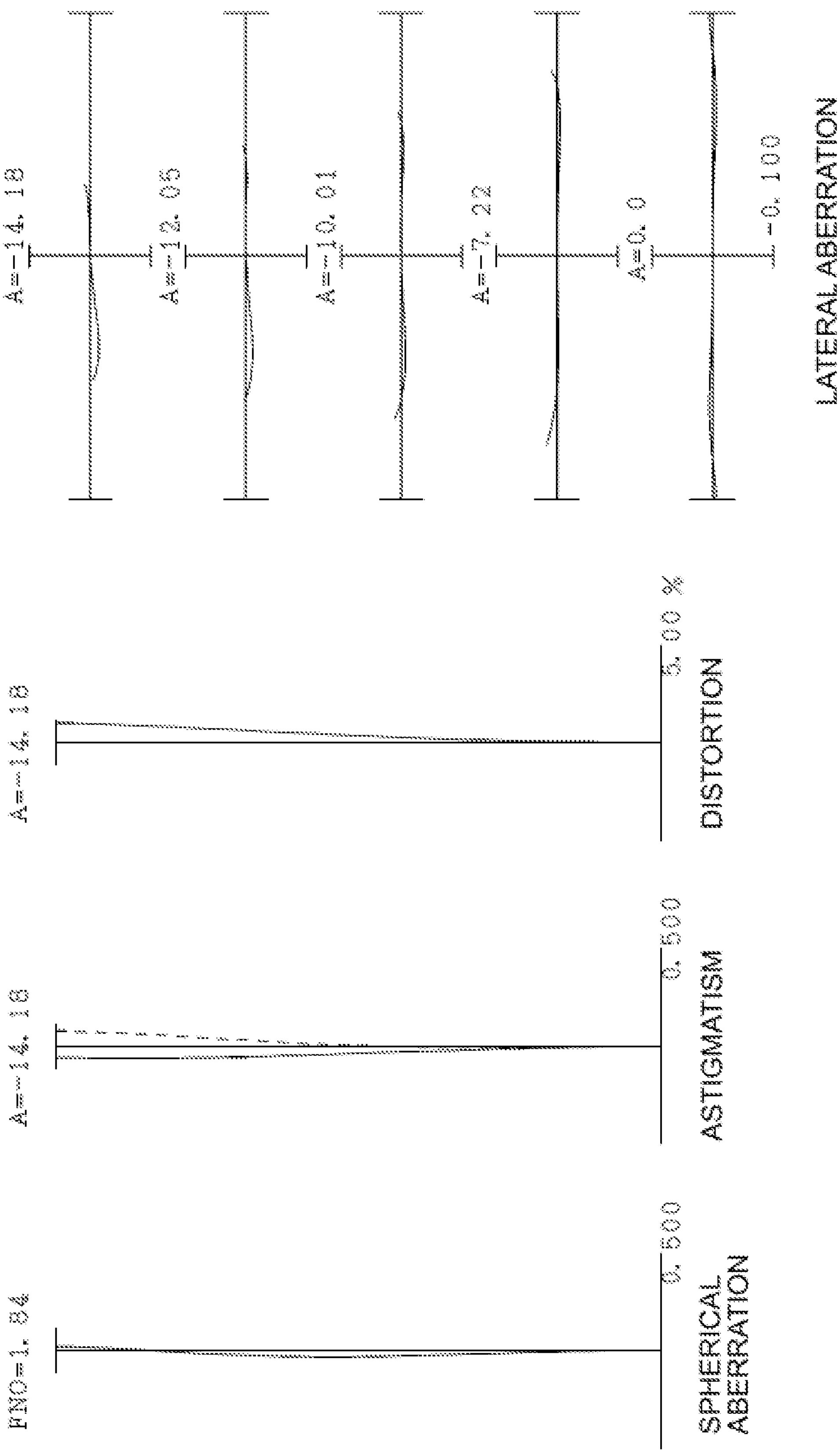
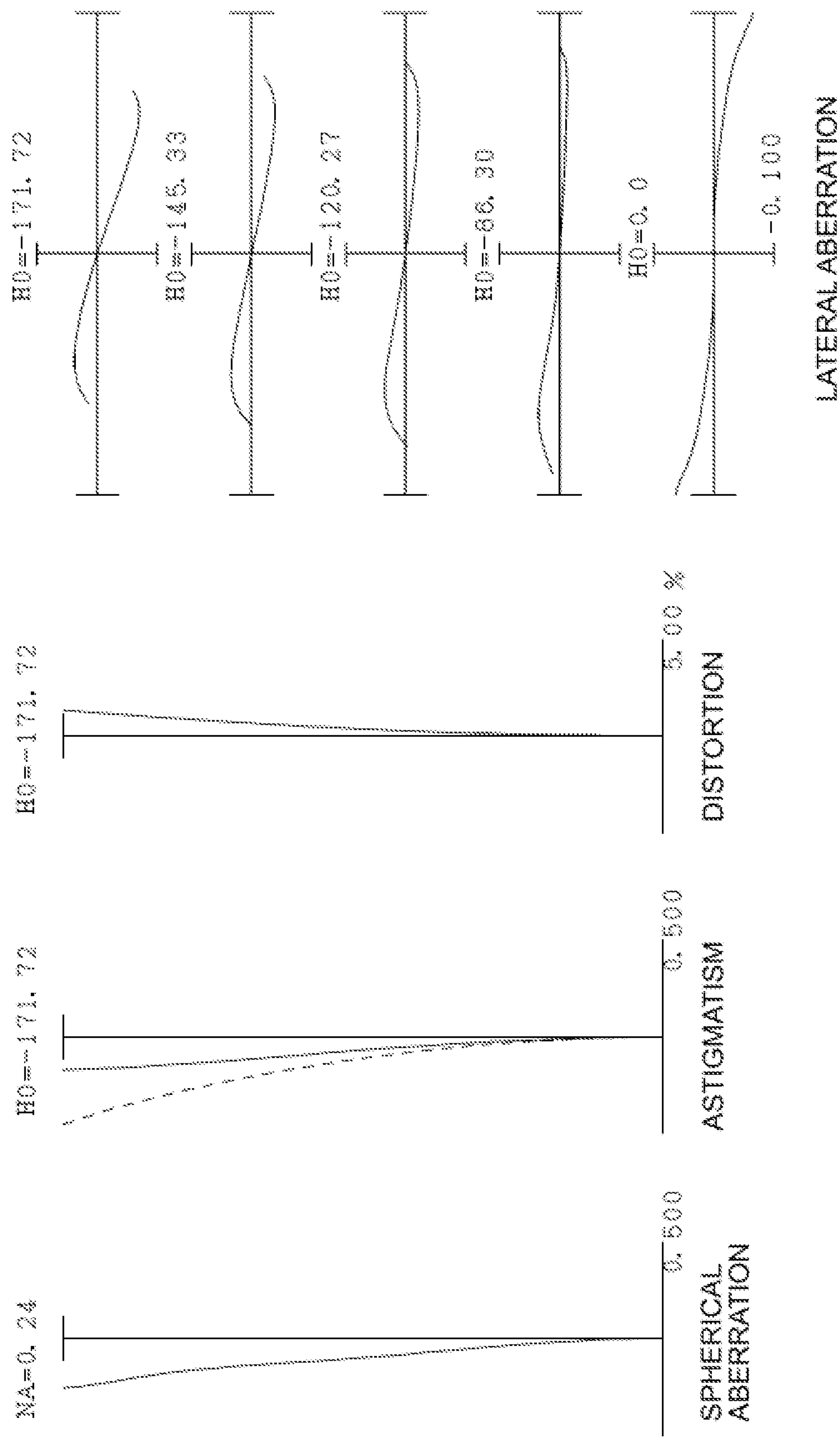
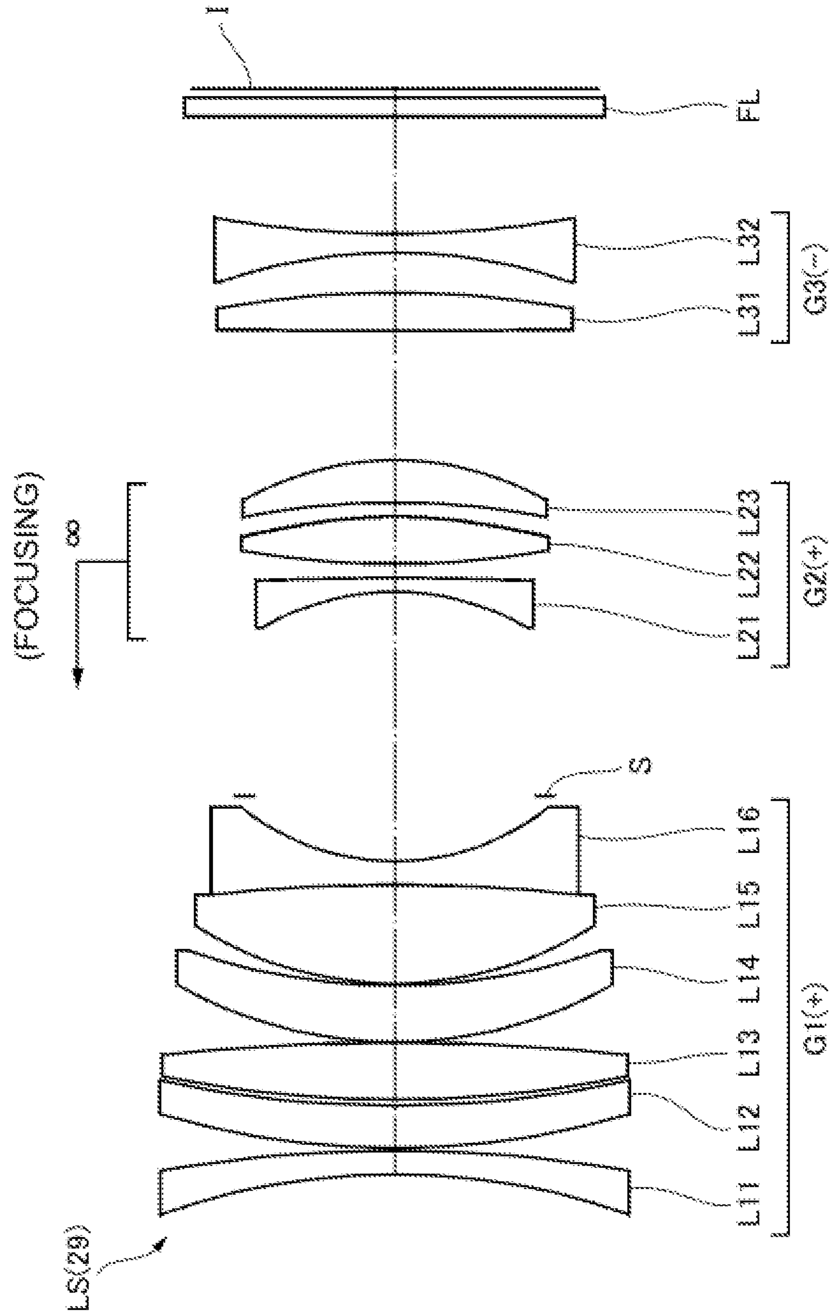

FNO=1.84
0.500
SPHERICAL ABERRATION
A=−14.18
0.500
ASTIGMATISM
A=−14.18
5.00 %
DISTORTION
A=−14.18
A=−12.05
A=−10.01
A=−7.22
A=0.0
−0.100
LATERAL ABERRATION

FIG. 56B



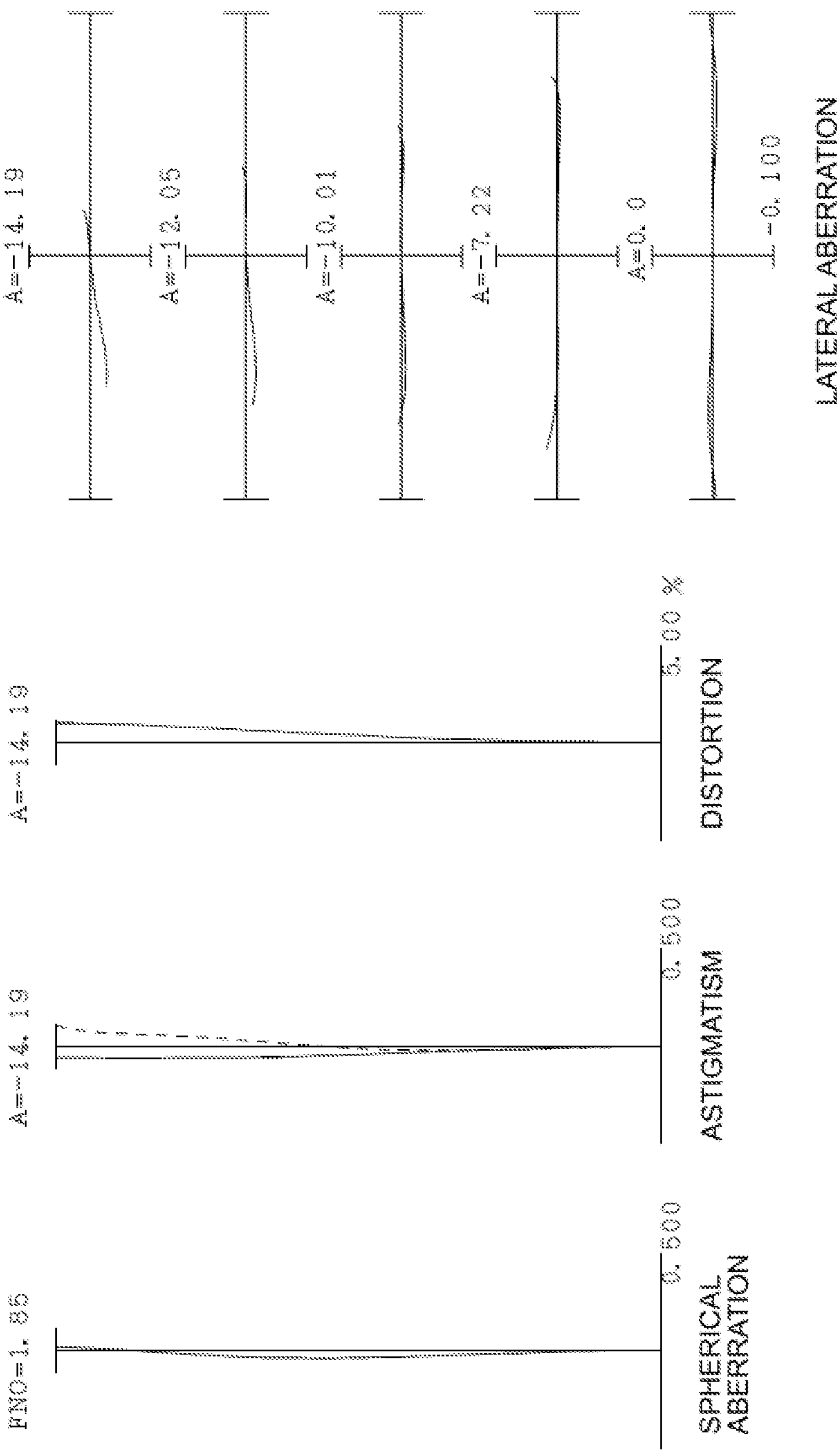
HO=-171. 72
HO=-145. 33
HO=-120. 27
HO=-86. 30
HO=0. 0
-0. 100
LATERAL ABERRATION
HO=-171. 72
5. 00 %
DISTORTION
HO=-171. 72
0. 500
ASTIGMATISM
NA=0. 24
0. 500
SPHERICAL ABERRATION

FIG. 57



(FOCUSING)
∞
I
FL
L32
L31
G3(−)
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(29)

FIG. 58A



FNO=1. 85
0. 500
SPHERICAL ABERRATION
A=−14. 19
0. 500
ASTIGMATISM
A=−14. 19
5. 00 %
DISTORTION
A=−14. 19
A=−12. 05
A=−10. 01
A=−7. 22
A=0. 0
−0. 100
LATERAL ABERRATION

FIG. 58B

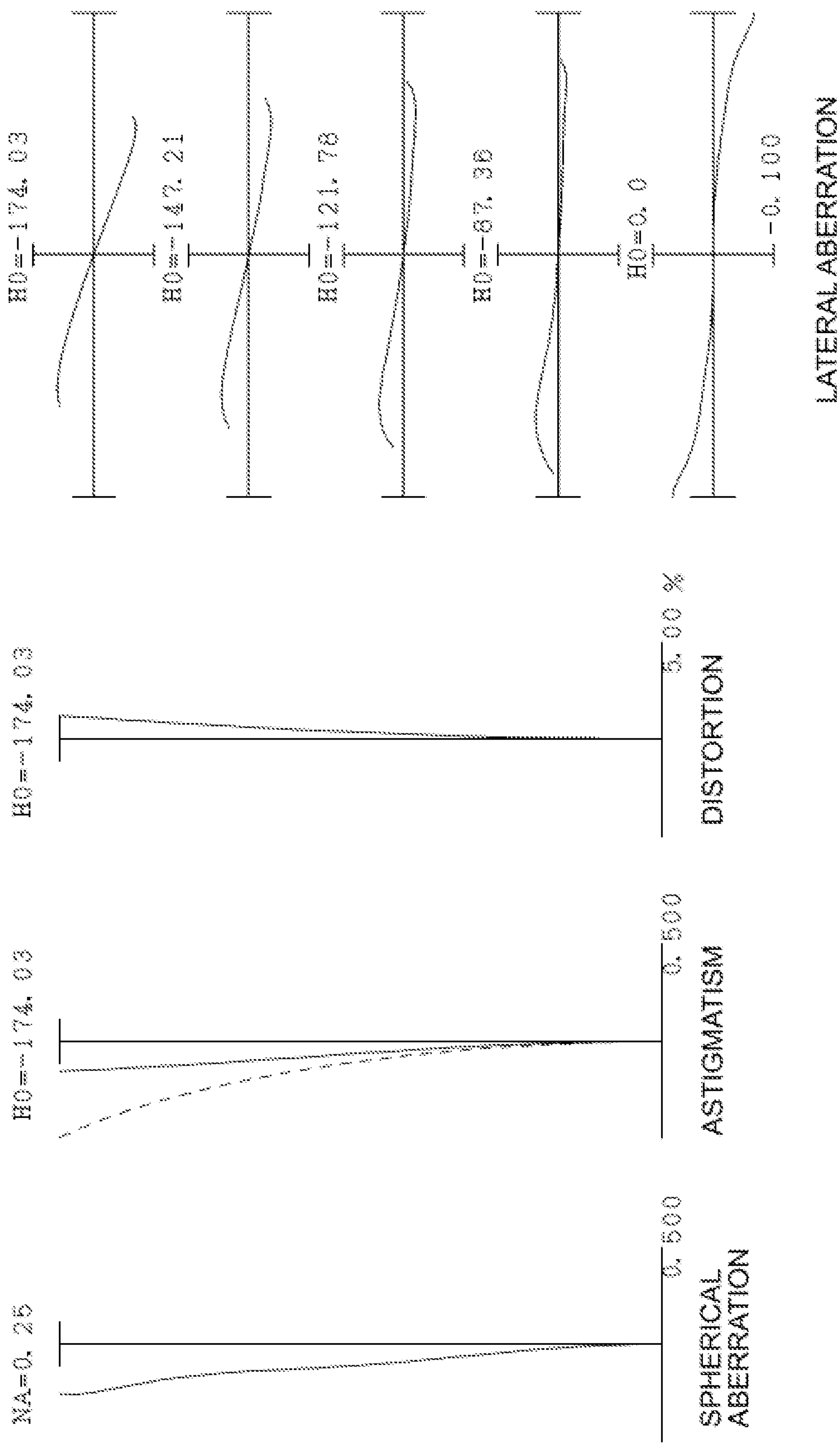

H0=-174.03
H0=-147.21
H0=-121.78
H0=-87.30
H0=0.0
-0.100
LATERAL ABERRATION
H0=-174.03
5.00 %
DISTORTION
H0=-174.03
0.500
ASTIGMATISM
NA=0.25
0.500
SPHERICAL ABERRATION

FIG. 59

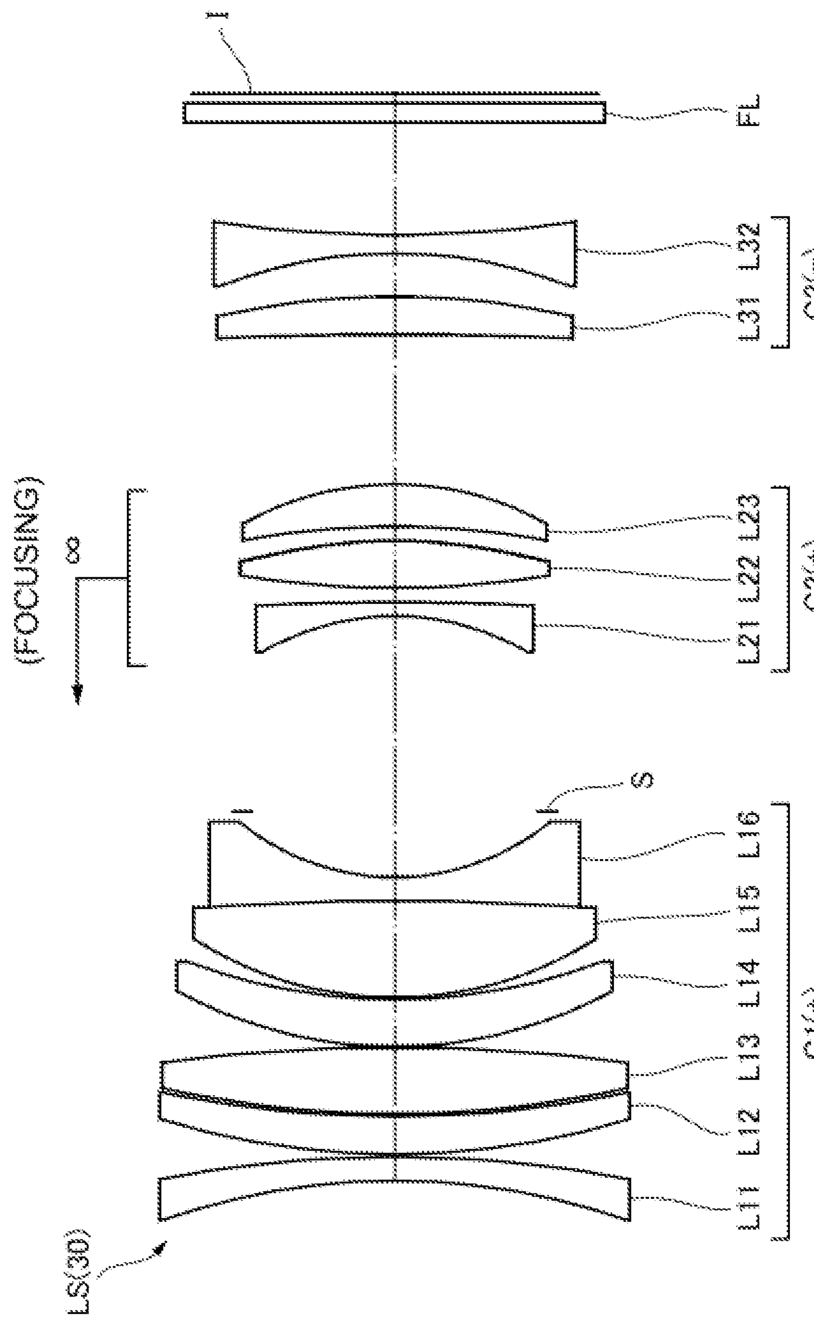

I
FL
L32
L31
G3(−)
(FOCUSING)
∞
L23
L22
L21
G2(+)
S
L16
L15
L14
L13
L12
L11
G1(+)
LS(30)

FIG. 60A

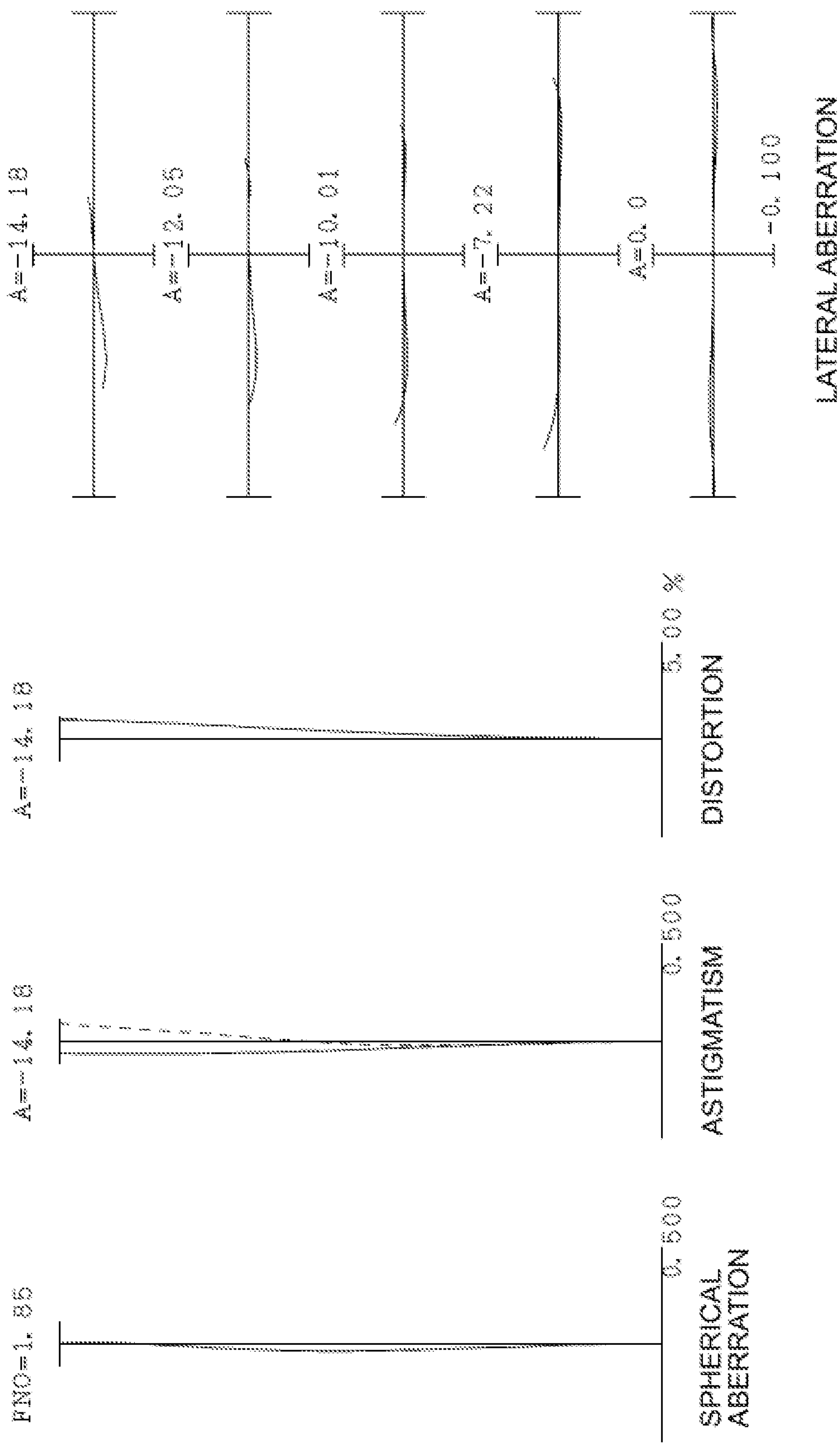

A=−14. 18
A=−12. 05
A=−10. 01
A=−7. 22
A=0. 0
−0. 100
LATERAL ABERRATION
A=−14. 18
5. 00 %
DISTORTION
A=−14. 18
0. 500
ASTIGMATISM
FNO=1. 85
0. 500
SPHERICAL ABERRATION

FIG. 60B

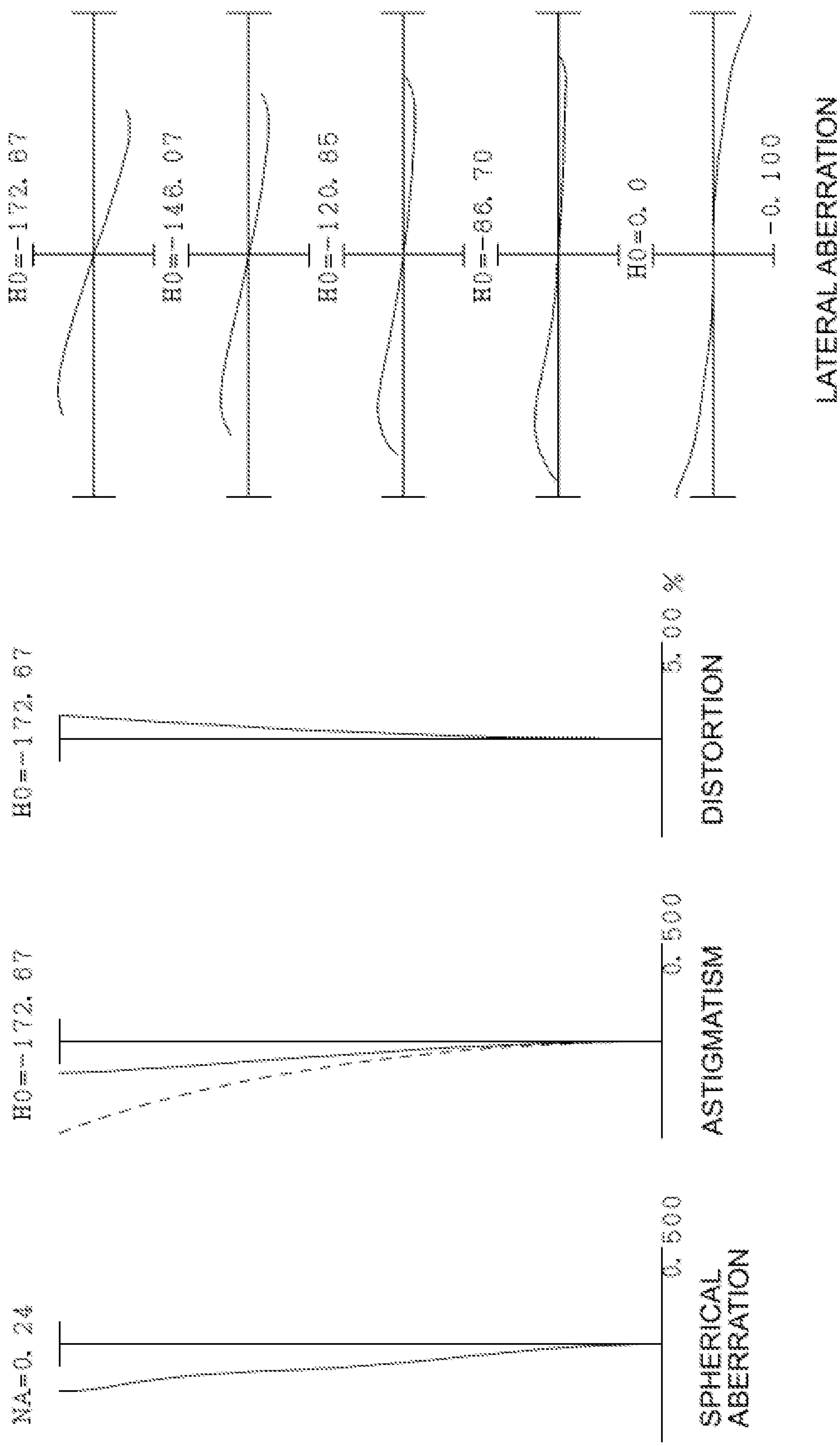
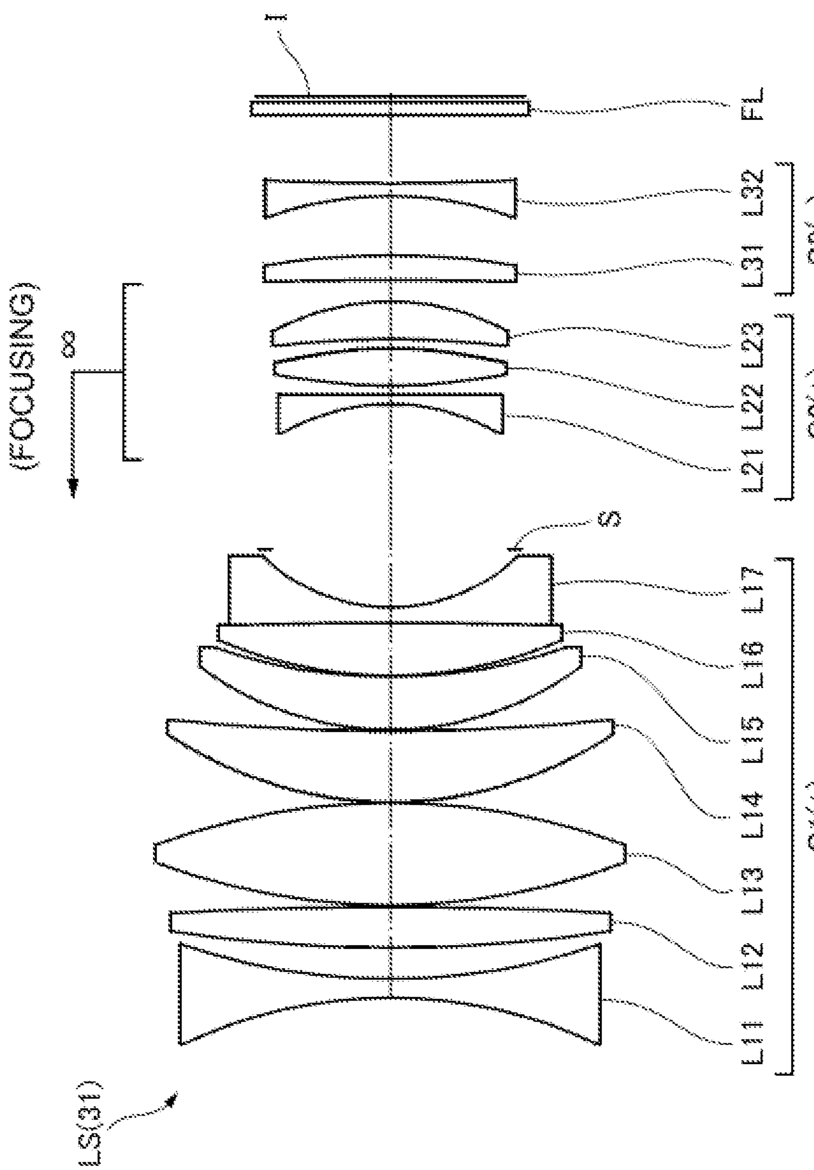

NA=0. 24
0. 500
SPHERICAL ABERRATION
H0=−172. 67
0. 500
ASTIGMATISM
H0=−172. 67
5. 00 %
DISTORTION
H0=−172. 67
H0=−146. 07
H0=−120. 85
H0=−86. 70
H0=0. 0
−0. 100
LATERAL ABERRATION

FIG. 61



I
FL
L32
L31
G3(−)
L23
L22
L21
G2(+)
(FOCUSING)
∞
S
L17
L16
L15
L14
L13
L12
L11
G1(+)
LS(31)

FIG. 62A

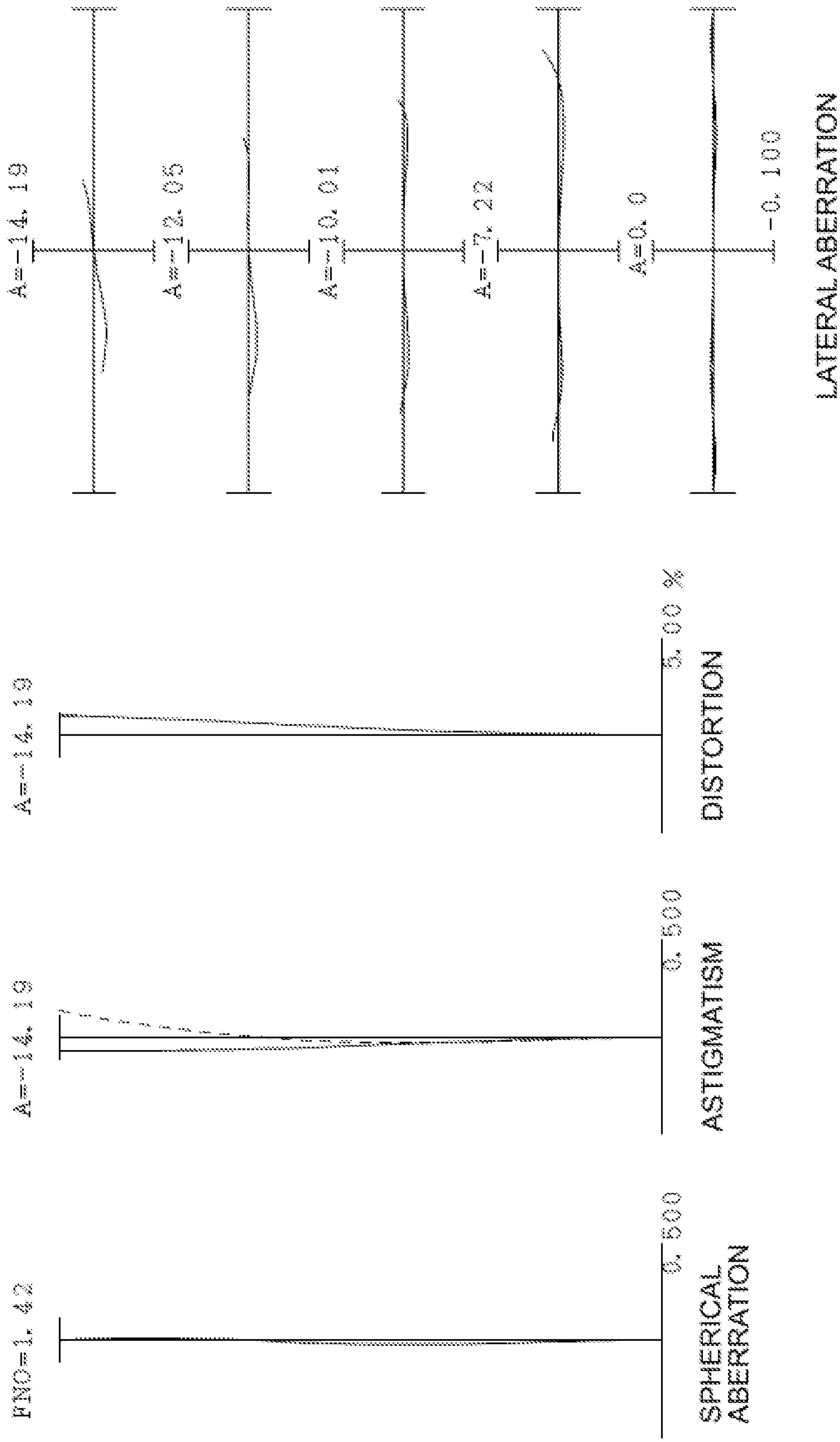

FNO=1.42
0.500
SPHERICAL ABERRATION
A=−14.19
0.500
ASTIGMATISM
A=−14.19
5.00 %
DISTORTION
A=−14.19
A=−12.05
A=−10.01
A=−7.22
A=0.0
−0.100
LATERAL ABERRATION

FIG. 62B

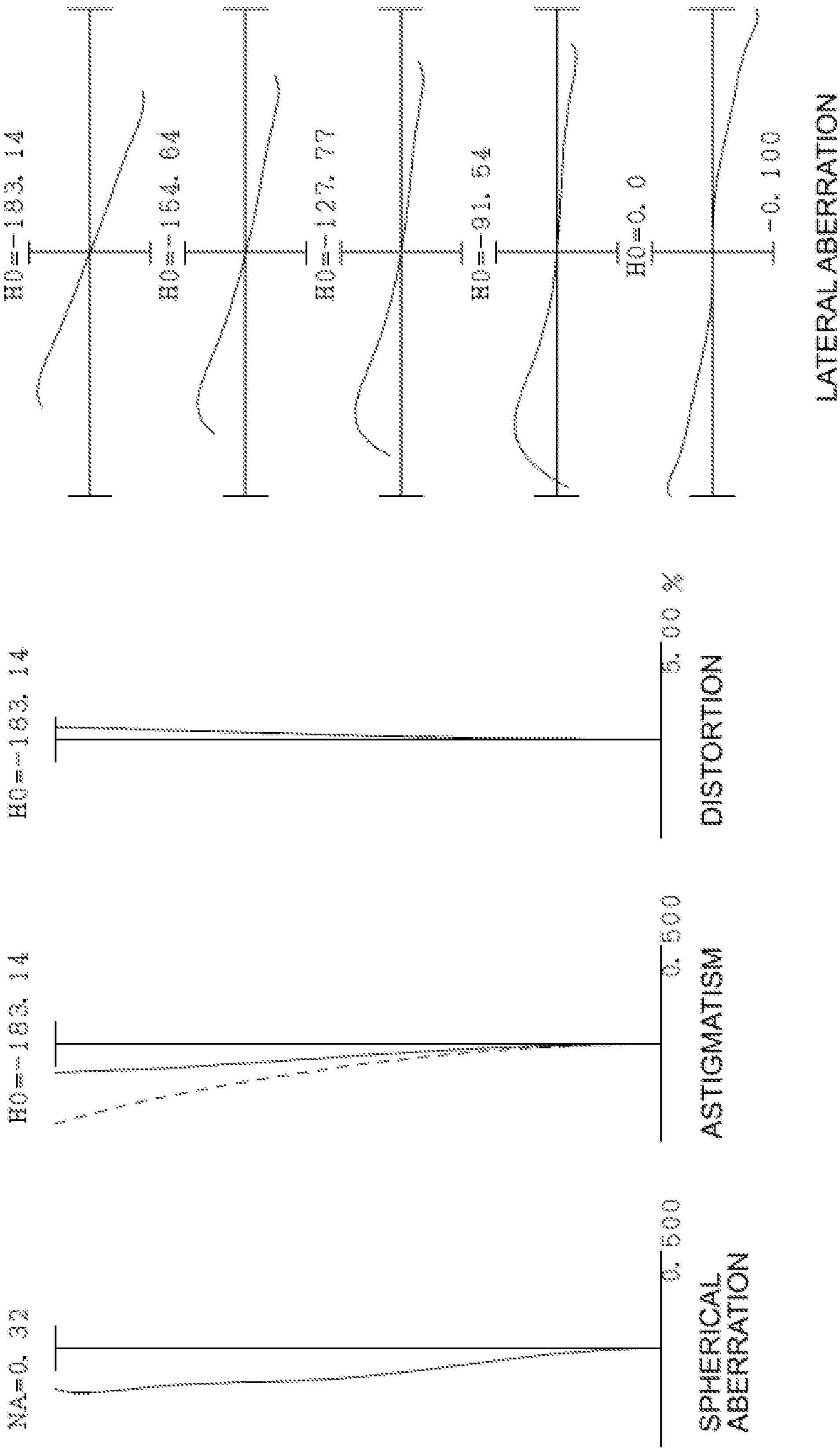

NA=0. 32
0. 500
SPHERICAL ABERRATION
H0=-183. 14
0. 500
ASTIGMATISM
H0=-183. 14
5. 00 %
DISTORTION
H0=-183. 14
H0=-154. 04
H0=-127. 77
H0=-91. 54
H0=0. 0
-0. 100
LATERAL ABERRATION

FIG. 63

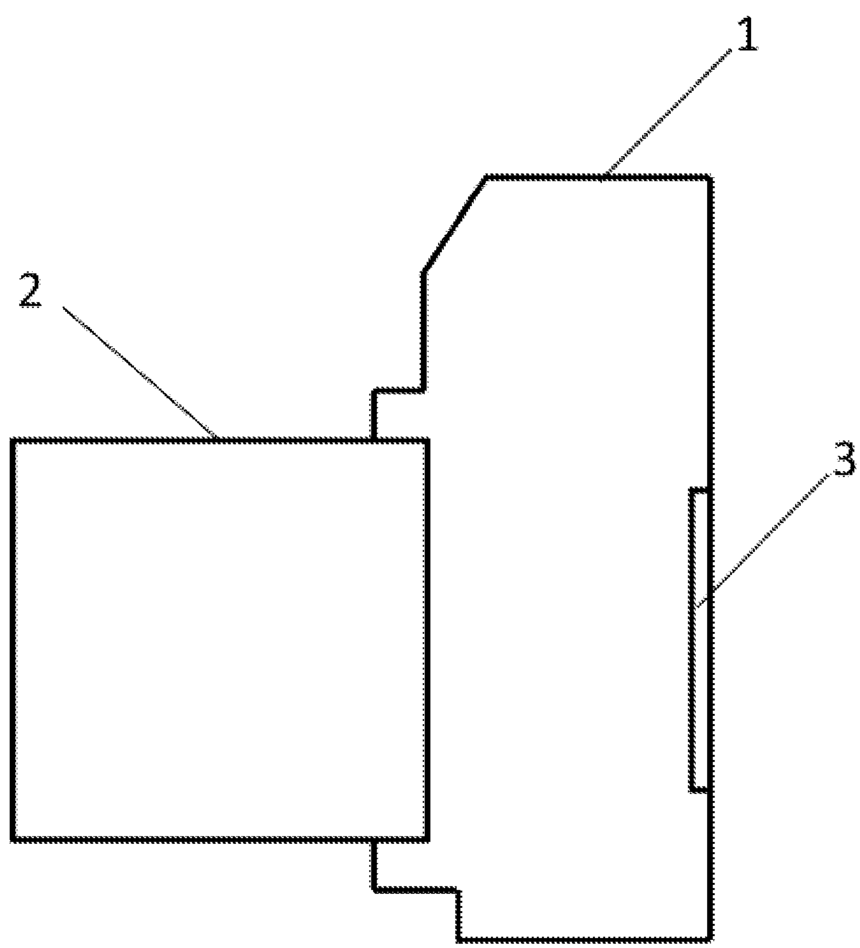
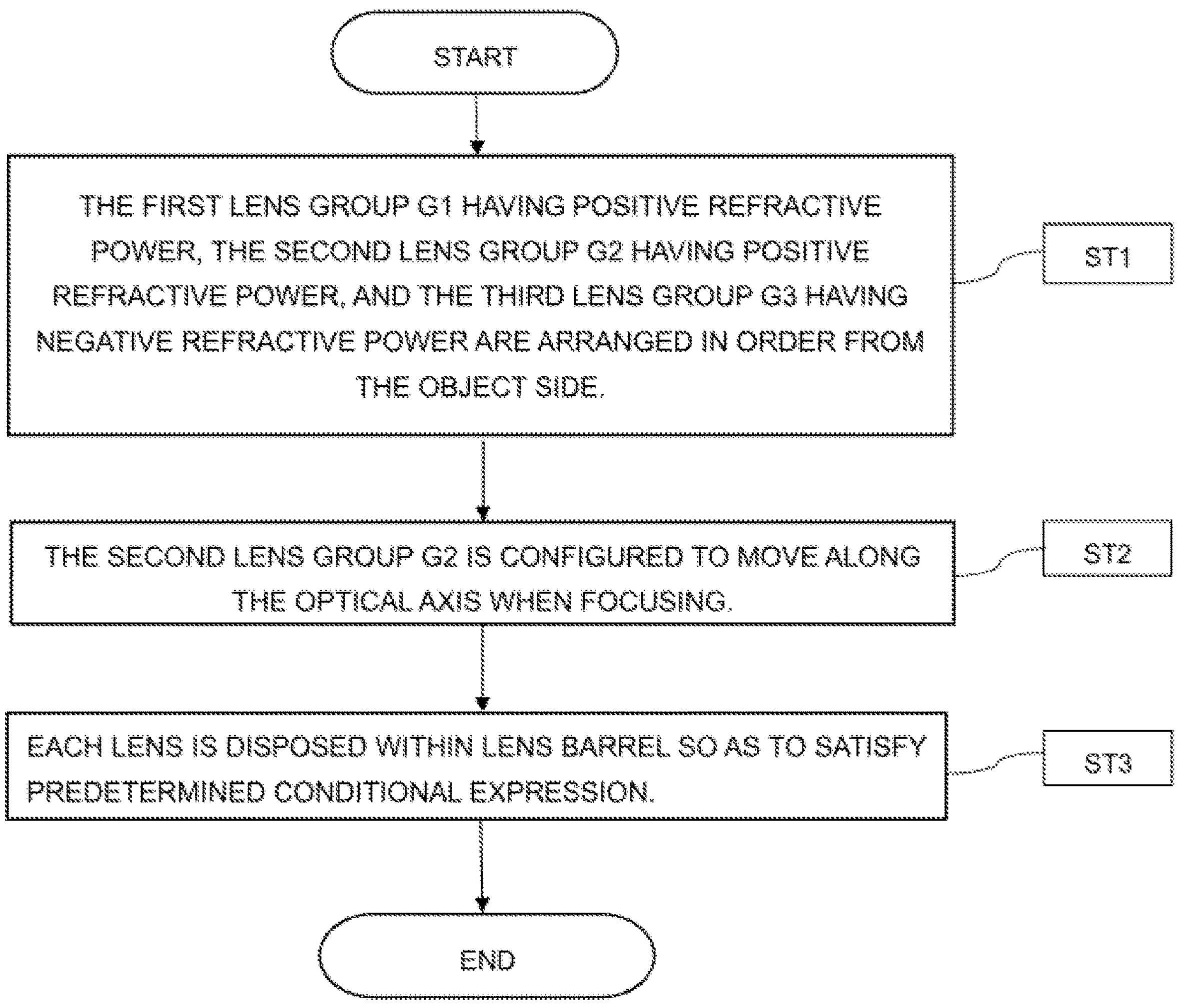


FIG.64


START
THE FIRST LENS GROUP G1 HAVING POSITIVE REFRACTIVE POWER, THE SECOND LENS GROUP G2 HAVING POSITIVE REFRACTIVE POWER, AND THE THIRD LENS GROUP G3 HAVING NEGATIVE REFRACTIVE POWER ARE ARRANGED IN ORDER FROM THE OBJECT SIDE.
ST1
THE SECOND LENS GROUP G2 IS CONFIGURED TO MOVE ALONG THE OPTICAL AXIS WHEN FOCUSING.
ST2
EACH LENS IS DISPOSED WITHIN LENS BARREL SO AS TO SATISFY PREDETERMINED CONDITIONAL EXPRESSION.
ST3
END

OPTICAL SYSTEM, OPTICAL APPARATUS, AND METHOD OF MANUFACTURING OPTICAL SYSTEM

TECHNICAL FIELD

The present invention relates to an optical system, an optical apparatus, and a method of manufacturing an optical system.

TECHNICAL BACKGROUND

In the related art, a fixed focal point optical system of the inner focus type that focuses by drawing out a positive lens group disposed on the image side of the diaphragm to the object side has been proposed (for example, see Patent literature 1). In a case where such an optical system is increased in diameter, it is difficult to correct various aberrations favorably.

PRIOR ARTS LIST

Patent Document

Patent literature 1: Japanese Laid-open Patent Publication No. 2012-234169 (A)

SUMMARY OF THE INVENTION

An optical system according to a first mode comprises a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from the object side, wherein when focusing, the second lens group moves along the optical axis, and the optical system satisfies the following conditional expressions

$$0.100<BFa/f<0.500 \text{ and}$$

$$-5.000<(-G1R1)/f<500.000$$

where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system,

f is the focal length of the optical system, and

G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group.

An optical apparatus according to a second mode is provided with the above optical system.

A method of manufacturing an optical system according to a third mode is a method of manufacturing an optical system including a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from the object side, the method comprising: disposing each lens within a lens barrel such that when focusing, the second lens group moves along the optical axis, and the optical system satisfies the following conditional expressions

$$0.100<BFa/f<0.500 \text{ and}$$

$$-5.000<(-G1R1)/f<500.000$$

where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system,

f is the focal length of the optical system, and

G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 1st example;

FIG. **2**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 1st example, while FIG. **2**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 1st example;

FIG. **3** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 2nd example;

FIG. **4**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 2nd example, while FIG. **4**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 2nd example;

FIG. **5** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 3rd example;

FIG. **6**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 3rd example, while FIG. **6**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 3rd example;

FIG. **7** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 4th example;

FIG. **8**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 4th example, while FIG. **8**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 4th example;

FIG. **9** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 5th example;

FIG. **10**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 5th example, while FIG. **10**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 5th example;

FIG. **11** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 6th example;

FIG. **12**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 6th example, while FIG. **12**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 6th example;

FIG. **13** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 7th example;

FIG. **14**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 7th example, while FIG. **14**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 7th example;

FIG. **15** is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 8th example;

FIG. 16A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 8th example, while FIG. 16B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 8th example;

FIG. 17 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 9th example;

FIG. 18A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 9th example, while FIG. 18B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 9th example;

FIG. 19 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 10th example;

FIG. 20A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 10th example, while FIG. 20B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 10th example;

FIG. 21 is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 11th example;

FIG. 22A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 11th example, while FIG. 22B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 11th example;

FIG. 23 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 12th example;

FIG. 24A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 12th example, while FIG. 24B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 12th example;

FIG. 25 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 13th example;

FIG. 26A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 13th example, while FIG. 26B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 13th example;

FIG. 27 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 14th example;

FIG. 28A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 14th example, while FIG. 28B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 14th example;

FIG. 29 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 15th example;

FIG. 30A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 15th example, while FIG. 30B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 15th example;

FIG. 31 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 16th example;

FIG. 32A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 16th example, while FIG. 32B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 16th example;

FIG. 33 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 17th example;

FIG. 34A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 17th example, while FIG. 34B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 17th example;

FIG. 35 is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 18th example;

FIG. 36A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 18th example, while FIG. 36B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 18th example;

FIG. 37 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 19th example;

FIG. 38A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 19th example, while FIG. 38B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 19th example;

FIG. 39 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 20th

FIG. 40A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 20th example, while FIG. 40B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 20th example;

FIG. 41 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 21st example;

FIG. 42A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 21st example, while FIG. 42B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 21st example;

FIG. 43 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 22nd example;

FIG. 44A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 22nd example, while FIG. 44B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 22nd example;

FIG. 45 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 23rd example;

FIG. 46A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 23rd example, while FIG. 46B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 23rd example;

FIG. 47 is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 24th example;

FIG. 48A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 24th example, while FIG. 48B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 24th example;

FIG. **49** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 25th example;

FIG. **50**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 25th example, while FIG. **50**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 25th example;

FIG. **51** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 26th example;

FIG. **52**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 26th example, while FIG. **52**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 26th example;

FIG. **53** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 27th example;

FIG. **54**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 27th example, while FIG. **54**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 27th example;

FIG. **55** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 28th example;

FIG. **56**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 28th example, while FIG. **56**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 28th example;

FIG. **57** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 29th example;

FIG. **58**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 29th example, while FIG. **58**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 29th example;

FIG. **59** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 30th

FIG. **60**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 30th example, while FIG. **60**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 30th example;

FIG. **61** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 31st example;

FIG. **62**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 31st example, while FIG. **62**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 31st example;

FIG. **63** is a diagram illustrating a configuration of a camera provided with the optical system according to the present embodiment; and

FIG. **64** is a flowchart illustrating a method of manufacturing the optical system according to the present embodiment.

DESCRIPTION OF THE EMBODIMENT

Hereinafter, an optical system and an optical apparatus according to the present embodiment will be described with reference to the drawings. First, a camera (optical apparatus) provided with the optical system according to the present embodiment will be described on the basis of FIG. **63**. As illustrated in FIG. **63**, a camera **1** is a digital camera provided with the optical system according to the present embodiment as a photographic lens **2**. In the camera **1**, light from a physical object not illustrated (the subject) is condensed by the photographic lens **2**, and arrives at an image sensor **3**. With this arrangement, the light from the subject is captured by the image sensor **3** and recorded to memory not illustrated as a subject image. In this way, a photographer is able to capture an image of the subject with the camera **1**. Note that the camera may be a mirrorless camera or a single-lens reflex camera having a quick-return mirror.

As illustrated in FIG. **1**, an optical system LS(**1**) treated as an example of the optical system (photographic lens) LS according to the present embodiment comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing, the second lens group G**2** moves along the optical axis. This arrangement makes it possible to obtain favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification.

The optical system LS according to the present embodiment is not limited to the optical system LS(**1**) illustrated in FIG. **1**, and may also be the optical system LS(**2**) illustrated in FIG. **3**. Similarly, the optical system LS according to the present embodiment may be any of the optical systems LS(**3**) to LS(**31**) illustrated in FIG. **5** and subsequent drawings.

Given the above configuration, the optical system LS according to the present embodiment satisfies the following conditional expressions.

$$0.100<BFa/f<0.500 \tag{1}$$

$$-5.000<(-G1R1)/f<500.000 \tag{2}$$

where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system LS,

f is the focal length of the optical system LS, and

G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1**.

Conditional Expression (1) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the back focus. By satisfying Conditional Expression (1), astigmatism can be corrected favorably.

If the corresponding value of Conditional Expression (1) exceeds the upper limit, correcting astigmatism is difficult. By setting the upper limit of Conditional Expression (1) to 0.450, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (1) preferably is set to 0.420, 0.400, 0.380, 0.350, 0.320, 0.300, 0.290, 0.280, 0.275, 0.270, or 0.265, more preferably to 0.260.

If the corresponding value of Conditional Expression (1) falls below the lower limit, correcting astigmatism is also difficult. By setting the lower limit of Conditional Expression (1) to 0.110, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (1) preferably is set to 0.120, 0.130, 0.140, 0.150, or 0.160, more preferably to 0.170.

Conditional Expression (2) prescribes the appropriate range of the ratio between the radius of curvature of the lens surface farthest on the object side in the first lens group G1 and the focal length of the whole optical system LS. By satisfying Conditional Expression (2), favorable optical performance can be secured for the state of focusing on infinity. In the present embodiment, a lens component refers to a single lens or a cemented lens.

If the corresponding value of Conditional Expression (2) exceeds the upper limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G1 decreases, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (2) to 400.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (2) preferably is set to 300.000, 200.000, 100.000, 85.000, 75.000, 60.000, 45.000, or 30.000, more preferably to 20.000.

If the corresponding value of Conditional Expression (2) falls below the lower limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G1 increases, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (2) to −4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (2) preferably is set to −3.000, −2.000, −1.000, 0.010, 0.100, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.550, 0.600, or 0.650, more preferably to 0.700.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (3) below.

$$-5.000<(-G1R1)/f1<50.000 \quad (3)$$

where f1 is the focal length of the first lens group G1.

Conditional Expression (3) prescribes the appropriate range of the ratio between the radius of curvature of the lens surface farthest on the object side in the first lens group G1 and the focal length of the first lens group G1. By satisfying Conditional Expression (3), favorable optical performance can be secured for the state of focusing on infinity.

If the corresponding value of Conditional Expression (3) exceeds the upper limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G1 decreases, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (3) to 40.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (3) preferably is set to 30.000, 20.000, or 10.000, more preferably to 5.000.

If the corresponding value of Conditional Expression (3) falls below the lower limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G1 increases, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (3) to −4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (3) preferably is set to −3.000, −2.000, −1.000, 0.010, 0.050, 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, or 0.450, more preferably to 0.500.

The optical system LS according to the present embodiment may also satisfy Conditional Expression (3-1) below.

$$0.010<(-G1R1)/f1<1.100. \quad (3\text{-}1)$$

where f1 is the focal length of the first lens group G1.

Conditional Expression (3-1) is an expression similar to Conditional Expression (3), and effects similar to those of Conditional Expression (3) can be obtained. This range is desirable because various aberrations such as coma aberration can be corrected favorably. Particularly, by setting the lower limit of Conditional Expression (3-1) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (3-1) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, or 0.450, more preferably to 0.500. The optical system LS according to the present

embodiment may also satisfy Conditional Expression (3-2) below.

$$1.000<(-G1R1)/f1<50.000 \quad (3\text{-}2)$$

where f1 is the focal length of the first lens group G1.

Conditional Expression (3-2) is an expression similar to Conditional Expression (3), and effects similar to those of Conditional Expression (3) can be obtained. This range is desirable because various aberrations such as coma aberration can be corrected favorably. Particularly, by setting the upper limit of Conditional Expression (3-2) to 40.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (3-2) preferably is set to 30.000, 20.000, or 10.000, more preferably to 5.000.

In the optical system LS according to the present embodiment, it is desirable for the first lens group G1 to comprise a diaphragm. With this arrangement, various aberrations such as coma aberration and astigmatism can be corrected favorably for the state of focusing on a short-distance object.

In the optical system LS according to the present embodiment, it is desirable for the first lens group G1 to be stationary. With this arrangement, the optical system LS can be made more compact as a whole.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (4) below.

$$0.010<f/f1<5.000 \quad (4)$$

where f1 is the focal length of the first lens group G1.

Conditional Expression (4) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the focal length of the first lens group G1. By satisfying Conditional Expression (4), favorable optical performance can be secured for the state of focusing on infinity.

If the corresponding value of Conditional Expression (4) exceeds the upper limit, the focal length of the first lens group G1 is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (4) to 4.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (4) preferably is set to 4.000, 3.500, 3.000, 2.500, 2.000, 1.500, or 1.200, more preferably to 1.000.

If the corresponding value of Conditional Expression (4) falls below the lower limit, the focal length of the first lens group G1 is lengthened, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (4) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (4) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, or 0.500, more preferably to 0.550.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (5) below.

$$0.010<f/f2<5.000 \tag{5}$$

where f2 is the focal length of the second lens group G**2**.

Conditional Expression (5) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the focal length of the second lens group G**2**. By satisfying Conditional Expression (5), favorable optical performance can be secured for the state of focusing on a short-distance object.

If the corresponding value of Conditional Expression (5) exceeds the upper limit, the focal length of the second lens group G**2** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (5) to 4.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (5) preferably is set to 4.000, 3.500, 3.000, 2.500, 2.000, 1.800, or 1.500, more preferably to 1.300.

If the corresponding value of Conditional Expression (5) falls below the lower limit, the focal length of the second lens group G**2** is lengthened, and therefore the amount of movement by the second lens group G**2** when focusing increases, and variations in spherical aberration and curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (5) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (5) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.550, or 0.600, more preferably to 0.650.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (6) below.

$$0.010<f1/f2<5.000 \tag{6}$$

where f1 is the focal length of the first lens group G**1**, and

f2 is the focal length of the second lens group G**2**.

Conditional Expression (6) prescribes the appropriate range of the ratio between the focal length of the first lens group G**1** and the focal length of the second lens group G**2**. By satisfying Conditional Expression (6), favorable optical performance can be secured for the state of focusing on infinity and for the state of focusing on a short-distance object.

If the corresponding value of Conditional Expression (6) exceeds the upper limit, the focal length of the second lens group G**2** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (6) to 4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (6) preferably is set to 3.500, 3.000, 2.500, or 2.000, more preferably to 1.800.

If the corresponding value of Conditional Expression (6) falls below the lower limit, the focal length of the second lens group G**2** is lengthened, and therefore the amount of movement by the second lens group G**2** when focusing increases, and variations in spherical aberration and curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (6) to 0.100, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (6) preferably is set to 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.600, 0.700, or 0.800, more preferably to 0.900.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (7) below.

$$0.010<f1/(-f3)<3.000 \tag{7}$$

where f1 is the focal length of the first lens group G**1**, and

f3 is the focal length of the third lens group G**3**.

Conditional Expression (7) prescribes the appropriate range of the ratio between the focal length of the first lens group G**1** and the focal length of the third lens group G**3**. By satisfying Conditional Expression (7), favorable optical performance can be secured for the state of focusing on infinity and for the state of focusing on a short-distance object.

If the corresponding value of Conditional Expression (7) exceeds the upper limit, the focal length of the first lens group G**1** is lengthened, which makes correcting coma aberration difficult. By setting the upper limit of Conditional Expression (7) to 2.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (7) preferably is set to 2.000, 1.800, 1.500, 1.300, 1.200, 1.180, or 1.165, more preferably to 1.160.

If the corresponding value of Conditional Expression (7) falls below the lower limit, the focal length of the first lens group G**1** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. Also, the focal length of the third lens group G**3** is lengthened on the negative side, which makes it difficult to correct various aberrations, and variations in curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (7) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (7) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, or 0.520, more preferably to 0.550.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (8) below.

$$0.10<fF/fR<3.00 \tag{8}$$

where fF is the composite focal length of the lenses disposed farther on the object side than the diaphragm in the optical system LS, and

fR is the composite focal length of the lenses disposed farther on the image side than the diaphragm in the optical system LS.

Conditional Expression (8) prescribes the appropriate range of the ratio between the composite focal length of the lenses disposed farther on the object side than the diaphragm and the composite focal length of the lenses disposed farther on the image side than the diaphragm. Note that each composite focal length is the composite focal length for the state of focusing on infinity. By satisfying Conditional Expression (8), astigmatism and distortion can be corrected favorably.

If the corresponding value of Conditional Expression (8) exceeds the upper limit, correcting astigmatism and distortion is difficult. By setting the upper limit of Conditional Expression (8) to 2.50, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (8) preferably is set to 2.00, 1.80, 1.50, or 1.20, more preferably to 1.10.

If the corresponding value of Conditional Expression (8) falls below the lower limit, correcting astigmatism and distortion is also difficult. By setting the lower limit of Conditional Expression (8) to 0.20, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (8) preferably is set to 0.25, 0.27, 0.30, or 0.34, more preferably to 0.35.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (9) below.

$$-10.0<(G1R2+G1R1)/(G1R2-G1R1)<10.0 \qquad (9)$$

where G1R2 is the radius of curvature of the lens surface on the image side for the lens component disposed farthest on the object side in the first lens group G**1**.

Conditional Expression (9) prescribes the shape factor of the lens component disposed farthest on the object side in the first lens group G**1**. By satisfying Conditional Expression (9), favorable optical performance can be secured for the state of focusing on infinity.

If the corresponding value of Conditional Expression (9) exceeds the upper limit, the curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1** is tightened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (9) to 8.0, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (9) preferably is set to 7.0, 6.0, or 5.0, more preferably to 4.0.

If the corresponding value of Conditional Expression (9) falls below the lower limit, the curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1** is loosened, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (9) to −8.0, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (9) preferably is set to −7.0, −6.0, −5.0, −4.0, or −3.0, more preferably to −2.0.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (10) below.

$$0.30<\{1-(\beta 2)^2\}\times(\beta^3)^2<2.00 \qquad (10)$$

where β2 is the lateral magnification of the second lens group G**2** for the state of focusing on infinity, and

β3 is the lateral magnification of the third lens group G**3**.

Conditional Expression (10) prescribes the displacement of the focal position with respect to movement by the second lens group G**2**. By satisfying Conditional Expression (10), favorable optical performance can be secured for the state of focusing on a short-distance object both on-axis and off-axis.

If the corresponding value of Conditional Expression (10) exceeds the upper limit, correcting coma aberration and astigmatism for the state of focusing on a short-distance object is difficult. By setting the upper limit of Conditional Expression (10) to 1.80, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (10) preferably is set to 1.60, 1.40, 1.20, 1.00, 0.95, or 0.91, more preferably to 0.89.

If the corresponding value of Conditional Expression (10) falls below the lower limit, correcting coma aberration and astigmatism for the state of focusing on a short-distance object is also difficult. By setting the lower limit of Conditional Expression (10) to 0.35, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (10) preferably is set to 0.40, 0.45, or 0.48, more preferably to 0.50.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (11) below.

$$0.50<FNO\times(f1/f)<5.50 \qquad (11)$$

where FNO is the F-number of the optical system LS, and

f1 is the focal length of the first lens group G**1**.

Conditional Expression (11) prescribes a value corresponding to the F-number of the first lens group G**1**. By satisfying Conditional Expression (11), various aberrations such as coma aberration can be corrected favorably.

If the corresponding value of Conditional Expression (11) exceeds the upper limit, correcting coma aberration and astigmatism is difficult. By setting the upper limit of Conditional Expression (11) to 5.00, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (11) preferably is set to 4.50, 4.00, 3.50, or 3.20, more preferably to 3.00.

If the corresponding value of Conditional Expression (11) falls below the lower limit, correcting spherical aberration and coma aberration is also difficult. By setting the lower limit of Conditional Expression (11) to 0.80, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (11) preferably is set to 1.00, 1.40, 1.60, or 1.80, more preferably to 1.95.

It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (12) below.

$$15.0°<2\omega<85.0° \qquad (12)$$

where 2ω is the angle of view of the optical system LS.

Conditional Expression (12) prescribes the angle of view of the optical system LS. By satisfying Conditional Expression (12), various aberrations can be corrected favorably, while maintaining a wide angle of view. By setting the upper limit of Conditional Expression (12) to 80.0°, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (12) preferably is set to 75.0°, 70.0°, or 68.0°, more preferably to 65.0°. By setting the lower limit of Conditional Expression (12) to 17.0°, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (12) preferably is set to 18.0°, 20.0°, or 22.0°, more preferably to 25.0°.

In the optical system LS according to the present embodiment, the lens disposed farthest on the object side in the first lens group G1 may also be a negative lens. With this arrangement, coma aberration can be corrected favorably.

In the optical system LS according to the present embodiment, the lens disposed farthest on the object side in the second lens group G2 may also be a negative lens. With this arrangement, curvature of field can be corrected favorably.

In the optical system LS according to the present embodiment, the second lens group G2 may comprise at least one positive lens and at least one negative lens. With this arrangement, various aberrations such as chromatic aberration can be corrected favorably.

In the optical system LS according to the present embodiment, the third lens group G3 may comprise at least one positive lens and at least one negative lens. With this arrangement, various aberrations such as chromatic aberration can be corrected favorably.

Next, a method of manufacturing the optical system LS described above will be summarized with reference to FIG. **64**. First, the first lens group G1 having positive refractive power, the second lens group G2 having positive refractive power, and the third lens group G3 having negative refractive power are arranged in order from the object side (step ST**1**). Thereafter, the second lens group G**2** is configured to move along the optical axis when focusing (step ST**2**). Also, each lens is disposed within a lens barrel to satisfy at least Conditional Expressions (1) and (2) above (step ST**3**). According to such a manufacturing method, it is possible to manufacture an optical system capable of obtaining favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification.

EXAMPLES

Hereinafter, the optical system LS according to examples of the present embodiment will be described on the basis of the drawings. FIG. **1** is a cross section illustrating the configuration and the refractive power distribution of an optical system LS {LS(**1**)} according to a 1st example. Similarly, FIGS. **3**, **5**, **7**, **9**, **11**, **13**, **15**, **17**, **19**, and **21** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**2**) to LS(**11**)} according to second to 11th examples. FIGS. **23**, **25**, **27**, **29**, **31**, **33**, **35**, **37**, **39**, and **41** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**12**) to LS(**21**)} according to 12th to 21st examples. FIGS. **43**, **45**, **47**, **49**, **51**, **53**, **55**, **57**, **59**, and **61** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**22**) to LS(**31**)} according to 22nd to 31st examples. In each cross section, the movement direction when the focusing lens group focuses from infinity to a short-distance object is indicated by the arrow labeled "Focusing".

In these diagrams, each lens group is denoted by the combination of the sign G and a numeral, while each lens is denoted by the combination of the sign L and a numeral. In this case, to avoid confusion due to a large variety of signs and numerals and their values, the lens groups and the like are referenced using combinations of signs and numerals that are respectively independent in each of the examples. Consequently, even if the same combinations of signs and numerals are used between examples, this does not mean that the examples have the same configuration.

Tables 1 to 31 below indicate data regarding each of the 1st to 31st examples. In each example, the d-line (wavelength λ=587.6 nm) is chosen as the target for computing aberration characteristics.

In the [General Data] table, f is the focal length of the entire lens system, FNO is the F-number, ω is the half angle of view (in units of degrees)) (°, and Y is the image height. Also, TL is the distance from the lens forefront surface to the lens last surface on the optical axis upon focusing on infinity plus BF, BF is the distance (back focus) from the lens last surface to the image surface I on the optical axis upon focusing on infinity, and BFa is the air equivalent length of the back focus.

In the [Lens Data] table, the surface number indicates the order of optical surfaces from the object side in the advancement direction of light rays, R is the radius of curvature of each optical surface (taken to be a positive value for a surface whose center of curvature is positioned on the image side), D is the distance from each optical surface to the next optical surface (or the image surface) on the optical axis, nd is the refractive index with respect to the d-line of the material of an optical member, and νd is the Abbe number with reference to the d-line of the material of an optical member. A radius of curvature of "∞" means a flat surface or an aperture, while "(Aperture Stop S)" means an aperture stop S. The refractive index of air nd=1.00000 is not listed. In a case where an optical surface is an aspherical surface, an asterisk (*) is appended to the surface number, and the paraxial radius of curvature is listed in the radius of curvature R field.

In the [Aspherical Surface Data] table, the shapes of the aspherical surfaces indicated in [Lens Data] are expressed by the subsequent expressions (A). X (y) is the distance (sag amount) in the optical axis direction from the tangential plane at the vertex of the aspherical surface to a position on the aspherical surface at the height y, R is the radius of curvature (paraxial radius of curvature) of a reference spherical surface, κ is the conical coefficient, and Ai is the ith order aspherical coefficient. Also, "E−n" denotes "$\times 10^{-n}$". For example, 1.234E−05=1.234×10^{-5}. Note that the 2nd order aspherical coefficient A2 is 0, and is not listed.

In the [Variable Distance Data] table, the distance to the next lens surface Di is indicated for the surface number i whose distance to the next lens surface is indicated as "variable" in the [Lens Data] table. For example, in the 1st example, the distances to the next lens surface D11, D17, and D23 are indicated for the surface numbers 11, 17, and 23. These values are indicated for the state of focusing on infinity and the state upon focusing on a short-distance (close-up) object.

In the [Lens Group Data] table, the first surface (the surface farthest on the object side) and the focal length of each lens group are indicated.

In the [Conditional Expression Corresponding Value] table, the value corresponding to each conditional expression is indicated.

In all of the data values hereinafter, the listed values of the focal length f, the radius of curvature R, the distance to the next lens surface D, and other lengths generally are given in "mm" unless otherwise specified, but are not limited thereto, because the same optical performance is obtained even if the optical system is enlarged proportionally or reduced proportionally.

The description of the tables so far is common to all of the examples, and hereinafter a duplicate description will be omitted.

1st Example

The 1st example will be described using FIGS. **1** and **2** and Table 1. FIG. **1** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 1st example of the present embodiment. The optical system LS(**1**) according to the 1st example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place. The sign (+) or (−) appended to each lens group sign indicates the refractive power of each lens group. The same applies to all of the examples hereinafter.

The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** that is biconvex, a second negative lens L**15** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**13** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I. A filter such as a neutral color (NC) filter, a color filter, a polarizing filter, a neutral density (ND) filter, or an infrared cut-off (IR) filter is used as the interchangeable optical filter FL, for example. Note that the above also applies to the interchangeable optical filter FL described in the 2nd to 31st examples described later.

Table 1 below lists data values regarding the optical system according to the 1st example.

TABLE 1

[General Data]

f	51.59
FNO	1.85
ω	22.6
Y	21.70
TL	80.800
BF	13.599
BFa	13.054

[Lens Data]

Surface Number	R	D	nd	νd
1	−37.21999	1.800	1.60342	38.0
2	−301.75553	2.422		
3	−50.10561	3.350	1.49782	82.6
4	−32.57310	0.200		
5*	45.59156	5.050	1.82080	42.7
6*	−214.20431	0.200		
7	24.72595	7.194	1.59319	67.9
8	−5040.38050	0.100		
9	1752.78680	1.000	1.60342	38.0
10	18.45027	5.608		
11	∞	D11 (Variable)		(Aperture Stop S)
12	−23.43011	1.000	1.67270	32.2
13	−582.82234	0.200		
14*	127.87476	4.350	1.82080	42.7
15*	−43.94757	1.950		
16	−157.95993	5.600	1.60300	65.4
17	−28.85150	D17 (Variable)		
18	−374.08672	3.200	2.00100	29.1
19	−68.25108	4.109		
20	−36.81307	1.500	1.69895	30.1
21	177.00000	11.000		
22	∞	1.600	1.51680	63.9
23	∞	D23 (Variable)		

[Aspherical surface data]

Fifth surface

k = 1.00000
A4 = −1.10646E−06, A6 = −5.14585E−10,
A8 = 0.00000E+00, A10 = 0.00000E+00

Sixth surface

k = 1.00000
A4 = 3.82437E−07, A6 = −2.48354E−10,
A8 = 0.00000E+00, A10 = 0.00000E+00

Fourteenth surface

k = 1.00000
A4 = 2.59966E−06, A6 = 2.78570E−09,
A8 = 0.00000E+00, A10 = 0.00000E+00

Fifteenth surface

k = 1.00000
A4 = 9.97453E−06, A6 = 1.00933E−08,
A8 = 0.00000E+00, A10 = 0.00000E+00

[Variable distance data]

	Upon focusing on infinity f = 51.59	Upon focusing on a short-distance object β = −0.1508
D0	∞	319.20
D11	15.367	5.165
D17	3.000	13.203
D23	0.999	0.999

[lens group data]

group	starting surface	focal length
G1	1	68.17
G2	12	56.22
G3	18	−101.37

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.253
Conditional Expression (2)	(−G1R1)/f = 0.721
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.546
Conditional Expression (4)	f/f1 = 0.757
Conditional Expression (5)	f/f2 = 0.918
Conditional Expression (6)	f1/f2 = 1.213
Conditional Expression (7)	f1/(−f3) = 0.672
Conditional Expression (8)	fF/fR = 0.646
Conditional Expression (9)	(G1R2 + G1R1)/

TABLE 1-continued

	(G1R2 − G1R1) = 1.281
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = 0.613$
Conditional Expression (11)	FNO × (f1/f) = 2.451
Conditional Expression (12)	2ω = 45.2

FIG. 2A illustrates various aberration n graphs upon focusing on infinity in the optical system according to the 1st example. In each aberration graph of FIG. 2A, FNO is the F-number and A is the half angle of view. Note that in the spherical aberration graph, the value of the F-number corresponding to the maximum aperture is illustrated, while in each of the astigmatism graph and the distortion graph, the maximum value of the half angle of view is illustrated, and in the lateral aberration graph, the value of each half angle of view is illustrated. FIG. 2B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 1st example. In each aberration graph of FIG. 2B, NA is the numerical aperture and H0 is the object height. Note that in the spherical aberration graph, the value of the numerical aperture corresponding to the maximum aperture is illustrated, while in each of the astigmatism graph and the distortion graph, the maximum value of the object height is illustrated, and in the lateral aberration graph, the value of each object height is illustrated. Also, in the astigmatism graphs of FIGS. 2A and 2B, the solid line illustrates the sagittal image surface, while the dashed line illustrates the meridional image surface. Note that in the aberration graphs of each example illustrated hereinafter, signs similar to the present example will be used, and a duplicate description will be omitted.

The various aberration graphs demonstrate that the optical system according to the 1st example has excellent image forming performance in which various aberrations are corrected favorably.

2nd Example

The 2nd example will be described using FIGS. **3** and **4** and Table 2. FIG. **3** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 2nd example of the present embodiment. The optical system LS(**2**) according to the 2nd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 2 below lists data values regarding the optical system according to the 2nd example. Note that the 13th surface is a virtual surface.

TABLE 2

[General Data]

f	51.60
FNO	1.85
ω	22.8
Y	21.70
TL	88.456
BF	13.100
BFa	12.555

[Lens Data]

Surface Number	R	D	nd	νd
1	−39.70605	1.800	1.73800	32.3
2	68.44172	3.469	1.92286	20.9
3	740.55070	0.985		
4	−250.61896	4.504	1.59319	67.9
5	−42.16654	0.200		
6*	41.73745	0.103	1.56093	36.6
7	40.99975	5.408	1.83481	42.7
8	−316.20679	0.200		
9	36.83151	7.628	1.49782	82.6
10	−47.01014	1.500	1.62004	36.4
11	25.38130	4.386		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	3.000		
14	−22.68035	1.100	1.64769	33.7
15	219.09880	0.200		
16	85.95366	4.848	1.83481	42.7
17	−48.70070	0.100	1.56093	36.6
18*	−38.65718	2.196		
19	−133.55548	6.300	1.60300	65.4
20	−26.81373	D20 (Variable)		
21	−112.24414	2.782	1.90265	35.7
22	−53.62057	5.134		
23	−41.69274	2.000	1.53172	48.8
24	−133.37205	2.166		
25	−49.50596	2.000	1.60342	38.0
26	∞	10.500		
27	∞	1.600	1.51680	64.1
28	∞	D28		

TABLE 2-continued

(Variable)		
[Aspherical surface data] Sixth surface		
k = 1.00000 A4 = −8.44128E−07, A6 = 9.38473E−10, A8 = −2.90073E−12, A10 = 6.84753E−15		
Eighteenth surface		
k = 1.00000 A4 = 1.66834E−05, A6 = 1.07396E−08, A8 = 3.36895E−11, A10 = −1.25245E−13		
[Variable distance data]		
	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1562
D0	∞	311.54
D12	10.848	2.392
D20	2.500	10.956
D28	1.000	1.000
[lens group data]		
group	starting surface	focal length
G1	1	78.05
G2	13	49.80
G3	21	−88.77

[Conditional Expression Corresponding Value]	
Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.769
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.509
Conditional Expression (4)	f/f1 = 0.661
Conditional Expression (5)	f/f2 = 1.036
Conditional Expression (6)	f1/f2 = 1.567
Conditional Expression (7)	f1/(−f3) = 0.879
Conditional Expression (8)	fF/fR = 0.877
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.898
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = 0.827$
Conditional Expression (11)	FNO × (f1/f) = 2.805
Conditional Expression (12)	2ω = 45.6

FIG. **4**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 2nd example. FIG. **4**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 2nd example. The various aberration graphs demonstrate that the optical system according to the 2nd example has excellent image forming performance in which various aberrations are corrected favorably.

3rd Example

The 3rd example will be described using FIGS. **5** and **6** and Table 3. FIG. **5** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 3rd example of the present embodiment . . . . The optical system LS(**3**) according to the 3rd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** that is biconvex, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 3 below lists data values regarding the optical system according to the 3rd example. Note that the 6th surface and the 14th surface are virtual surfaces.

TABLE 3

[General Data]	
f	51.60
FNO	1.86
ω	23.0
Y	21.70
TL	95.000
BF	13.826
BFa	13.291

[Lens Data]

Surface Number	R	D	nd	νd
1	−43.62202	1.800	1.95375	32.3
2	62.41759	5.000	1.84666	23.8
3	−281.93425	0.654		
4	−167.37782	5.500	1.59319	67.9
5	−40.10469	0.476		
6	∞	0.000		
7*	39.95627	0.100	1.56093	36.6
8	41.35117	6.000	1.83481	42.7
9	−308.32218	0.200		
10	32.49687	8.500	1.49782	82.6
11	−50.34522	1.500	1.58144	41.0
12	20.84633	5.400		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.100		
15	−19.87542	1.100	1.67270	32.2
16	−102.49215	0.200		
17	349.06334	4.800	1.75500	52.3
18	−33.68733	0.100	1.56093	36.6
19*	−30.20400	1.700		
20	−294.17915	6.900	1.49782	82.6
21	−26.73936	D21		

TABLE 3-continued

		(Variable)		
22	−208.87897	3.500	2.00069	25.5
23	−59.64897	4.172		
24	−45.02223	2.000	1.62004	36.4
25	−133.33333	2.419		
26	−45.00000	2.000	1.62004	36.4
27	224.57692	11.236		
28	∞	1.600	1.51680	64.1
29	∞	D29 (Variable)		

[Aspherical surface data]

Seventh surface

k = 1.00000
A4 = −1.17140E−06, A6 = 4.04242E−10,
A8 = 0.00000E+00, A10 = 0.00000E+00

Nineteenth surface

k = 1.00000
A4 = 1.13379E−05, A6 = 1.62636E−08,
A8 = 0.00000E+00, A10 = 0.00000E+00

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1591
D0	∞	305.00
D13	11.043	2.821
D21	3.000	11.223
D29	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	82.69
G2	14	49.27
G3	22	−80.88

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.258
Conditional Expression (2)	(−G1R1)/f = 0.845
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.528
Conditional Expression (4)	f/f1 = 0.624
Conditional Expression (5)	f/f2 = 1.047
Conditional Expression (6)	f1/f2 = 1.678
Conditional Expression (7)	f1/(−f3) = 1.022
Conditional Expression (8)	fF/fR = 0.923
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 1.366
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.881$
Conditional Expression (11)	FNO × (f1/f) = 2.983
Conditional Expression (12)	2ω = 46.0

FIG. **6**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 3rd example. FIG. **6**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 3rd example. The various aberration graphs demonstrate that the optical system according to the 3rd example has excellent image forming performance in which various aberrations are corrected favorably.

4th Example

The 4th example will be described using FIGS. **7** and **8** and Table 4. FIG. **7** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 4th example of the present embodiment. The optical system LS(**4**) according to the 4th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 4 below lists data values regarding the optical system according to the 4th example. Note that the 13th surface is a virtual surface.

TABLE 4

[General Data]

f	51.60
FNO	1.85
ω	23.0
Y	21.70
TL	93.423
BF	13.099
BFa	12.554

[Lens Data]

Surface Number	R	D	nd	νd
1	−49.34582	1.800	1.64769	33.7
2	46.34338	4.852	1.94595	18.0
3	88.17135	2.830		
4	−385.68443	6.805	1.75500	52.3
5	−55.81519	0.100		
6*	32.37146	0.300	1.56093	36.6
7	34.78660	6.291	1.75500	52.3
8	3421.80810	0.200		
9	34.21341	7.021	1.59319	67.9
10	−76.80721	1.500	1.64769	33.7
11	20.90542	5.045		

TABLE 4-continued

12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.99823	1.100	1.64769	33.7
15	814.45031	0.200		
16	93.44777	5.100	1.80400	46.6
17	−40.16052	0.152	1.56093	36.6
18*	−34.60672	3.204		
19	−128.30142	6.400	1.49782	82.6
20	−26.31276	D20 (Variable)		
21	−78.26552	2.798	1.94595	18.0
22	−44.00653	2.232		
23	−46.73961	2.000	1.64769	33.7
24	−150.55235	2.958		
25	−40.00000	1.900	1.64769	33.7
26	−179.87126	10.500		
27	∞	1.600	1.51680	64.1
28	∞	D28 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −1.82369E−06, A6 = −1.73726E−09,
A8 = 2.00735E−12, A10 = −4.32700E−15

Eighteenth surface

k = 1.00000
A4 = 1.61711E−05, A6 = 1.10899E−08,
A8 = 3.81964E−11, A10 = −1.19949E−13

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1563
D0	∞	306.58
D12	10.336	2.398
D20	2.500	10.438
D28	0.999	0.999

[lens group data]

group	starting surface	focal length
G1	1	73.48
G2	13	47.81
G3	21	−81.77

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.845
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.528
Conditional Expression (4)	f/f1 = 0.624
Conditional Expression (5)	f/f2 = 1.047
Conditional Expression (6)	f1/f2 = 1.678
Conditional Expression (7)	f1/(−f3) = 1.022
Conditional Expression (8)	fF/fR = 0.923
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 1.366
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.881$
Conditional Expression (11)	FNO × (f1/f) = 2.983
Conditional Expression (12)	2ω = 46.0

FIG. 8A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 4th example. FIG. 8B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 4th example. The various aberration graphs demonstrate that the optical system according to the 4th example has excellent image forming performance in which various aberrations are corrected favorably.

5th Example

The 5th example will be described using FIGS. **9** and **10** and Table 5. FIG. **9** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 5th example of the present embodiment. The optical system LS(**5**) according to the 5th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 5 below lists data values regarding the optical system according to the 5th example. Note that the 13th surface is a virtual surface.

TABLE 5

[General Data]

f	51.61
FNO	1.85
ω	22.8
Y	21.70
TL	94.298
BF	13.104
BFa	12.558

TABLE 5-continued

[Lens Data]

Surface Number	R	D	nd	νd
1	−55.81981	2.351	1.67270	32.2
2	40.92718	3.030	1.94595	18.0
3	73.81686	2.866		
4	−2179.29960	8.923	1.75500	52.3
5	−55.86755	0.100		
6*	31.91227	0.300	1.56093	36.6
7	33.62812	5.941	1.80400	46.6
8	179.47342	0.200		
9	31.36834			
10	−117.41333	1.500	1.67270	32.2
11	20.83074	5.078		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.88176	1.100	1.64769	33.7
15	−464.00395	0.306		
16*	107.59212	4.886	1.77377	47.2
17*	−34.57866	3.604		
18	−87.29087	6.386	1.49782	82.6
19	−24.79412	D19 (Variable)		
20	−168.93770	2.949	1.94595	18.0
21	−62.61109	1.900	1.62004	36.4
22	−408.98106	2.897		
23	−49.70122	1.900	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −9.25285E−07, A6 = −2.44172E−10,
A8 = −5.83429E−13, A10 = 9.84913E−16

Sixteenth surface

k = 1.00000
A4 = 2.83184E−06, A6 = 1.30771E−08,
A8 = 3.97727E−11, A10 = 2.50432E−13

Seventeenth surface

k = 1.00000
A4 = 1.51803E−05, A6 = 3.07472E−08,
A8 = −2.44486E−11, A10 = 5.97193E−13

[Variable distance data]

	Upon focusing on infinity f = 51.61	Upon focusing on a short-distance object β = −0.1566
D0	∞	305.70
D12	10.295	2.359
D19	4.868	12.804
D26	1.004	1.004

[lens group data]

group	starting surface	focal length
G1	1	74.25
G2	13	47.70
G3	20	−83.87

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 1.082
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.752
Conditional Expression (4)	f/f1 = 0.695
Conditional Expression (5)	f/f2 = 1.082
Conditional Expression (6)	f1/f2 = 1.556

TABLE 5-continued

Conditional Expression (7)	f1/(−f3) = 0.885
Conditional Expression (8)	fF/fR = 0.805
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.139
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = 0.883$
Conditional Expression (11)	FNO × (f1/f) = 2.668
Conditional Expression (12)	2ω = 45.6

FIG. **10**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 5th example. FIG. **10**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 5th example. The various aberration graphs demonstrate that the optical system according to the 5th example has excellent image forming performance in which various aberrations are corrected favorably.

6th Example

The 6th example will be described using FIGS. **11** and **12** and Table 6. FIG. **11** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 6th example of the present embodiment. The optical system LS(**6**) according to the 6th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 6 below lists data values regarding the optical system according to the 6th example. Note that the 13th surface is a virtual surface.

TABLE 6

[General Data]

f	51.61
FNO	1.85
ω	22.7
Y	21.70
TL	94.879
BF	13.103
BFa	12.558

[Lens Data]

Surface Number	R	D	nd	νd
1	−59.41700	3.521	1.67270	32.2
2	39.22460	3.028	1.94595	18.0
3	67.63630	2.963		
4	3381.87660	8.656	1.75500	52.3
5	−56.77477	0.200		
6*	32.10469	0.100	1.56093	36.6
7	32.39825	5.977	1.77250	49.6
8	150.72327	0.200		
9	29.50426	7.110	1.59319	67.9
10	−150.81319	1.500	1.64769	33.7
11	20.38598	5.145		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.88655	1.100	1.64769	33.7
15	11241.53800	0.200		
16*	115.09348	4.892	1.77377	47.2
17*	−33.45446	3.784		
18	−154.31773	6.454		
19	−26.83890	D19 (Variable)		
20	−99.15080	2.941	1.94595	18.0
21	−50.06903	1.900	1.60342	38.0
22	−157.80139	2.610		
23	−45.69693	10.500		
24	−615.80945	1.600	1.51680	64.1
25	∞			
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −7.49375E−07, A6 = −1.64453E−10,
A8 = −6.23627E−13, A10 = 1.37024E−15

Sixteenth surface

k = 1.00000
A4 = 4.71706E−08, A6 = 1.49836E−08,
A8 = 4.37655E−13, A10 = 2.84793E−13

Seventeenth surface

k = 1.00000
A4 = 1.11172E−05, A6 = 3.11358E−08,
A8 = −9.41425E−11, A10 = 7.16057E−13

[Variable distance data]

	Upon focusing on infinity f = 51.61	Upon focusing on a short-distance object β = −0.1566
D0	∞	305.12
D12	10.330	2.348
D19	4.563	12.545
D26	1.003	1.005

TABLE 6-continued

[lens group data]

group	starting surface	focal length
G1	1	71.11
G2	13	47.97
G3	20	−83.32

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 1.151
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.836
Conditional Expression (4)	f/f1 = 0.726
Conditional Expression (5)	f/f2 = 1.076
Conditional Expression (6)	f1/f2 = 1.482
Conditional Expression (7)	f1/(−f3) = 0.853
Conditional Expression (8)	fF/fR = 0.731
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.065
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.886$
Conditional Expression (11)	FNO × (f1/f) = 2.555
Conditional Expression (12)	2ω = 45.4

FIG. **12**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 6th example. FIG. **12**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 6th example. The various aberration graphs demonstrate that the optical system according to the 6th example has excellent image forming performance in which various aberrations are corrected favorably.

7th Example

The 7th example will be described using FIGS. **13** and **14** and Table 7. FIG. **13** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 7th example of the present embodiment. The optical system LS(**7**) according to the 7th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G3 comprises a cemented lens consisting of a positive lens L31 having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L32 having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L33 having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 7 below lists data values regarding the optical system according to the 7th example. Note that the 13th surface is a virtual surface.

TABLE 7

[General Data]

f	51.60
FNO	1.85
ω	23.0
Y	21.70
TL	92.606
BF	13.099
BFa	12.554

[Lens Data]

Surface Number	R	D	nd	νd
1	−45.97401	3.464	1.67270	32.2
2	49.61070	3.386	1.94595	18.0
3	104.71966	2.977		
4	−171.07801	4.990	1.72916	54.6
5	−45.04067	0.200		
6*	34.58722	0.100	1.56093	36.6
7	35.08925	6.046	1.80400	46.6
8	271.36284	0.200		
9	30.75373	7.301	1.59319	67.9
10	−109.57751	1.500	1.64769	33.7
11	21.09749	5.107		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.42611	1.100	1.64769	33.7
15	1293.83890	0.200		
16*	96.25206	5.000	1.77377	47.2
17*	−33.63182	2.984		
18	−84.68095	6.400	1.49782	82.6
19	−24.24361	D19 (Variable)		
20	−198.33414	2.923	1.94595	18.0
21	−66.60448	2.000	1.64769	33.7
22	−1255.72680	2.962		
23	−53.07631	2.000	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −9.44039E−07, A6 = −7.11276E−10,
A8 = 1.77477E−12, A10 = −1.49090E−15

Sixteenth surface

k = 1.00000
A4 = −7.09863E−07, A6 = 1.39281E−08,
A8 = −7.11118E−11, A10 = −9.85203E−14

Seventeenth surface

k = 1.00000
A4 = 1.29000E−05, A6 = 1.77000E−08,
A8 = 4.64016E−11, A10 = −4.30856E−13

TABLE 7-continued

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1564
D0	∞	307.39
D12	10.322	2.393
D19	5.645	13.574
D26	0.999	0.999

[lens group data]

group	starting surface	focal length
G1	1	73.64
G2	13	48.40
G3	20	−83.16

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.891
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.624
Conditional Expression (4)	f/f1 = 0.701
Conditional Expression (5)	f/f2 = 1.066
Conditional Expression (6)	f1/f2 = 1.522
Conditional Expression (7)	f1/(−f3) = 0.886
Conditional Expression (8)	fF/fR = 0.769
Conditional Expression (9)	(G1R2 + G1R1)/ (G1R2 − G1R1) = 0.390
Conditional Expression (10)	$\{1-(\beta2)^2\}\times(\beta3)^2 = 0.883$
Conditional Expression (11)	FNO × (f1/f) = 2.646
Conditional Expression (12)	2ω = 46.0

FIG. 14A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 7th example. FIG. 14B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 7th example. The various aberration graphs demonstrate that the optical system according to the 7th example has excellent image forming performance in which various aberrations are corrected favorably.

8th Example

The 8th example will be described using FIGS. 15 and 16 and Table 8. FIG. 15 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 8th example of the present embodiment. The optical system LS(8) according to the 8th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a cemented lens consisting of a first negative lens L11 that is biconcave and a first positive lens L12 having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L13 having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L14 having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L15 that is biconvex and a second negative lens

L16 that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L14 is an aspherical surface.

The second lens group G2 comprises a negative lens L21 that is biconcave, a first positive lens L22 that is biconvex, and a second positive lens L23 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L22 is an aspherical surface.

The third lens group G3 comprises a cemented lens consisting of a positive lens L31 having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L32 having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L33 having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 8 below lists data values regarding the optical system according to the 8th example. Note that the 13th surface is a virtual surface.

TABLE 8

[General Data]

f	51.60
FNO	1.85
ω	22.9
Y	21.70
TL	93.035
BF	13.101
BFa	12.556

[Lens Data]

Surface Number	R	D	nd	νd
1	−49.74101			
2	51.83840	3.342	1.94595	18.0
3	105.00000	2.890		
4	−198.79923	5.698	1.72916	54.6
5	−48.74109	0.216		
6*	39.85460	0.100	1.56093	36.6
7	39.94369	5.459	1.80400	46.6
8	306.55979	0.200		
9	27.39919	7.979	1.59319	67.9
10	−244.36823	1.500	1.64769	33.7
11	21.09582	5.098		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.37434	1.100	1.64769	33.7
15	630.74141	0.200		
16*	88.88240	5.000	1.77377	47.2
17*	−34.54296	2.466		
18	−91.09112	6.400	1.49782	82.6
19	−24.26835	D19 (Variable)		
20	−173.73017	2.915	1.94595	18.0
21	−63.36086	2.000	1.64769	33.7
22	−410.38800	2.872		
23	−49.55593	1.900	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26		

TABLE 8-continued

(Variable)

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −1.98971E−07, A6 = −9.88462E−10,
A8 = 4.89667E−12, A10 = −4.46361E−15

Sixteenth surface

k = 1.00000
A4 = −1.30154E−06, A6 = 1.97109E−08,
A8 = −1.12019E−10, A10 = −2.74309E−14

Seventeenth surface

k = 1.00000
A4 = 1.29000E−05, A6 = 1.77000E−08,
A8 = 4.40194E−11, A10 = −4.63161E−13

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1566
D0	∞	306.96
D12	10.321	2.394
D19	6.070	13.997
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	73.37
G2	13	48.59
G3	20	−81.56

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.964
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.678
Conditional Expression (4)	f/f1 = 0.703
Conditional Expression (5)	f/f2 = 1.062
Conditional Expression (6)	f1/f2 = 1.510
Conditional Expression (7)	f1/(−f3) = 0.900
Conditional Expression (8)	fF/fR = 0.747
Conditional Expression (9)	(G1R2 + G1R1)/ (G1R2 − G1R1) = 0.357
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.885$
Conditional Expression (11)	FNO × (f1/f) = 2.636
Conditional Expression (12)	2ω = 45.8

FIG. 16A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 8th example. FIG. 16B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 8th example. The various aberration graphs demonstrate that the optical system according to the 8th example has excellent image forming performance in which various aberrations are corrected favorably.

9th Example

The 9th example will be described using FIGS. 17 and 18 and Table 9. FIG. 17 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 9th example of the present embodiment. The optical system LS(9) according to the 9th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 9 below lists data values regarding the optical system according to the 9th example. Note that the 13th surface is a virtual surface.

TABLE 9

[General Data]

f	51.60
FNO	1.85
ω	22.9
Y	21.70
TL	92.330
BF	13.100
BFa	12.554

[Lens Data]

Surface Number	R	D	nd	νd
1	−48.06457	2.000	1.67270	32.2
2	50.03333	2.861	1.94595	18.0
3	105.00000	2.805		
4	−226.31231	6.827	1.72916	54.6
5	−47.98013	0.644		
6*	36.64910	0.100	1.56093	36.6
7	36.85687	5.622	1.80400	46.6
8	217.92780	0.200		
9	28.49361	7.332	1.59319	67.9
10	−161.37986	1.500	1.64769	33.7
11	20.99038	5.164		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.41799	1.100	1.64769	33.7
15	998.77224	0.200		
16*	85.12299	5.000	1.77377	47.2
17*	−35.29338	2.485		
18	−73.80381	6.400	1.49782	82.6
19	−23.23519	D19 (Variable)		
20	−177.75440	2.927	1.94595	18.0
21	−63.69645	1.900	1.64769	33.7
22	−482.01125	2.887		
23	−50.20764	1.900	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface
κ = 1.00000
A4 = −4.74106E−07, A6 = −3.40824E−10, A8 = 2.15394E−12, A10 = −1.54492E−15
Sixteenth surface
κ = 1.00000
A4 = −1.95205E−07, A6 = 1.94342E−08, A8 = −8.61846E−11, A10 = −2.07763E−13

TABLE 9-continued

Seventeenth surface		
$\kappa = 1.00000$		
A4 = 1.47643E−05, A6 = 2.08671E−08, A8 = 8.44852E−11, A10 = −6.93210E−13		

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object $\beta = -0.1565$
D0	∞	307.67
D12	10.320	2.409
D19	6.356	14.267
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	73.63
G2	13	48.76
G3	20	−81.76

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.964
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.676
Conditional Expression (4)	f/f1 = 0.701
Conditional Expression (5)	f/f2 = 1.058
Conditional Expression (6)	f1/f2 = 1.510
Conditional Expression (7)	f1/(−f3) = 0.900
Conditional Expression (8)	fF/fR = 0.748
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.357
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.888$
Conditional Expression (11)	FNO × (f1/f) = 2.645
Conditional Expression (12)	2ω = 45.8

FIG. **18**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 9th example. FIG. **18**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 9th example. The various aberration graphs demonstrate that the optical system according to the 9th example has excellent image forming performance in which various aberrations are corrected favorably.

10th Example

The 10th example will be described using FIGS. **19** and **20** and Table 10. FIG. **19** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 10th example of the present embodiment. The optical system LS(**10**) according to the 10th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 10 below lists data values regarding the optical system according to the 10th example. Note that the 13th surface is a virtual surface.

TABLE 10

[General Data]	
f	51.61
FNO	1.85
ω	23.0
Y	21.70
TL	92.630
BF	13.111
BFa	12.566

[Lens Data]

Surface Number	R	D	nd	vd
1	−47.48420	2.000	1.67270	32.2
2	49.34200	2.900	1.94595	18.0
3	105.06869	2.850		
4	−214.61709	6.650	1.72916	54.6
5	−47.45376	0.640		
6*	36.92032	0.100	1.56093	36.6
7	37.08029	5.650	1.80400	46.6
8	227.67817	0.250		
9	28.81243	7.400	1.59319	67.9
10	−141.32000	1.500	1.64769	33.7
11	21.19231	5.130		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−23.47056	1.100	1.64769	33.7
15	682.91466	0.200		
16*	83.29512	5.000	1.77377	47.2
17*	−35.02672	2.570		
18	−71.96528	6.400	1.49782	82.6
19	−23.20263	D19 (Variable)		
20	−192.79576	2.950	1.94595	18.0
21	−65.62300	2.000	1.64769	33.7
22	−664.53730	2.909		
23	−51.20031	1.900	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface
κ = 1.00000
A4 = −4.82693E−07, A6 = −2.32147E−10, A8 = 1.82978E−12, A10 = −1.19713E−15
Sixteenth surface
κ = 1.00000
A4 = −2.77465E−07, A6 = 1.84476E−08, A8 = −7.60811E−11, A10 = −2.05509E−13
Seventeenth surface
κ = 1.00000
A4 = 1.46947E−05, A6 = 2.13572E−08, A8 = 8.25934E−11, A10 = −6.58549E−13

[Variable distance data]

	Upon focusing on infinity f = 51.61	Upon focusing on a short-distance object β = −0.1568
D0	∞	307.37
D12	10.320	2.403
D19	6.400	14.317
D26	1.011	1.011

[lens group data]

group	starting surface	focal length
G1	1	74.30
G2	13	48.80
G3	20	−82.85

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.920
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.639

TABLE 10-continued

Conditional Expression (4)	f/f1 = 0.695
Conditional Expression (5)	f/f2 = 1.058
Conditional Expression (6)	f1/f2 = 1.523
Conditional Expression (7)	f1/(−f3) = 0.897
Conditional Expression (8)	fF/fR = 0.768
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.377
Conditional Expression (10)	$\{1-(\beta2)^2\} \times (\beta3)^2 = 0.890$
Conditional Expression (11)	FNO × (f1/f) = 2.670
Conditional Expression (12)	2ω = 46.0

FIG. **20**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 10th example. FIG. **20**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 10th example. The various aberration graphs demonstrate that the optical system according to the 10th example has excellent image forming performance in which various aberrations are corrected favorably.

11th Example

The 11th example will be described using FIGS. **21** and **22** and Table 11. FIG. **21** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 11th example of the present embodiment. The optical system LS(**11**) according to the 11th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 11 below lists data values regarding the optical system according to the 11th example. Note that the 14th surface is a virtual surface.

TABLE 11

[General Data]

f	37.63
FNO	1.85
ω	30.0
Y	21.70
TL	110.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	vd
1	−662.83160	3.000	1.80920	33.6
2	33.87219	9.404		
3	−109.33916	3.000	1.48749	70.4
4	89.77072	4.000	1.94595	18.0
5	317.57072	1.945		
6	44.26915	8.500	1.48749	70.4
7	−112.47821	3.972		
8*	41.20576	6.500	1.80400	46.6
9	−255.27183	0.200		
10	26.75656	9.000	1.59319	67.9
11	−57.15784	1.500	1.67270	32.2
12	17.14008	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.000		

TABLE 11-continued

15	−21.57444	1.000	1.67270	32.2
16	−1291.14570	0.200		
17*	157.44017	4.500	1.77377	47.2
18*	−44.84339	0.200		
19	155.77289	9.000	1.59319	67.9
20	−25.32306	D20 (Variable)		
21	71.98835	3.000	1.94595	18.0
22	81.46254	6.736		
23*	−41.56282	1.500	1.64769	33.7
24	−168.89768	7.000		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Eighth surface
κ = 1.00000
A4 = −1.90145E−06, A6 = −9.52591E−10, A8 = −1.08708E−12, A10 = −6.77034E−16
Seventeenth surface
κ = 1.00000
A4 = 6.23513E−06, A6 = −1.23942E−08, A8 = 3.34827E−11, A10 = −3.01713E−13
Eighteenth surface
κ = 1.00000
A4 = 1.88293E−05, A6 = 1.24857E−08, A8 = 2.84962E−11, A10 = −3.23051E−13
Twenty-third surface
κ = 1.00000
A4 = 5.43854E−06, A6 = −1.52554E−08, A8 = 0.00000E+00, A10 = 0.00000E+00

[Variable distance data]

	Upon focusing on infinity f = 37.63	Upon focusing on a short-distance object β = −0.2078
D0	∞	151.72
D13	11.387	2.404
D20	3.456	12.439
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	58.79
G2	14	43.00
G3	21	−104.59

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.241
Conditional Expression (2)	(−G1R1)/f = 17.613
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 11.275
Conditional Expression (4)	f/f1 = 0.640
Conditional Expression (5)	f/f2 = 0.875
Conditional Expression (6)	f1/f2 = 1.367
Conditional Expression (7)	f1/(−f3) = 0.562
Conditional Expression (8)	fF/fR = 0.945
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.903
Conditional Expression (10)	$\{1 - (\beta2)^2\} \times (\beta3)^2 = 0.728$
Conditional Expression (11)	FNO × (f1/f) = 2.893
Conditional Expression (12)	2ω = 60.0

FIG. **22**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 11th example. FIG. **22**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 11th example. The various aberration graphs demonstrate that the optical system according to the 11th example has excellent image forming performance in which various aberrations are corrected favorably.

12th Example

The 12th example will be described using FIGS. **23** and **24** and Table 12. FIG. **23** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 12th example of the present embodiment. The optical system LS(**12**) according to the 12th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 12 below lists data values regarding the optical system according to the 12th example. Note that the 14th surface is a virtual surface.

TABLE 12

[General Data]

f	37.70
FNO	1.88
ω	30.0
Y	21.70
TL	110.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−3112.32120	3.000	1.73282	32.6
2	32.68764	8.690		
3	−440.00413	3.000	1.48749	70.4
4	57.93171	4.000	1.94595	18.0
5	108.74454	3.168		
6	42.60783	8.500	1.50267	62.2
7	−141.78756	3.866		
8*	45.06258	6.500	1.80400	46.6
9	−210.82291	0.200		
10	36.02017	9.000	1.59319	67.9
11	−45.79266	1.500	1.67270	32.2
12	22.46589	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.000		
15	−22.15003	1.000	1.67270	32.2
16	−98.33346	0.318		
17*	−130.89892	2.500	1.77377	47.2
18*	−43.35291	1.224		
19	101.79100	5.500	1.59319	67.9
20	−53.62571	0.100		
21	−81.82793	6.000	1.59319	67.9
22	−25.48031	D22 (Variable)		
23	−75.16977	3.000	1.94595	18.0
24	−63.16701	8.776		
25*	−25.51533	1.500	1.64769	33.7
26	−99.50792	7.000		
27	∞	1.600	1.51680	64.1
28	∞	D28 (Variable)		

[Aspherical surface data]

Eighth surface
κ = 1.00000
A6 = −1.62936E−06, A6 = −1.61898E−09, A8 = 3.72851E−12, A10 = −6.56781E−15
Seventeenth surface
κ = 1.00000
A4 = 3.15178E−05, A6 = 1.77790E−07, A8 = −3.27517E−10, A10 = −1.26227E−12
Eighteenth surface
κ = 1.00000
A4 = 4.17433E−05, A6 = 1.91618E−07, A8 = 1.40927E−10, A10 = −2.86119E−12

TABLE 12-continued

Twenty-fifth surface
κ = 1.00000
A4 = 1.10584E−05, A6 = −1.56481E−10, A8 = 0.00000E+00, A10 = 0.00000E+00

[Variable distance data]

	Upon focusing on infinity f = 37.70	Upon focusing on a short-distance object β = −0.1179
D0	∞	290.00
D13	6.605	2.441
D22	4.053	8.217
D28	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	63.38
G2	14	39.22
G3	23	−62.57

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.240
Conditional Expression (2)	(−G1R1)/f = 82.547
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 49.101
Conditional Expression (4)	f/f1 = 0.595
Conditional Expression (5)	f/f2 = 0.961
Conditional Expression (6)	f1/f2 = 1.616
Conditional Expression (7)	f1/(−f3) = 1.013
Conditional Expression (8)	fF/fR = 0.873
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.979
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2$ = 0. 994
Conditional Expression (11)	FNO × (f1/f) = 3.160
Conditional Expression (12)	2ω = 60.0

FIG. **24**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 12th example. FIG. **24**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 12th example. The various aberration graphs demonstrate that the optical system according to the 12th example has excellent image forming performance in which various aberrations are corrected favorably.

13th Example

The 13th example will be described using FIGS. **25** and **26** and Table 13. FIG. **25** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 13th example of the present embodiment. The optical system LS(**13**) according to the 13th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 13 below lists data values regarding the optical system according to the 13th example. Note that the 14th surface is a virtual surface.

TABLE 13

[General Data]

f	36.52
FNO	1.85
ω	30.6
Y	21.70
TL	100.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	vd
1	−344.23276	3.000	1.71736	29.6
2	31.47663	8.864		
3	−5197.94500	3.000	1.48749	70.3
4	59.50193	4.000	1.94595	18.0
5	141.00357	0.152		
6	49.20783	7.500	1.60300	65.4
7	−563.87665	4.981		
8*	39.11480	6.000	1.77250	49.6
9	−139.68211	0.427		
10	28.58681	8.000	1.59319	67.9
11	−50.06370	1.500	1.67270	32.2
12	19.18437	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.000		
15	−22.50724	1.000	1.67270	32.2
16	−81.31951	0.549		
17*	−74.31824	3.000	1.77377	47.2
18	−35.67165	0.203		
19	180.93759	5.000	1.59319	67.9
20	−43.85092	0.500		
21	−132.62507	6.000	1.59319	67.9
22	−29.07561	D22 (Variable)		
23	317.64282	3.000	1.94595	18.0
24	314.90339	6.932		
25*	−26.84153	1.500	1.64769	33.7
26	−77.55848	7.000		
27	∞	1.600	1.51680	64.1
28	∞	D28 (Variable)		

[Aspherical surface data]

Eighth surface
κ = 1.00000
A4 = −1.59558E−06, A6 = −1.61180E−09, A8 = 2.67206E−12, A10 = −4.02129E−15
Seventeenth surface
κ = 1.00000
A4 = −1.62012E−05, A6 = −2.42502E−08, A8 = 1.25145E−10, A10 = −1.02694E−12
Twenty-fifth surface
κ = 1.00000
A4 = 7.25982E−06, A6 = 1.79235E−08, A8 = −4.70327E−11, A10 = 2.68072E−14

[Variable distance data]

	Upon focusing on infinity f = 36.52	Upon focusing on a short-distance object β = −0.1131
D0	∞	290.00
D13	6.346	1.987
D22	0.549	4.907
D28	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	52.27
G2	14	37.19
G3	23	−64.36

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.248
Conditional Expression (2)	(−G1R1)/f = 9.427

TABLE 13-continued

Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 6.586
Conditional Expression (4)	f/f1 = 0.699
Conditional Expression (5)	f/f2 = 0.982
Conditional Expression (6)	f1/f2 = 1.406
Conditional Expression (7)	f1/(−f3) = 0.812
Conditional Expression (8)	fF/fR = 0.724
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.832
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = 0.853$
Conditional Expression (11)	FNO × (f1/f) = 2.645
Conditional Expression (12)	2ω = 61.2

FIG. **26**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 13th example. FIG. **26**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 13th example. The various aberration graphs demonstrate that the optical system according to the 13th example has excellent image forming performance in which various aberrations are corrected favorably.

14th Example

The 14th example will be described using FIGS. **27** and **28** and Table 14. FIG. **27** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 14th example of the present embodiment. The optical system LS(**14**) according to the 14th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 14 below lists data values regarding the optical system according to the 14th example. Note that the 14th surface is a virtual surface.

TABLE 14

[General Data]

f	36.50
FNO	1.85
ω	30.7
Y	21.70
TL	100.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−328.51209	3.000	1.71736	29.6
2	30.62735	8.724		
3	862.45645	3.000	1.48749	70.3
4	57.42336	4.000	1.94595	18.0
5	141.63170	0.100		
6	44.98135	7.500	1.60300	65.4
7	5539.31740	5.241		
8*	41.34810	6.000	1.77250	49.6
9	−119.73719	0.200		
10	28.47480	8.000	1.59319	67.9

TABLE 14-continued

11	−45.24565	1.500	1.67270	32.2
12	19.20206	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.000		
15	−23.51305	1.000	1.67270	32.2
16	−129.15388	0.457		
17*	−103.44705	3.000	1.77377	47.2
18*	−39.20704	0.417		
19	131.40567	5.000	1.59319	67.9
20	−48.12075	0.500		
21	−100.00000	6.000	1.59319	67.9
22	−26.83541	D22 (Variable)		
23	102.68371	3.000	1.94595	18.0
24	106.30512	6.996		
25*	−28.73049	1.500	1.64769	33.7
26	−98.04242	7.000		
27	∞	1.600	1.51680	64.1
28	∞	D28 (Variable)		

[Aspherical surface data]

Eighth surface
κ = 1.00000
A4 = −1.74572E−06, A6 = −1.86902E−09, A8 = 3.70243E−12, A10 = −5.65794E−15
Seventeenth surface
κ = 1.00000
A4 = −4.49752E−06, A6 = −4.35264E−08, A8 = 1.70129E−10, A10 = −7.71012E−13
Eighteenth surface
κ = 1.00000
A4 = 1.06552E−05, A6 = 0.00000E+00, A8 = 0.00000E+00, A10 = 0.00000E+00
Twenty-fifth surface
κ = 1.00000
A4 = 6.97711E−06, A6 = 8.30426E−09, A8 = −3.04728E−11, A10 = −2.65514E−15

[Variable distance data]

	Upon focusing on infinity f = 36.50	Upon focusing on a short-distance object β = −0.1131
D0	∞	290.00
D13	6.366	1.830
D22	0.500	5.036
D28	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	52.56
G2	14	38.05
G3	23	−66.26

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.248
Conditional Expression (2)	(−G1R1)/f = 9.000
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 6.250
Conditional Expression (4)	f/f1 = 0.694
Conditional Expression (5)	f/f2 = 0.959
Conditional Expression (6)	f1/f2 = 1.381
Conditional Expression (7)	f1/(−f3) = 0.793
Conditional Expression (8)	fF/fR = 0.729
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1)
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = -0.829$
Conditional Expression (11)	FNO × (f1/f) = 2.664
Conditional Expression (12)	2ω = 61.4

FIG. 28A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 14th example. FIG. 28B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 14th example. The various aberration graphs demonstrate that the optical system according to the 14th example has excellent image forming performance in which various aberrations are corrected favorably.

15th Example

The 15th example will be described using FIGS. 29 and 30 and Table 15. FIG. 29 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 15th example of the present embodiment. The optical system LS(15) according to the 15th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a first negative lens L11 that is biconcave, a cemented lens consisting of a second negative lens L12 having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L13 having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L14 that is biconvex, a third positive lens L15 that is biconvex, a cemented lens consisting of a fourth positive lens L16 that is biconvex and a third negative lens L17 that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L15 is an aspherical surface.

The second lens group G2 comprises a negative lens L21 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L22 having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L23 that is biconvex, and a third positive lens L24 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L22 is an aspherical surface.

The third lens group G3 comprises a negative lens L31 having a meniscus shape whose concave surface is pointed toward the object. The lens surface on the object side of the negative lens L31 is an aspherical surface. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 15 below lists data values regarding the optical system according to the 15th example. Note that the 14th surface is a virtual surface.

TABLE 15

[General Data]

f	36.50
FNO	1.87
ω	30.7
Y	21.70
TL	100.000
BF	9.600
BFa	9.054

[Lens Data]

Surface Number	R	D	nd	νd
1	−188.20085	3.000	1.71736	29.6
2	30.66496	8.404		
3	547.03690	3.000	1.48749	70.3
4	62.69373	4.000	1.94595	18.0
5	190.11798	0.100		
6	45.62385	7.500	1.60300	65.4
7	−115579.46000	5.673		
8*	44.63892	6.000	1.77250	49.6
9	−102.19551	0.200		
10	28.17341	8.000	1.59319	67.9
11	−42.44281	1.500	1.67270	32.2
12	19.02911	5.399		
13	∞	D13 (Variable)		(Aperture
14	∞	3.000		Stop S)
15	−23.61092	1.000	1.67270	32.2
16	−109.82047	0.899		
17*	−60.75679	3.000	1.77377	47.2
18*	−33.74626	0.200		
19	105.85192	5.000	1.59319	67.9
20	−52.67684	0.500		
21	−100.00000	6.000	1.59319	67.9
22	−26.83541	D22 (Variable)		
23*	−35.17199	1.500	1.64769	33.7
24	−148.75840	7.000		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

TABLE 15-continued

[Aspherical surface data]

Eighth surface
κ = 1.00000
A4 = −1.59317E−06, A6 = −1.58329E−09, A8 = 3.51477E−12, A10 = −5.52433E−15
Seventeenth surface
κ = 1.00000
A4 = −1.23191E−05, A6 = −4.63629E−08, A8 = 2.30352E−10, A10 = −1.55636E−12
Eighteenth surface
κ = 1.00000
A4 = 3.43104E−06, A6 = 0.00000E+00, A8 = 0.00000E+00, A10 = 0.00000E+00
Twenty-third surface
κ = 1.00000
A4 = 2.07644E−06, A6 = 2.61568E−09, A8 = −1.43218E−11, A10 = −5.83085E−14

[Variable distance data]

	Upon focusing on infinity f = 36.50	Upon focusing on a short-distance object β = −0.1132
D0	8	290.00
D13	6.253	1.764
D22	10.273	14.761
D28	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	52.70
G2	14	38.26
G3	23	−71.49

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.248
Conditional Expression (2)	(−G1R1)/f = 5.156
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 3.571
Conditional Expression (4)	f/f1 = 0.693
Conditional Expression (5)	f/f2 = 0.954
Conditional Expression (6)	f1/f2 = 1.377
Conditional Expression (7)	f1/(−f3) = 0.737
Conditional Expression (8)	fF/fR = 0.758
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.720
Conditional Expression (10)	$\{1 - (\beta 2)^2\} \times (\beta 3)^2 = 0.828$
Conditional Expression (11)	FNO × (f1/f) = 2.696
Conditional Expression (12)	2ω = 61.4

FIG. **30**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 15th example. FIG. **30**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 15th example. The various aberration graphs demonstrate that the optical system according to the 15th example has excellent image forming performance in which various aberrations are corrected favorably.

16th Example

The 16th example will be described using FIGS. **31** and **32** and Table 16. FIG. **31** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 16th example of the present embodiment. The optical system LS(**16**) according to the 16th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G3 comprises a positive lens L31 having a meniscus shape whose convex surface is pointed toward the object and a negative lens L32 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L32 is an aspherical surface. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 16 below lists data values regarding the optical system according to the 16th example. Note that the 14th surface is a virtual surface.

TABLE 16

[General Data]

f	36.50
FNO	1.86
ω	30.8
Y	21.70
TL	100.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−133.60683	2.000	1.71736	29.6
2	32.54620	8.076		
3	388.71645	2.500	1.48749	70.3
4	65.47753	4.000	1.94595	18.0
5	219.57835	0.100		
6	57.60424	7.000	1.60300	65.4
7	−387.08519	6.523		
8*	44.24367	6.000	1.77250	49.6
9	−104.52830	0.200		
10	31.09490	9.000	1.59319	67.9
11	−42.99037	1.500	1.67270	32.2
12	20.68411	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	∞	3.000		
15	−23.39527	1.000	1.67270	32.2
16	−374.05277	0.224		
17*	89.21164	4.000	1.77377	47.2
18*	−62.00927	1.388		
19	−586.47623	4.500	1.59319	67.9
20	−38.88857	0.500		
21	−100.00000	5.500	1.59319	67.9
22	−29.94109	D22 (Variable)		
23	59.66877	3.000	1.94595	18.0
24	59.44379	6.722		
25*	−32.82899	1.500	1.64769	33.7
26	−177.92654	7.000		
27	∞	1.600	1.51680	63.9
28	∞	D28 (Variable)		

[Aspherical surface data]

Eighth surface

k = 1.00000
A4 = −1.04917E−06, A6 = −1.42831E−09,
A8 = 4.66129E−12, A10 = −6.33796E−15

Seventeenth surface

k = 1.00000
A4 = 1.65960E−05, A6 = 5.96989E−08,
A6 = −6.57382E−11, A10 = 1.19611E−13

TABLE 16-continued

Eighteenth surface

k = 1.00000
A4 = 2.95825E−05, A6 = 7.91633E−08,
A8 = 0.00000E+00, A10 = 0.00000E+00

Twenty-fifth surface

k = 1.00000
A4 = 4.39415E−06, A6 = −1.10198E−08,
A8 = 5.26933E−11, A10 = −1.66739E−13

[Variable distance data]

	Upon focusing on infinity f = 36.50	Upon focusing on a short-distance object β = −0.1137
D0	∞	290.00
D13	6.258	1.649
D22	0.509	5.118
D28	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	53.58
G2	14	39.30
G3	23	−65.49

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.248
Conditional Expression (2)	(−G1R1)/f = 3.660
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 2.494
Conditional Expression (4)	f/f1 = 0.681
Conditional Expression (5)	f/f2 = 0.929
Conditional Expression (6)	f1/f2 = 1.363
Conditional Expression (7)	f1/(−f3) = 0.818
Conditional Expression (8)	fF/fR = 0.714
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.608
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.810$
Conditional Expression (11)	FNO × (f1/f) = 2.734
Conditional Expression (12)	2ω = 61.6

FIG. 32A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 16th example. FIG. 32B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 16th example. The various aberration graphs demonstrate that the optical system according to the 16th example has excellent image forming performance in which various aberrations are corrected favorably.

17th Example

The 17th example will be described using FIGS. 33 and 34 and Table 17. FIG. 33 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 17th example of the present embodiment. The optical system LS(17) according to the 17th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a first negative lens L11 that is biconcave, a first positive lens L12 having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L13 having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L14 that is biconvex, a cemented lens consisting of a third positive lens L15 that is biconvex and a third negative lens L16 that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the image surface I side of the second negative lens L13 is an aspherical surface. The lens surface on the object side of the second positive lens L14 is an aspherical surface.

The second lens group G2 comprises a negative lens L21 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L22 that is biconvex, and a second positive lens L23 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L22 is an aspherical surface.

The third lens group G3 comprises a cemented lens consisting of a positive lens L31 having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L32 having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L33 having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 17 below lists data values regarding the optical system according to the 17th example. Note that the 13th surface is a virtual surface.

TABLE 17

[General Data]

f	36.05
FNO	1.85
ω	31.6
Y	21.70
TL	99.592
BF	13.100
BFa	12.555

[Lens Data]

Surface Number	R	D	nd	νd
1	−500.00000	2.000	1.59270	35.3
2	27.30135	8.716		
3	60.46320	3.840	1.94594	18.0
4	220.11217	9.742		
5	−29.41908	1.659	1.77377	47.2
6*	−33.35969	1.884		
7*	47.17368	10.592	1.76801	49.2
8	−60.97010	0.200		
9	27.06671	6.869	1.59319	67.9
10	−38.40610	1.500	1.69895	30.1
11	22.53254	3.899		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.700		
14	−20.48042	1.100	1.64769	33.7
15	−452.00052	0.648		
16*	80.79578	4.788	1.77377	47.2
17*	−31.41145	0.568		
18	−137.97943	6.400	1.49782	82.6
19	−21.82018	D19 (Variable)		
20	−72.37319	4.704	1.94594	18.0
21	−25.72015	1.900	1.80518	25.4
22	−96.08935	2.660		
23	−34.82473	1.900	1.64769	33.7
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −1.02986E−07, A6 = 4.20882E−09,
A8 = −1.01963E−11, A10 = 2.17897E−14

Seventh surface

k = 1.00000
A4 = −2.57635E−07, A6 = 3.44388E−09,
A8 = −9.56027E−12, A10 = 7.45193E−15

Sixteenth surface

k = 1.00000
A4 = −2.53184E−06, A6 = 4.68537E−08,
A8 = −1.77268E−11, A10 = −7.02284E−13

Seventeenth surface

k = 1.00000
A4 = 2.23902E−05, A6 = 1.94868E−08,
A8 = 4.29642E−10, A10 = −1.80787E−12

[Variable distance data]

	Upon focusing on infinity f = 36.05	Upon focusing on a short-distance object β = −0.1049
D0	∞	314.50
D12	5.722	2.550
D19	2.500	5.667
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	49.49
G2	13	36.41
G3	20	−55.61

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.348
Conditional Expression (2)	(−G1R1)/f = 13.870
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 10.103
Conditional Expression (4)	f/f1 = 0.728
Conditional Expression (5)	f/f2 = 0.990
Conditional Expression (6)	f1/f2 = 1.359
Conditional Expression (7)	f1/(−f3) = 0.890
Conditional Expression (8)	fF/fR = 0.554
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.896
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 1.114$
Conditional Expression (11)	FNO × (f1/f) = 2.534
Conditional Expression (12)	2ω = 63.2

FIG. 34A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 17th example. FIG. 34B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 17th example. The various aberration graphs demonstrate that the optical system according to the 17th example has excellent image forming performance in which various aberrations are corrected favorably.

18th Example

The 18th example will be described using FIGS. **35** and **36** and Table 18. FIG. **35** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 18th example of the present embodiment. The optical system LS(**18**) according to the 18th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** that is biconvex, a second negative lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**14** that is biconvex, a cemented lens consisting of a third positive lens L**15** that is biconvex and a third negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the image surface I side of the second negative lens L**13** is an aspherical surface. The lens surface on the object side of the second positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a first positive lens L**21** that is biconvex, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** that is biconcave, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 18 below lists data values regarding the optical system according to the 18th example.

TABLE 18

[General Data]

f	36.05
FNO	1.86
ω	31.6
Y	21.70
TL	99.539
BF	13.100
BFa	12.555

[Lens Data]

Surface Number	R	D	nd	νd
1	−500.00000	2.000	1.59270	35.3
2	31.30252	8.752		
3	77.05411	4.224	1.94594	18.0
4	−4995.87340	12.332		
5	−34.14226	3.140	1.77377	47.2
6*	−47.59110	0.100		
7*	41.62130	5.898	1.76801	49.2
8	−65.35489	0.294		
9	31.07689	6.046	1.59319	67.9
10	−44.14843	1.500	1.69895	30.1
11	22.96400	3.883		
12	∞	D12 (Variable)		(Aperture Stop S)
13	95.03984	2.062	1.49782	82.6
14	−345.94097	2.289		
15	−19.00516	1.100	1.64769	33.7
16*	−992.59484	1.622		
17*	123.45937	4.722	1.77377	47.2
18	−28.92599	0.200		
19	−129.08817	6.400	1.49782	82.6
20	−21.31763	D20 (Variable)		
21	−134.41671	5.154	1.94594	18.0
22	−26.15911	1.900	1.80518	25.4
23	1225.10730	3.764		
24	−34.85007	1.900	1.64769	33.7
25	∞	10.500		
26	∞	1.600	1.51680	64.1
27	∞	D27 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = 9.02554E−07, A6 = 3.14643E−09,
A8 = −1.89905E−12, A10 = 1.77634E−14

Seventh surface

k = 1.00000
A4 = −1.81054E−07, A6 = 2.54149E−09,
A8 = −7.43973E−12, A10 = 8.48515E−15

Seventeenth surface

k = 1.00000
A4 = 3.23226E−06, A6 = 4.85057E−08,
A8 = 1.37810E−11, A10 = −1.32577E−13

Eighteenth surface

k = 1.00000
A4 = 2.32157E−05, A6 = 3.57378E−08,
A8 = 3.07145E−10, A10 = −6.42283E−13

[Variable distance data]

	Upon focusing on infinity f = 36.05	Upon focusing on a short-distance object β = −0.1053
D0	∞	314.50
D12	4.656	2.000
D20	2.500	5.150
D27	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	58.73
G2	13	33.00
G3	20	−46.85

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.348
Conditional Expression (2)	(−G1R1)/f = 13.870
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 8.514
Conditional Expression (4)	f/f1 = 0.614
Conditional Expression (5)	f/f2 = 1.092
Conditional Expression (6)	f1/f2 = 1.780
Conditional Expression (7)	f1/(−f3) = 1.253
Conditional Expression (8)	fF/fR = 0.765
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.882

TABLE 18-continued

Conditional Expression (10)	$\{1-(\beta2)^2\} \times (\beta3)^2 = 1.369$
Conditional Expression (11)	FNO × (f1/f) = 3.025
Conditional Expression (12)	2ω = 63.2

FIG. **36**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 18th example. FIG. **36**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 18th example. The various aberration graphs demonstrate that the optical system according to the 18th example has excellent image forming performance in which various aberrations are corrected favorably.

19th Example

The 19th example will be described using FIGS. **37** and **38** and Table 19. FIG. **37** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 19th example of the present embodiment. The optical system LS(**19**) according to the 19th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a cemented lens consisting of a third positive lens L**14** that is biconvex and a second negative lens L**15** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**13** is an aspherical surface.

The second lens group G**2** comprises a first positive lens L**21** having a plano-convex shape whose convex surface is pointed toward the image surface I, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 19 below lists data values regarding the optical system according to the 19th example. Note that the 5th surface and the 6th surface are virtual surfaces.

TABLE 19

[General Data]

f	36.05
FNO	1.87
ω	31.2
Y	21.70
TL	99.566
BF	13.100
BFa	12.555

[Lens Data]

Surface Number	R	D	nd	νd
1	−500.00000	2.000	1.59270	35.3
2	26.44740	11.431		
3	54.58955	3.977	1.94594	18.0
4	151.93034	2.197		
5	∞	0.000		
6	∞	10.067		
7*	40.90811	5.557	1.76801	49.2
8*	−104.02802	0.200		
9	29.51647	6.609	1.59319	67.9
10	−42.76988	1.500	1.69895	30.1
11	23.53316	6.210		
12	∞	D12 (Variable)		(Aperture Stop S)
13	∞	2.090	1.49782	82.6
14	−74.67300	2.012		
15	−18.81061	1.100	1.64769	33.7
16	−248.50402	1.512		
17*	118.78898	4.866	1.77377	47.2
18*	−28.64501	0.200		
19	−125.10532	6.400	1.49782	82.6
20	−22.16547	D20 (Variable)	1.94594	18.0
21	−66.18341	4.709	1.94594	18.0
22	−24.96921	1.900	1.80518	25.4
23	−199.98195	2.935		
24	−38.28094	1.900	1.64769	33.7
25	∞	10.500		
26	∞	1.600	1.51680	64.1
27	∞	D27 (Variable)		

[Aspherical surface data]

Seventh surface

k = 1.00000
A4 = 3.16584E−07, A6 = 2.60390E−09,
A8 = −1.78975E−11, A10 = 5.41316E−14

Eighth surface

k = 1.00000
A4 = 4.34400E−08, A6 = −4.51994E−10,
A8 = −7.80080E−12, A10 = 3.78367E−14

Seventeenth surface

k = 1.00000
A4 = −3.61366E−06, A6 = 5.25325E−08,
A8 = −5.32628E−12, A10 = 1.17020E−14

Eighteenth surface

k = 1.00000
A4 = 2.00858E−05, A6 = 3.18374E−08,
A8 = 2.71615E−10, A10 = −4.03272E−13

[Variable distance data]

	Upon focusing on infinity f = 36.05	Upon focusing on a short-distance object β = −0.1049
D0	∞	314.50
D12	4.594	2.000
D19	2.500	5.088
D26	1.000	1.000

TABLE 19-continued

[lens group data]		
group	starting surface	focal length
G1	1	53.15
G2	13	32.25
G3	20	−45.20

[Conditional Expression Corresponding Value]	
Conditional Expression (1)	BFa/f = 0.348
Conditional Expression (2)	(−G1R1)/f = 13.870
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 9.407
Conditional Expression (4)	f/f1 = 0.678
Conditional Expression (5)	f/f2 = 1.118
Conditional Expression (6)	f1/f2 = 1.648
Conditional Expression (7)	f1/(−f3) = 1.176
Conditional Expression (8)	fF/fR = 0.626
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.900
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 1.388$
Conditional Expression (11)	FNO × (f1/f) = 2.751
Conditional Expression (12)	2ω = 62.4

FIG. **38**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 19th example. FIG. **38**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 19th example. The various aberration graphs demonstrate that the optical system according to the 19th example has excellent image forming performance in which various aberrations are corrected favorably.

20th Example

The 20th example will be described using FIGS. **39** and **40** and Table 20. FIG. **39** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 20th example of the present embodiment. The optical system LS(**20**) according to the 20th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a third negative lens L**14** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**15** that is biconvex, a cemented lens consisting of a third positive lens L**16** that is biconvex and a fourth negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 20 below lists data values regarding the optical system according to the 20th example.

TABLE 20

[General Data]	
f	36.41
FNO	1.45
ω	30.7
Y	21.70
TL	120.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	117.52540	2.000	1.71736	29.6
2	26.99520	8.652		
3	42.97983	2.500	1.48749	70.3
4	34.72137	5.000	1.94595	18.0
5	45.17490	9.389		
6	−52.71945	6.000	1.60300	65.4
7	−131.66451	0.200		
8*	55.12835	9.000	1.77250	49.6
9	−66.63993	0.200		
10	57.67591	13.000	1.59319	67.9
11	−28.99052	1.500	1.67270	32.2
12	230.60272	5.399		
13	∞	D13 (Variable)		(Aperture Stop S)
14	−30.96994	1.000	1.67270	32.2
15	1151.90580	2.000		
16*	−406.76312	4.000	1.77377	47.2
17	−45.06075	0.881		
18	140.10078	6.000	1.59319	67.9
19	−58.07296	0.500		
20	−100.00000	7.000	1.59319	67.9
21	−30.10496	D21 (Variable)		
22	74.17179	3.000	1.94595	18.0
23	67.04188	7.824		
24*	−26.97932	1.500	1.64769	33.7
25	−290.34268	7.000		
26	∞	1.600	1.51680	63.9
27	∞	D27 (Variable)		

[Aspherical surface data]

Eighth surface

k = 1.00000
A4 = −6.93107E−07, A6 = −4.54051E−10,
A8 = 1.72053E−12, A10 = −1.39325E−15

Sixteenth surface

k = 1.00000
A4 = −1.46752E−05, A6 = −1.19814E−08,
A8 = 3.20679E−11, A10 = −2.43972E−13

TABLE 20-continued

Twenty-fourth surface		
k = 1.00000 A4 = 1.09875E−05, A6 = 2.56103E−09, A8 = −8.64670E−12, A10 = −3.14024E−14 [Variable distance data]		
	Upon focusing on infinity f = 36.41	Upon focusing on a short-distance object β = −0.1095
D0	∞	290.00
D13	13.354	9.399
D21	0.500	4.455
D27	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	48.51
G2	14	38.61
G3	22	−44.33

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.249
Conditional Expression (2)	(−G1R1)/f = −3.228
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = −2.423
Conditional Expression (4)	f/f1 = 0.751
Conditional Expression (5)	f/f2 = 0.943
Conditional Expression (6)	f1/f2 = 1.256
Conditional Expression (7)	f1/(−f3) = 1.094
Conditional Expression (8)	fF/fR = 0.358
Conditional Expression (9)	(G1R2 + G1R1)/ (G1R2 − G1R1) = −1.596
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.914$
Conditional Expression (11)	FNO × (f1/f) = 1.936
Conditional Expression (12)	2ω = 61.4

FIG. 40A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 20th example. FIG. 40B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 20th example. The various aberration graphs demonstrate that the optical system according to the 20th example has excellent image forming performance in which various aberrations are corrected favorably.

21st Example

The 21st example will be described using FIGS. **41** and **42** and Table 21. FIG. **41** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 21st example of the present embodiment. The optical system LS(**21**) according to the 21st example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a third negative lens L**14** that is biconcave, a second positive lens L**15** that is biconvex, a third positive lens L**16** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth negative lens L**17** having a meniscus shape whose convex surface is pointed toward the object and a fourth positive lens L**18** having a meniscus shape whose convex shape is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**15** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**32** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 21 below lists data values regarding the optical system according to the 21st example.

TABLE 21

[General Data]

f	36.00
FNO	1.42
ω	31.2
Y	21.70
TL	125.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−2103.91320	2.000	1.67884	31.5
2	35.70457	7.893		
3	323.10172	2.500	1.49086	69.1
4	67.22138	5.500	1.94595	18.0
5	787.71792	7.911		
6	39.04627	2.00	1.69166	30.1
7	213.89102	0.100		
8*	137.58827	12.000	1.85135	40.1
9*	−47.56574	0.200		
10	39.72534	7.000	1.83481	42.7
11	181.94050	2.130		
12	117.83429	1.500	1.75520	27.6
13	23.80746	9.000	1.59319	67.9
14	183.46004	3.500		
15	∞	D15 (Variable)		(Aperture Stop S)
16	−34.21404	1.000	1.67270	32.2
17	−122.91319	2.000		
18*	−86.16442	3.500	1.77377	47.2
19	−48.56224	2.416		
20	1800.15400	5.500	1.59319	67.9
21	−42.45537	0.500		

TABLE 21-continued

22	−100.00000	6.500	1.59319	67.9
23	−30.05033	D23 (Variable)		
24	39.40559	3.000	1.94595	18.0
25	34.37457	9.136		
26*	−44.57372	1.500	1.64769	33.7
27	∞	7.000		
28	∞	1.600	1.51680	63.9
29	∞	D29 (Variable)		

[Aspherical surface data]

Eighth surface

k = 1.00000
A4 = 3.90875E−07, A6 = 5.99792E−10,
A8 = −1.78965E−12, A10 = 1.89102E−15

Ninth surface

k = 1.00000
A4 = 5.52339E−07, A6 = 1.13820E−09,
A8 = −1.99242E−12, A10 = 2.23323E−15

Eighteenth surface

k = 1.00000
A4 = −1.62045E−05, A6 = −1.75085E−08,
A8 = 3.19334E−11, A10 = −3.05989E−13

Twenty-sixth surface

k = 1.00000
A4 = −1.48857E−06, A6 = −3.93600E−09,
A8 = 2.22864E−12, A10 = −4.82017E−14

[Variable distance data]

	Upon focusing on infinity f = 36.00	Upon focusing on a short-distance object β = −0.1086
D0	∞	290.00
D13	16.614	12.490
D21	0.500	4.624
D27	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	52.88
G2	16	39.96
G3	24	−59.46

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.252
Conditional Expression (2)	(−G1R1)/f = 58.442
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 39.787
Conditional Expression (4)	f/f1 = 0.681
Conditional Expression (5)	f/f2 = 0.901
Conditional Expression (6)	f1/f2 = 1.323
Conditional Expression (7)	f1/(−f3) = 0.889
Conditional Expression (8)	fF/fR = 0.622
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = −0.967
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.867$
Conditional Expression (11)	FNO × (f1/f) = 2.080
Conditional Expression (12)	2ω = 62.4

FIG. **42**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 21st example. FIG. **42**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 21st example. The various aberration graphs demonstrate that the optical system according to the 21st example has excellent image forming performance in which various aberrations are corrected favorably.

22nd Example

The 22nd example will be described using FIGS. **43** and **44** and Table 22. FIG. **43** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 22nd example of the present embodiment. The optical system LS(**22**) according to the 22nd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object and a positive lens L**22** that is biconvex, arranged in order from the object side. The lens surface on either side of the positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 22 below lists data values regarding the optical system according to the 22nd example. Note that the 12th surface is a virtual surface.

TABLE 22

[General Data]

f	36.00
FNO	1.42
ω	31.2
Y	21.70
TL	125.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−47.35217	2.500	1.67270	32.2
2	94.47970	3.500	1.94595	18.0
3	340.13397	3.236		
4	−287.21979	5.000	1.72916	54.6
5	−56.34930	0.100		
6*	35.86692	6.000	1.80400	46.6
7	−2318.43510	0.200		
8	45.67330	7.000	1.59319	67.9
9	−80.81919	1.500	1.64769	33.7
10	23.62983	4.933		

TABLE 22-continued

11	∞	D11 (Variable)		(Aperture Stop S)
12	∞	3.000		
13	−19.53832	1.100	1.75520	27.6
14	−43.18210	1.500		
15*	190.26772	7.000	1.75501	51.2
16*	−24.77289	D16 (Variable)		
17	−104.87147	2.500	1.94595	18.0
18	−78.84438	14.090		
19	−38.56539	1.900	1.64769	33.7
20	−200.67448	7.000		
21	∞	1.600	1.51680	64.1
22	∞	D22 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −1.5861E−06, A6 = −8.54477E−10,
A8 = −4.09102E−13, A10 = 5.85218E−16

Fifteenth surface

k = 1.00000
A4 = 4.66858E−07, A6 = −2.10629E−08,
A8 = 1.67228E−10, A10 = −2.90665E−13

Sixteenth surface

k = 1.00000
A4 = 8.47233E−06, A6 = 2.18602E−10,
A8 = 2.67616E−11, A10 = 1.23427E−13

[Variable distance data]

	Upon focusing on infinity f = 51.50	Upon focusing on a short-distance object β = −0.1588
D0	∞	305.05
D11	12.719	2.695
D16	2.111	12.136
D22	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	75.53
G2	12	56.74
G3	17	−100.37

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.176
Conditional Expression (2)	(−G1R1)/f = 0.919
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.627
Conditional Expression (4)	f/f1 = 0.682
Conditional Expression (5)	f/f2 = 0.908
Conditional Expression (6)	f1/f2 = 1.331
Conditional Expression (7)	f1/(−f3) = 0.753
Conditional Expression (8)	fF/fR = 0.762
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.756
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.687$
Conditional Expression (11)	FNO × (f1/f) = 2.716
Conditional Expression (12)	2ω = 45.8

FIG. **44**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 22nd example. FIG. **44**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 22nd example. The various aberration graphs demonstrate that the optical system according to the 22nd example has excellent image forming performance in which various aberrations are corrected favorably.

23rd Example

The 23rd example will be described using FIGS. **45** and **46** and Table 23. FIG. **45** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 23rd example of the present embodiment. The optical system LS(**23**) according to the 23rd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**16** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a second negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 23 below lists data values regarding the optical system according to the 23rd example. Note that the 20th surface is a virtual surface.

TABLE 23

[General Data]

f	51.08
FNO	1.86
ω	23.0
Y	21.70
TL	90.000
BF	9.600
BFa	9.055

TABLE 23-continued

[Lens Data]

Surface Number	R	D	nd	νd
1	−52.31571	2.500	1.67270	32.2
2	167.47695	3.500	1.94595	18.0
3	223.17328	4.121		
4	−82.07390	4.000	1.72916	54.6
5	−45.42951	0.100		
6*	38.12626	6.000	1.80400	46.6
7	−3600.28350	1.699		
8	27.04928	5.000	1.59319	67.9
9	41.33566	1.500	1.64769	33.7
10	20.68760	5.718		
11	∞	D11 (Variable)		(Aperture Stop S)
12	−22.93194	2.500	1.49700	81.6
13	−17.98615	0.500		
14	−17.23374	1.100	1.67270	32.2
15	−49.04852	1.500		
16*	279.75740	6.000	1.75501	51.2
17*	−26.00590	D17 (Variable)		
18	−221.46549	2.500	1.94595	18.0
19	−230.39803	0.000		
20	∞	10.724		
21	−38.50025	1.900	1.64769	33.7
22	−110.45885	7.000		
23	∞	1.600	1.51680	63.9
24	∞	D24 (Variable)		

[Aspherical surface data]

Sixth surface

k = 1.00000
A4 = −1.19548E−06, A6 = −9.73538E−10,
A8 = 3.03150E−12, A10 = −5.31839E−15

Sixteenth surface

k = 1.00000
A4 = −1.22099E−06, A6 = −9.91302E−09,
A8 = 8.68866E−11, A10 = −1.19726E−13

Seventeenth surface

k = 1.00000
A4 = 5.66916E−06, A6 = 2.72450E−09,
A8 = −8.54602E−12, A10 = 1.63651E−13

[Variable distance data]

	Upon focusing on infinity f = 51.08	Upon focusing on a short-distance object β = −0.1171
D0	∞	413.36
D11	12.216	4.956
D17	7.322	14.582
D24	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	68.94
G2	12	58.61
G3	18	−90.38

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.177
Conditional Expression (2)	(−G1R1)/f = 1.024
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.759
Conditional Expression (4)	f/f1 = 0.741
Conditional Expression (5)	f/f2 = 0.872
Conditional Expression (6)	f1/f2 = 1.176
Conditional Expression (7)	f1/(−f3) = 0.763

TABLE 23-continued

Conditional Expression (8)	fF/fR = 0.542
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.620
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.721$
Conditional Expression (11)	FNO × (f1/f) = 2.508
Conditional Expression (12)	2ω = 46.0

FIG. **46**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 23rd example. FIG. **46**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 23rd example. The various aberration graphs demonstrate that the optical system according to the 23rd example has excellent image forming performance in which various aberrations are corrected favorably.

24th Example

The 24th example will be described using FIGS. **47** and **48** and Table 24. FIG. **47** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 24th example of the present embodiment. The optical system LS(**24**) according to the 24th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**15** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**13** is an aspherical surface.

The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 24 below lists data values regarding the optical system according to the 24th example.

TABLE 24

[General Data]	
f	51.50
FNO	1.85
ω	22.9
Y	21.70
TL	82.941
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−47.29734	2.000	1.67270	32.2
2	2331.06620	3.670		
3	−71.21945	4.000	1.72916	54.6
4	−42.49265	0.100		
5*	34.70954	6.000	1.80400	46.6
6	6260.90290	0.947		
7	27.53256	5.000	1.59319	67.9
8	40.45186	1.500	1.64769	33.7
9	19.48030	5.755		
10	∞	D10 (Variable)		(Aperture Stop S)
11	−21.95759	2.500	1.49700	81.6
12	−17.97990	0.500		
13	−17.33726	1.100	1.67270	32.2
14	−65.42718	0.387		
15*	210.98797	6.000	1.75501	51.2
16*	−24.41048	D16 (Variable)		
17	79.42309	2.500	1.94595	18.0
18	102.63179	8.767		
19	−46.77211	1.900	1.84666	23.8
20	−182.21442	7.000		
21	∞	1.600	1.51680	63.9
22	∞	D22 (Variable)		

[Aspherical surface data]

Fifth surface

k = 1.00000
A4 = −1.79931E−06, A6 = −1.35228E−09,
A8 = 1.30531E−12, A10 = −3.27717E−15

Fifteenth surface

k = 1.00000
A4 = −1.14256E−06, A6 = −1.30370E−08,
A8 = 1.13854E−10, A10 = −1.79669E−13

Sixteenth surface

k = 1.00000
A4 = 6.47116E−06, A6 = 6.32503E−09,
A8 = −2.44521E−11, A10 = 2.46075E−13

[Variable distance data]

	Upon focusing on infinity f = 51.50	Upon focusing on a short-distance object β = 0.1181
D0	∞	413.36
D10	14.069	5.072
D16	6.646	15.643
D22	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	68.06
G2	11	64.03
G3	17	−99.89

TABLE 24-continued

[Conditional Expression Corresponding Value]	
Conditional Expression (1)	BFa/f = 0.176
Conditional Expression (2)	(−G1R1)/f = 0.918
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.695
Conditional Expression (4)	f/f1 = 0.757
Conditional Expression (5)	f/f2 = 0.804
Conditional Expression (6)	f1/f2 = 1.063
Conditional Expression (7)	f1/(−f3) = 0.681
Conditional Expression (8)	fF/fR = 0.514
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.960
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2$ = 0.563
Conditional Expression (11)	FNO × (f1/f) = 2.445
Conditional Expression (12)	2ω = 45.8

FIG. **48**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 24th example. FIG. **48**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 24th example. The various aberration graphs demonstrate that the optical system according to the 24th example has excellent image forming performance in which various aberrations are corrected favorably.

25th Example

The 25th example will be described using FIGS. **49** and **50** and Table 25. FIG. **49** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 25th example of the present embodiment. The optical system LS(**25**) according to the 25th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L**14** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**13** is an aspherical surface.

The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group

G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 25 below lists data values regarding the optical system according to the 25th example.

TABLE 25

[General Data]

f	50.81
FNO	1.85
ω	23.1
Y	21.70
TL	80.000
BF	9.600
BFa	9.055

[Lens Data]

Surface Number	R	D	nd	νd
1	−48.70279	2.000	1.67270	32.2
2	958.65257	2.567		
3	−87.18050	3.500	1.72916	54.6
4	−45.33683	0.100		
5*	28.25675	6.500	1.77250	49.6
6	735.50092	0.365		
7	28.50942	2.465	1.67270	32.2
8	19.47871	6.238		
9	∞	D9 (Variable)		(Aperture Stop S)
10	−21.86257	2.000	1.49700	81.6
11	−18.15776	0.500		
12	−17.46272	1.100	1.67270	32.2
13	−78.54612	0.200		
14*	259.64263	6.500	1.75501	51.2
15*	−23.47358	D15 (Variable)		
16	45.54867	2.500	1.94595	18.0
17	56.06952	6.419		
18	−49.21248	1.900	1.84666	23.8
19	∞	7.000		
20	∞	1.600	1.51680	63.9
21	∞	D21 (Variable)		

[Aspherical surface data]

Fifth surface

k = 1.00000
A4 = −3.06009E−06, A6 = −3.83923E−09,
A8 = 3.08021E−12, A10 = −1.31813E−14

Fourteenth surface

k = 1.00000
A4 = −2.38445E−06, A6 = −7.07397E−10,
A8 = 4.93804E−11, A10 = −6.99716E−14

Fifteenth surface

k = 1.00000
A4 = 6.07250E−06, A6 = 1.41158E−08,
A8 = −5.03385E−11, A10 = 2.68237E−13

[Variable distance data]

	Upon focusing on infinity f = 50.81	Upon focusing on a short-distance object β = −0.1180
D0	∞	413.36
D9	14.286	5.350
D15	11.261	20.197
D21	1.000	1.000

TABLE 25-continued

[lens group data]

group	starting surface	focal length
G1	1	67.37
G2	10	68.93
G3	16	−83.91

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.178
Conditional Expression (2)	(−G1R1)/f = 0.958
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.695
Conditional Expression (4)	f/f1 = 0.754
Conditional Expression (5)	f/f2 = 0.737
Conditional Expression (6)	f1/f2 = 0.977
Conditional Expression (7)	f1/(−f3) = 0.803
Conditional Expression (8)	fF/fR = 0.349
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.903
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.567$
Conditional Expression (11)	FNO × (f1/f) = 2.456
Conditional Expression (12)	2ω = 46.2

FIG. 50A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 25th example. FIG. 50B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 25th example. The various aberration graphs demonstrate that the optical system according to the 25th example has excellent image forming performance in which various aberrations are corrected favorably.

26th Example

The 26th example will be described using FIGS. 51 and 52 and Table 26. FIG. 51 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 26th example of the present embodiment. The optical system LS(26) according to the 26th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. Additionally, the second lens group G2 includes a first subgroup G2A having negative refractive power and a second subgroup G2B having positive refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the first subgroup G2A and the second subgroup G2B of the second lens group G2 move toward the object by different amounts along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a cemented lens consisting of a first negative lens L11 that is biconcave and a first positive lens L12 having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L13 that is biconcave, a second positive lens L14 that is biconvex, a third positive lens L15 that is biconvex, a cemented lens consisting of a fourth positive lens L16 that is biconvex and a third negative lens L17 that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the third positive lens L15 is an aspherical surface.

The first subgroup G2A of the second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object. The second subgroup G2B of the second lens group G**2** comprises a first positive lens L**22** that is biconvex and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** that is biconcave, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**33** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 26 below lists data values regarding the optical system according to the 26th example.

TABLE 26

[General Data]

f	51.60
FNO	1.44
ω	22.7
Y	21.70
TL	113.685
BF	13.100
BFa	12.555

[Lens Data]

Surface Number	R	D	nd	νd
1	−171.72474	2.000	1.62588	35.7
2	35.44631	5.392	1.94594	18.0
3	74.33039	6.970		
4	−53.50931	3.610	1.75520	27.6
5	91.70821	0.200		
6	74.06522	7.512	1.90265	35.7
7	−104.97613	0.100		
8*	56.97323	7.742	1.85135	40.1
9*	−173.82221	0.200		
10	38.89486	12.894	1.59319	67.9
11	−34.37837	1.500	1.74077	27.7
12	37.65571	4.597		
13	∞	D13 (Variable)		(Aperture Stop S)
14	−22.59808	1.100	1.64769	33.7
15	−145.29857	D15 (Variable)		
16*	85.83165	6.797	1.77377	47.2
17*	−32.92442	1.000		
18	−62.36306	6.400	1.49782	82.6
19	−26.53221	D19 (Variable)		
20	−15532.87600	5.451	1.94594	18.0
21	−42.26207	4.169	1.75520	27.6
22	1509.21760	3.688		
23*	−47.39475	1.900	1.88202	37.2
24	∞	10.500		
25	∞	1.600	1.51680	64.1
26	∞	D26 (Variable)		

TABLE 26-continued

[Aspherical surface data]

Eighth surface

k = 1.00000
A4 = 1.10048E−06, A6 = 1.15261E−10,
A8 = 4.34134E−12, A10 = −9.02791E−16

Ninth surface

k = 1.00000
A4 = 2.53480E−06, A6 = −1.36378E−09,
A8 = 6.90741E−12, A10 = −6.44423E−15

Sixteenth surface

k = 1.00000
A4 = −2.74525E−06, A6 = 1.71160E−08,
A8 = −1.40699E−11, A10 = 1.45752E−14

Seventeenth surface

k = 1.00000
A4 = 1.20601E−05, A6 = 1.19411E−08,
A8 = 3.74420E−11, A10 = −3.48136E−14

Twenty-third surface

k = 1.00000
A4 = 1.37602E−06, A6 = −3.97295E−09,
A8 = 7.39073E−12, A10 = −9.76367E−15

[Variable distance data]

	Upon focusing on infinity f = 51.60	Upon focusing on a short-distance object β = −0.1471
D0	∞	314.50
D13	13.416	6.329
D15	1.447	1.481
D19	2.500	9.547
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	81.01
G2	14	42.29
(G2A	14	−41.46)
(G2B	16	25.11)
G4	20	−70.49

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.243
Conditional Expression (2)	(−G1R1)/f = 0.922
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.588
Conditional Expression (4)	f/f1 = 0.637
Conditional Expression (5)	f/f2 = 1.192
Conditional Expression (6)	f1/f2 = 1.871
Conditional Expression (7)	f1/(−f3) = 1.149
Conditional Expression (8)	fF/fR = 0.976
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.219
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.957$
Conditional Expression (11)	FNO × (f1/f) = 2.263
Conditional Expression (12)	2ω = 45.4

FIG. **52**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 26th example. FIG. **52**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 26th example. The various aberration graphs demonstrate that the optical system according to the 26th example has excellent image forming performance in which various aberrations are corrected favorably.

27th Example

The 27th example will be described using FIGS. **53** and **54** and Table 27. FIG. **53** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 27th example of the present embodiment. The optical system LS(**27**) according to the 27th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 27 below lists data values regarding the optical system according to the 27th example.

TABLE 27

[General Data]

f	85.00
FNO	1.86
ω	14.2
Y	21.70
TL	115.209
BF	21.685
BFa	21.004

[Lens Data]

Surface Number	R	D	nd	νd
1	−64.83088			
2	−188.98518	0.300		
3	153.82997	4.500	1.94595	18.0
4	508.32386	0.300		
5	420.81318	6.000	1.72916	54.6
6	−110.04917	0.100		
7	48.16622	7.000	1.72916	54.6
8	79.79724	0.200		
9	40.00000	10.958	1.59282	68.7

TABLE 27-continued

Surface Number	R	D	nd	νd
10	−125.87904	2.500	1.67270	32.2
11	25.51317	7.152		
12	∞	D12 (Variable)		(Aperture Stop S)
13	−30.69513	1.500	1.64769	33.7
14	−1583.64670	1.500		
15	84.28063	5.000	1.77377	47.2
16*	−60.30181	1.500		
17	−115.77812	4.500	1.49700	81.6
18	−35.95414	D18 (Variable)		
19	−79.69114	4.000	1.94595	18.0
20	−48.89207	6.639		
21	−37.38750	2.000	1.64769	33.7
22	−237.55752	18.685		
23	∞	2.000	1.51680	64.1
24	∞	D24 (Variable)		

[Aspherical surface data]
Sixteenth surface

k = 1.00000
A4 = 4.07807E−06, A6 = 3.17226E−09,
A8 = −8.77566E−12, A10 = 1.60757E−14

[Variable distance data]

	Upon focusing on infinity f = 85.00	Upon focusing on a short-distance object β = −0.1471
D0	∞	661.16
D12	17.304	5.692
D18	8.071	19.684
D24	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	129.04
G2	13	75.91
G3	19	−161.19

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.247
Conditional Expression (2)	(−G1R1)/f = 0.763
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.502
Conditional Expression (4)	f/f1 = 0.659
Conditional Expression (5)	f/f2 = 1.120
Conditional Expression (6)	f1/f2 = 1.700
Conditional Expression (7)	f1/(−f3) = 0.801
Conditional Expression (8)	fF/fR = 1.054
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 2.044
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.804$
Conditional Expression (11)	FNO × (f1/f) = 2.825
Conditional Expression (12)	2ω = 28.4

FIG. **54**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 27th example. FIG. **54**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 27th example. The various aberration graphs demonstrate that the optical system according to the 27th example has excellent image forming performance in which various aberrations are corrected favorably.

28th Example

The 28th example will be described using FIGS. **55** and **56** and Table 28. FIG. **55** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 28th example of the present embodiment. The optical system LS(**28**) according to the 28th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** that is biconvex and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 28 below lists data values regarding the optical system according to the 28th example.

TABLE 28

[General Data]

f	85.00
FNO	1.83
ω	14.2
Y	21.70
TL	115.187
BF	19.721
BFa	19.039

[Lens Data]

Surface Number	R	D	nd	νd
1	−72.98373	2.500	1.67270	32.2
2	−170.26652	0.300		
3	117.64422	4.500	1.94595	18.0
4	186.71439	0.436		
5	189.13820	6.000	1.72916	54.6
6	−151.29429	0.100		
7	50.47764	7.000	1.72916	54.6
8	72.74698	0.200		
9	40.25986	11.919	1.59282	68.7
10	−195.06452	2.500	1.67270	32.2
11	26.55143	6.702		
12	∞	D12 (Variable)		(Aperture Stop S)
13	−29.45199	1.500	1.64769	33.7
14	−432.91007	1.500		
15	95.51607	5.000	1.77377	47.2
16*	−57.35798	1.500		
17	−90.11025	4.500	1.49700	81.6
18	−33.31937	D18 (Variable)		
19	17922.25800	4.000	1.94595	18.0
20	−128.51263	6.878		
21	−63.86657	2.000	1.64769	33.7
22	153.63984	16.721		
23	∞	2.000	1.51680	64.1
24	∞	D24 (Variable)		

[Aspherical surface data]
Sixteenth surface
k = 1.00000
A4 = 4.53083E−06, A6 = 3.16311E−09,
A8 = −8.83761E−12, A10 = 1.81194E−14

[Variable distance data]

	Upon focusing on infinity f = 85.00	Upon focusing on a short-distance object β = −0.1247
D0	∞	661.16
D12	18.306	5.696
D18	8.127	20.736
D24	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	131.54
G2	13	77.05
G3	19	−160.72

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.224
Conditional Expression (2)	(−G1R1)/f = 0.859
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.555
Conditional Expression (4)	f/f1 = 0.646
Conditional Expression (5)	f/f2 = 1.103
Conditional Expression (6)	f1/f2 = 1.707
Conditional Expression (7)	f1/(−f3) = 0.818
Conditional Expression (8)	fF/fR = 1.101
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 2.500
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.727$
Conditional Expression (11)	FNO × (f1/f) = 2.839
Conditional Expression (12)	2ω = 28.4

FIG. **56**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 28th example. FIG. **56**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 28th example. The various aberration graphs demonstrate that the optical system according to the 28th example has excellent image forming performance in which various aberrations are corrected favorably.

29th Example

The 29th example will be described using FIGS. **57** and **58** and Table 29. FIG. **57** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 29th example of the present embodiment. The optical system LS(**29**) according to the 29th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a first negative lens L11 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L12 having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L13 that is biconvex, a third positive lens L14 having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L15 that is biconvex and a second negative lens L16 that is biconcave, and an aperture stop S, arranged in order from the object side.

The second lens group G2 comprises a negative lens L21 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L22 that is biconvex, and a second positive lens L23 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L22 is an aspherical surface.

The third lens group G3 comprises a positive lens L31 that is biconvex and a negative lens L32 that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 29 below lists data values regarding the optical system according to the 29th example.

TABLE 29

[General Data]

f	85.00
FNO	1.85
ω	14.2
Y	21.70
TL	115.297
BF	15.435
BFa	14.754

[Lens Data]

Surface Number	R	D	nd	νd
1	−75.54007	2.500	1.67270	32.2
2	−147.54550	0.300		
3	88.89576	4.500	1.94595	18.0
4	118.01688	0.648		
5	127.59306	6.000	1.80400	46.6
6	−246.54425	0.100		
7	47.61283	6.000	1.59282	68.6
8	67.76235	0.200		
9	40.00000	10.476	1.59282	68.7
10	−185.31557	2.500	1.67270	32.2
11	26.38137	6.867		
12	∞	D12 (Variable)		(Aperture Stop S)
13	−28.70718	1.500	1.64769	33.7
14	−336.87946	1.500		
15	97.83173	5.000	1.77377	47.2
16*	−54.59764	1.500		
17	−87.32308	4.500	1.49700	81.6
18	−32.94421	D18 (Variable)		
19	3326.05740	4.000	1.94595	18.0
20	−105.25167	4.274		
21	−57.51449	2.000	1.64769	33.7
22	111.93382	12.435		

TABLE 29-continued

23	∞	2.000	1.51680	64.1
24	∞	D24 (Variable)		

[Aspherical surface data]
Sixteenth surface

k = 1.00000
A4 = 4.61985E−06, A6 = 4.41333E−09,
A8 = −1.50995E−11, A10 = 2.98769E−14

[Variable distance data]

	Upon focusing on infinity f = 85.00	Upon focusing on a short-distance object β = −0.1232
D0	∞	661.16
D12	21.713	9.146
D18	13.783	26.349
D24	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	131.08
G2	13	74.60
G3	19	−140.71

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.174
Conditional Expression (2)	(−G1R1)/f = 0.889
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.576
Conditional Expression (4)	f/f1 = 0.648
Conditional Expression (5)	f/f2 = 1.139
Conditional Expression (6)	f1/f2 = 1.757
Conditional Expression (7)	f1/(−f3) = 0.932
Conditional Expression (8)	fF/fR = 1.081
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 3.098
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.717$
Conditional Expression (11)	FNO × (f1/f) = 2.850
Conditional Expression (12)	2ω = 28.4

FIG. 58A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 29th example. FIG. 58B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 29th example. The various aberration graphs demonstrate that the optical system according to the 29th example has excellent image forming performance in which various aberrations are corrected favorably.

30th Example

The 30th example will be described using FIGS. 59 and 60 and Table 30. FIG. 59 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 30th example of the present embodiment. The optical system LS(30) according to the 30th example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a first negative lens L11 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L12 having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L13 that is biconvex, a third positive lens L14 having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L15 that is biconvex and a second negative lens L16 that is biconcave, and an aperture stop S, arranged in order from the object side.

The second lens group G2 comprises a negative lens L21 having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L22 that is biconvex, and a second positive lens L23 having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L22 is an aspherical surface.

The third lens group G3 comprises a positive lens L31 having a meniscus shape whose concave surface is pointed toward the object and a negative lens L32 that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G3. An interchangeable optical filter FL is arranged between the third lens group G3 and the image surface I.

Table 30 below lists data values regarding the optical system according to the 30th example.

TABLE 30

[General Data]

f	85.00
FNO	1.85
ω	14.2
Y	21.70
TL	115.242
BF	14.943
BFa	14.261

[Lens Data]

Surface Number	R	D	nd	νd
1	−74.95148	2.500	1.67270	32.2
2	−131.91024	0.300		
3	85.64889	4.000	1.94595	18.0
4	120.40884	0.300		
5	115.73186	7.000	1.59282	68.6
6	−191.64403	0.100		
7	48.88487	5.000	1.80400	46.6
8	63.21824	0.200		
9	40.00000	10.246	1.59282	68.7
10	−287.51510	2.500	1.67270	32.2
11	26.35774	7.011		
12	∞	D12 (Variable)		(Aperture Stop S)
13	−28.44113	1.500	1.64769	33.7
14	−287.07114	1.500		
15	102.04030	5.000	1.77377	47.2
16*	−53.66013	1.500		
17	−88.84311	4.500	1.49700	81.6
18	−33.17367	D18 (Variable)		
19	−397.22387	4.000	1.94595	18.0
20	−86.37143	4.578		
21	−52.43868	2.000	1.64769	33.7
22	143.09995	11.943		
23	∞	2.000	1.51680	64.1
24	∞	D24 (Variable)		

TABLE 30-continued

[Aspherical surface data]
Sixteenth surface

k = 1.00000
A4 = 4.49957E−06, A6 = 4.10925E−09,
A8 = −1.26128E−11, A10 = 2.42467E−14

[Variable distance data]

	Upon focusing on infinity f = 85.00	Upon focusing on a short-distance object β = −0.1242
D0	∞	661.16
D12	20.672	8.633
D18	15.892	27.931
D24	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	134.72
G2	13	74.30
G3	19	−130.08

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.168
Conditional Expression (2)	(−G1R1)/f = 0.882
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.556
Conditional Expression (4)	f/f1 = 0.631
Conditional Expression (5)	f/f2 = 1.144
Conditional Expression (6)	f1/f2 = 1.813
Conditional Expression (7)	f1/(−f3) = 1.036
Conditional Expression (8)	fF/fR = 1.075
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 3.632
Conditional Expression (10)	$\{1-(\beta 2)^2\} \times (\beta 3)^2 = 0.766$
Conditional Expression (11)	FNO × (f1/f) = 2.929
Conditional Expression (12)	2ω = 28.4

FIG. 60A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 30th example. FIG. 60B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 30th example. The various aberration graphs demonstrate that the optical system according to the 30th example has excellent image forming performance in which various aberrations are corrected favorably.

31st Example

The 31st example will be described using FIGS. 61 and 62 and Table 31. FIG. 61 is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 31st example of the present embodiment. The optical system LS(31) according to the 31st example comprises a first lens group G1 having positive refractive power, a second lens group G2 having positive refractive power, and a third lens group G3 having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G2 moves toward the object along the optical axis, while the first lens group G1 and the third lens group G3 remain fixed in place.

The first lens group G1 comprises a first negative lens L11 that is biconcave, a first positive lens L12 that is biconvex, a second positive lens L13 that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a fourth positive lens L**15** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fifth positive lens L**16** that is biconvex and a second negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

Table 31 below lists data values regarding the optical system according to the 31st example.

TABLE 31

[General Data]

f	85.00
FNO	1.42
ω	14.2
Y	21.70
TL	145.265
BF	14.071
BFa	13.389

[Lens Data]

Surface Number	R	D	nd	νd
1	−79.06766	3.000	1.67270	32.2
2	104.61579	5.110		
3	243.58488	6.500	1.94595	18.0
4	−628.66078	0.300		
5	109.12437	16.500	1.59282	68.6
6	−110.85187	0.100		
7*	63.25612	11.500	1.77250	49.6
8	360.60495	0.200		
9	52.11101	8.500	1.59282	68.7
10	88.79834	0.200		
11	71.03249	8.500	1.59282	68.6
12	−790.77200	2.500	1.85025	30.0
13	30.29304	9.299		
14	∞	D14 (Variable)		(Aperture Stop S)
15	−35.50553	1.500	1.67270	32.2
16	−19114.07500	1.500		
17	96.59624	6.000	1.77377	47.2
18*	−65.15132	1.500		
19	−154.43166	6.000	1.49700	81.6
20	−40.92465	D20 (Variable)		
21	−793.09360	4.000	1.94595	18.0
22	−123.62638	9.551		
23	−59.68219	2.000	1.64769	33.7
24	388.46258	11.071		
25	∞	2.000	1.51680	63.9
26	∞	D26 (Variable)		

TABLE 31-continued

[Aspherical surface data]

Seventh surface

A4 = −1.31502E−07, A6 = −4.69010E−11,
A8 = 1.13722E−14, A10 = −8.34540E−18

Eighteenth surface

k = 1.00000
A4 = 2.96560E−06, A6 = 2.23513E−09,
A8 = −5.41262E−12, A10 = 7.26232E−15

[Variable distance data]

	Upon focusing on infinity f = 85.00	Upon focusing on a short-distance object β = −0.1177
D0	∞	661.16
D14	23.433	7.955
D20	3.500	18.978
D26	1.000	1.000

[lens group data]

group	starting surface	focal length
G1	1	117.63
G2	15	83.50
G3	21	−188.48

[Conditional Expression Corresponding Value]

Conditional Expression (1)	BFa/f = 0.158
Conditional Expression (2)	(−G1R1)/f = 0.930
Conditional Expression (3), (3-1), (3-2)	(−G1R1)/f1 = 0.672
Conditional Expression (4)	f/f1 = 0.723
Conditional Expression (5)	f/f2 = 1.018
Conditional Expression (6)	f1/f2 = 1.409
Conditional Expression (7)	f1/(−f3) = 1.624
Conditional Expression (8)	fF/fR = 1.943
Conditional Expression (9)	(G1R2 + G1R1)/(G1R2 − G1R1) = 0.139
Conditional Expression (10)	$\{1-(\beta 2)^2\}\times(\beta 3)^2 = 0.510$
Conditional Expression (11)	FNO × (f1/f) = 1.968
Conditional Expression (12)	2ω = 28.4

FIG. **62**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 31st example. FIG. **62**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 31st example. The various aberration graphs demonstrate that the optical system according to the 31st example has excellent image forming performance in which various aberrations are corrected favorably.

According to the above examples, an optical system capable of obtaining favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification can be achieved.

The foregoing examples illustrate concrete instances of the present disclosure, but the present disclosure is not limited to these examples.

Note that it is possible to adopt the following content appropriately within a range that does not hinder the optical performance of the optical system according to the present embodiment.

The focusing lens group refers to a portion having at least one lens separated by a distance that changes when focusing (for example, the second lens group of the present embodiment). In other words, a single lens group, a plurality of lens groups, or a partial lens group may also be treated as the focusing lens group that is moved in the optical axis direction to focus from an infinite distant object to a short-distance object. The focusing lens group can also be applied to autofocus, and is also suited to autofocus motor driving (using an ultrasonic motor or the like).

The examples of the optical system according to the present embodiment illustrate a configuration that lacks an anti-vibration function, but the present disclosure is not limited thereto and may also be configured to have an anti-vibration function.

Each lens surface may be formed as a spherical surface, a planar surface, or an aspherical surface. It is preferable for the lens surface to be spherical or planar because lens processing and assembly adjustment are easy, degraded optical performance due to errors in processing and assembly adjustment can be prevented, and also because depiction performance suffers little degradation even in a case where the image surface is displaced.

In a case where the lens surface is aspherical, the aspherical surface may be any of an aspherical surface obtained by grinding, a molded glass aspherical surface obtained by forming glass into an aspherical shape using a mold, or a composite type aspherical surface obtained by formed a resin into an aspherical shape on the surface of glass. Additionally, the lens surface may also be a diffractive surface, and the lens may also be a gradient index lens (GRIN lens) or a plastic lens.

To achieve high-contrast optical performance with reduced flaring and ghosting, an anti-reflective coating having high transmittance over a wide wavelength range may also be applied to each lens surface. With this arrangement, high-contrast high optical performance with reduced flaring and ghosting can be achieved.

EXPLANATION OF NUMERALS AND CHARACTERS

G**1** first lens group
G**2** second lens group
G**3** third lens group
I image surface
S aperture stop

The invention claimed is:

1. An optical system comprising:

a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein

when focusing, the second lens group moves along an optical axis,

the first lens group is stationary when focusing, and

the optical system satisfies the following conditional expressions:

$$0.100<BFa/f<0.350$$

$$0.25<fF/fR<3.00$$

$$0.50<FNO\times(f1/f)<3.20 \text{ and}$$

$$1.000<(-G1R1)/f1<50.000$$

where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image,

f is a focal length of the optical system,

fF is a composite focal length of lenses disposed farther on the object side than a diaphragm in the optical system,

fR is a composite focal length of lenses disposed farther on the image side than the diaphragm in the optical system at a state of focusing on infinity,

FNO is an F-number of the optical system,

f1 is a focal length of the first lens group, and

G1R1 is a radius of curvature of a lens surface on the object side of a lens component disposed closest to the object in the first lens group.

2. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$1.000<(-G1R1)/f1<5.000.$$

3. The optical system according to claim **1**, wherein the first lens group comprises a diaphragm.

4. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$0.010<f/f1<5.000.$$

5. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$0.010<f/f2<5.000$$

where f2 is a focal length of the second lens group.

6. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$0.010<f1/f2<5.000$$

where

f2 is a focal length of the second lens group.

7. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$0.010<f1/(-f3)<3.000$$

where

f3 is a focal length of the third lens group.

8. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$-10.0<(G1R2+G1R1)/(G1R2-G1R1)<10.0$$

where

G1R2 is a radius of curvature of a lens surface on the image side for a lens component disposed farthest on the object side in the first lens group.

9. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$0.30<\{1-(\beta 2)^2\}\times(\beta 3)^2<2.00$$

where β2 is a lateral magnification of the second lens group for a state of focusing on infinity, and

β3 is a lateral magnification of the third lens group.

10. The optical system according to claim **1**, wherein the optical system satisfies the following conditional expression

$$15.0°<2\omega<85.00$$

where 2ω is an angle of view of the optical system.

11. An optical apparatus comprising a lens barrel including the optical system according to claim **1**.

12. A method of manufacturing an optical system including a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, the method comprising:

disposing each lens within a lens barrel such that

when focusing, the second lens group moves along an optical axis,

the first lens group is stationary when focusing, and

the optical system satisfies set A or set B of conditional expressions,

wherein set A comprises:

$$0.100<BFa/f<0.350$$

$$0.25<fF/fR<3.00$$

$$0.50<FNO\times(f1/f)<3.20 \text{ and}$$

$$1.000<(-G1R1)/f1<50.000$$

where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image,

f is a focal length of the optical system,

fF is a composite focal length of lenses disposed farther on the object side than a diaphragm in the optical system,

fR is a composite focal length of lenses disposed farther on the image side than the diaphragm in the optical system at a state of focusing on infinity,

FNO is an F-number of the optical system,

f1 is a focal length of the first lens group, and

G1R1 is a radius of curvature of a lens surface on the object side of a lens component disposed closest to the object in the first lens group, and

wherein set B comprises:

$$0.100<BFa/f\leq 0.249$$

$$0.50<FNO\times(f1/f)<3.00 \text{ and}$$

$$20.0°<2\omega<85.0°$$

where 2ω is an angle of view of the optical system.

13. An optical system comprising:

a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein

when focusing, the second lens group moves along an optical axis,

the first lens group is stationary when focusing, and

the optical system satisfies the following conditional expressions:

$$0.100<BFa/f\leq 0.249 \text{ and}$$

$$0.50<FNO\times(f1/f)<3.00 \text{ and}$$

$$20.0°<2\omega<85.0°$$

where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image,

f is a focal length of the optical system,

FNO is an F-number of the optical system,

f1 is a focal length of the first lens group, and

2ω is an angle of view of the optical system.

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