US 20250258363A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0258363 A1
(43) Pub. Date: Aug. 14, 2025
MACHIDA et al.

(54) VARIABLE MAGNIFICATION OPTICAL SYSTEM, OPTICAL DEVICE, AND METHOD FOR MANUFACTURING VARIABLE MAGNIFICATION OPTICAL SYSTEM

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(21) Appl. No.: **19/194,828**

(22) Filed: **Apr. 30, 2025**

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2023/038491, filed on Oct. 25, 2023.

(30) **Foreign Application Priority Data**

Nov. 4, 2022 (JP) 2022-177062

Publication Classification

(51) **Int. Cl.**
G02B 15/14 (2006.01)
G02B 15/167 (2006.01)

(52) **U.S. Cl.**
CPC *G02B 15/1455* (2019.08); *G02B 15/1461* (2019.08); *G02B 15/167* (2013.01)

(57) **ABSTRACT**

A variable magnification optical system including, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups is configured so that at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied, and that the following conditional expression is satisfied:

$$0.24<(TL/f1)/(ft/fw)<0.55$$

where TL is the distance from a lens surface closest to the object side to the image plane, f1 is the focal length of the first lens group, ft is the focal length of the variable magnification optical system in a telephoto end state, and fw is the focal length of the variable magnification optical system in a wide-angle end state.

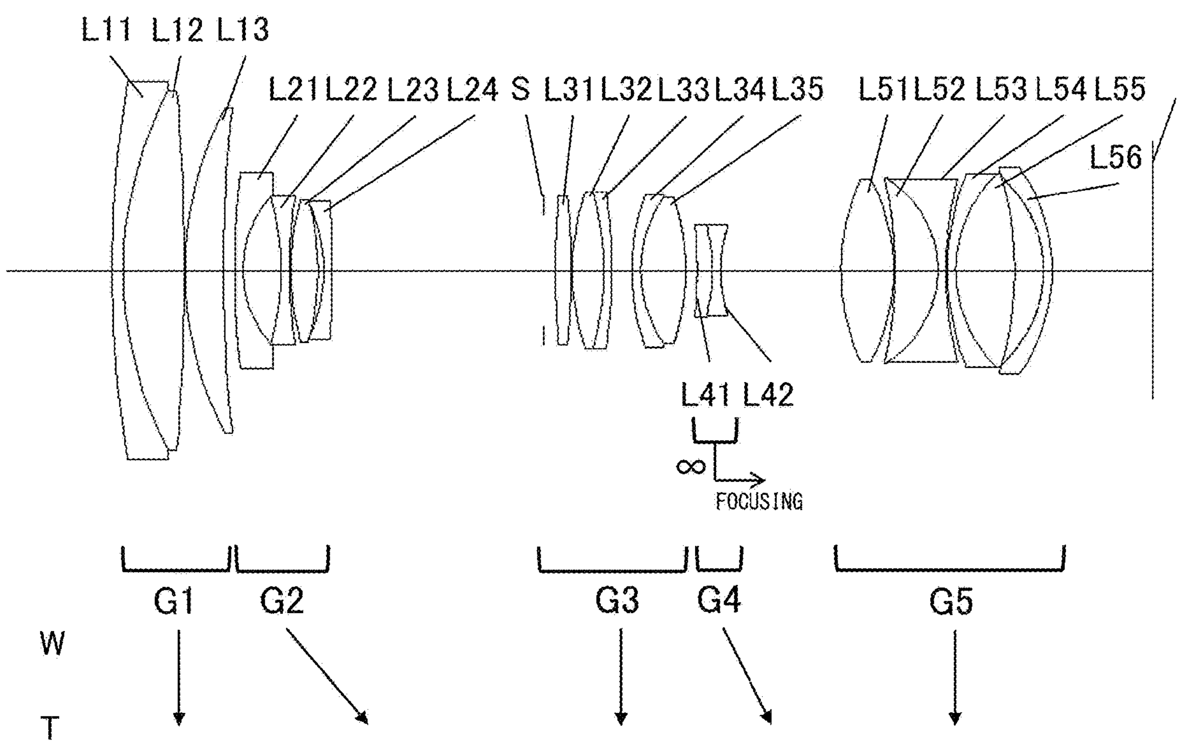
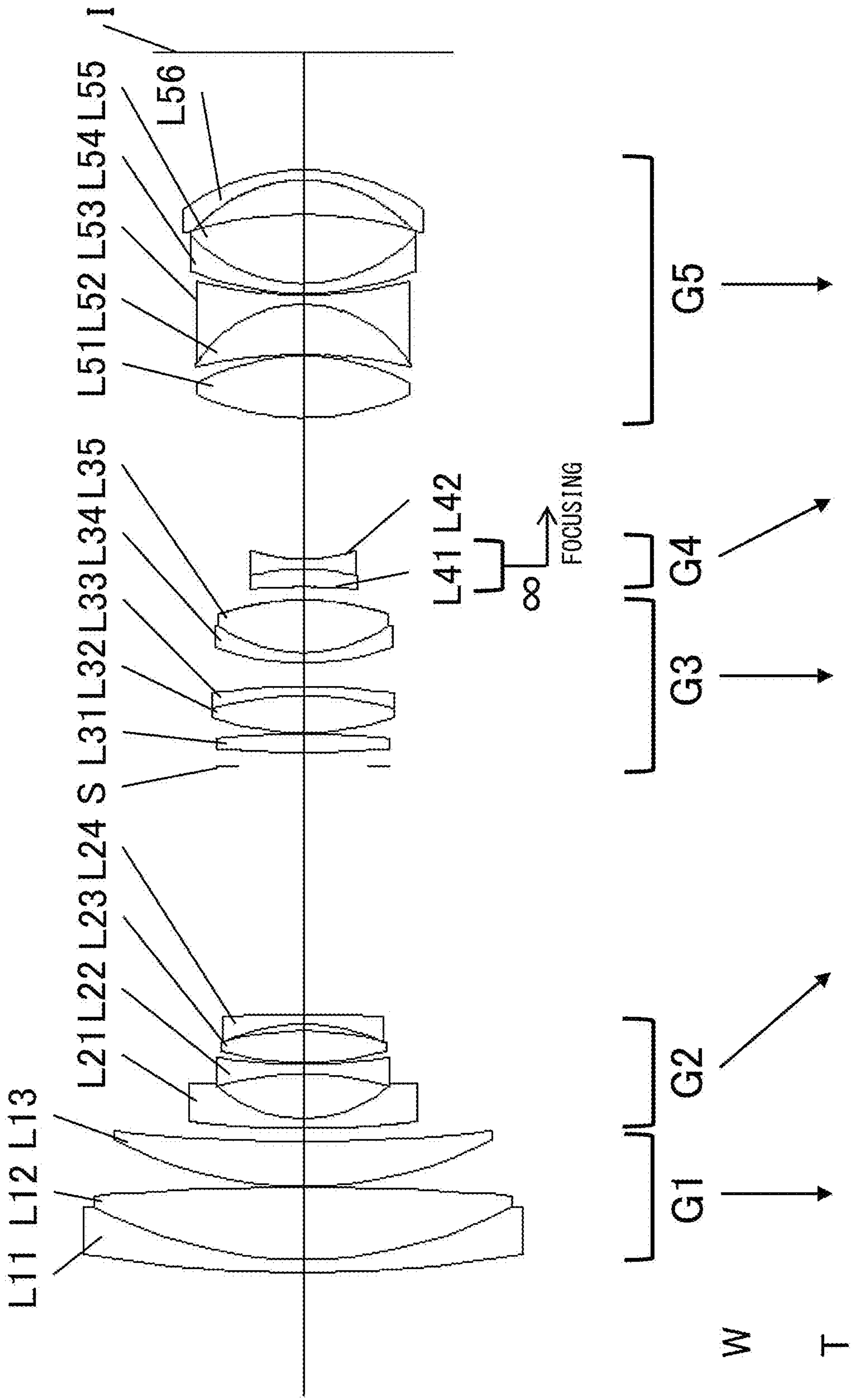


Fig. 1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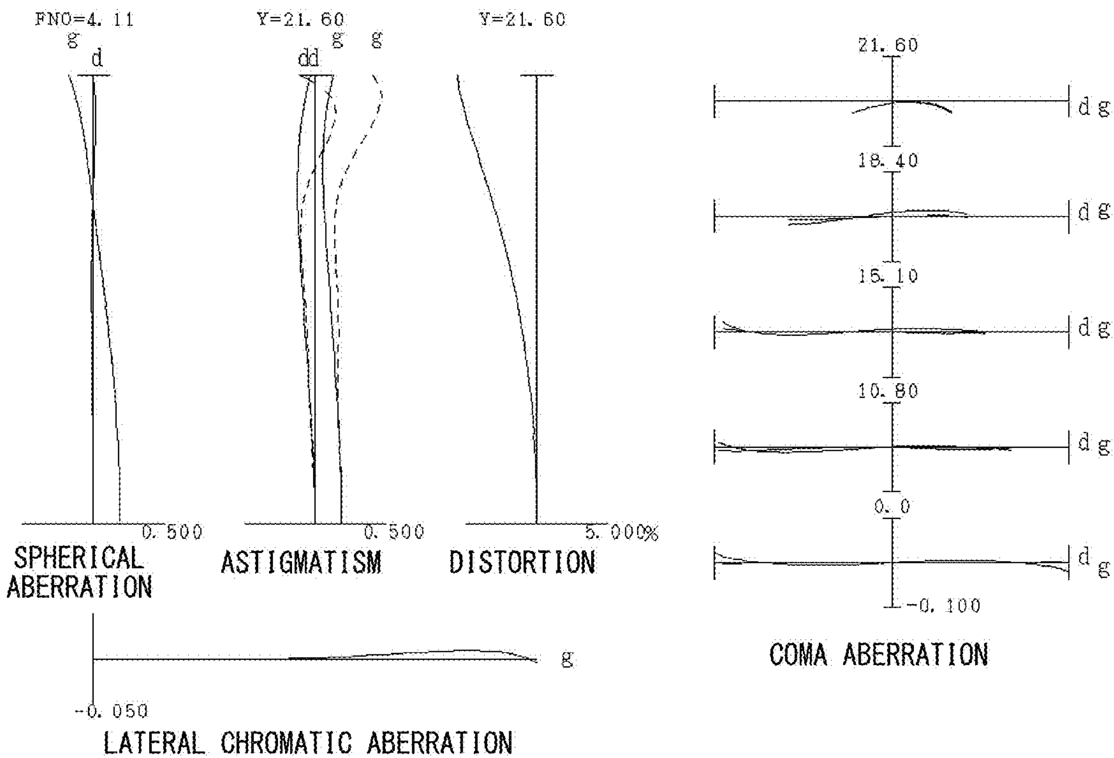
L22
L21
L13
L12
L11
L42
L41
FOCUSING
∞
G1
G2
G3
G4
G5
W
T

Fig. 2

(a)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15. 10
d g
10. 80
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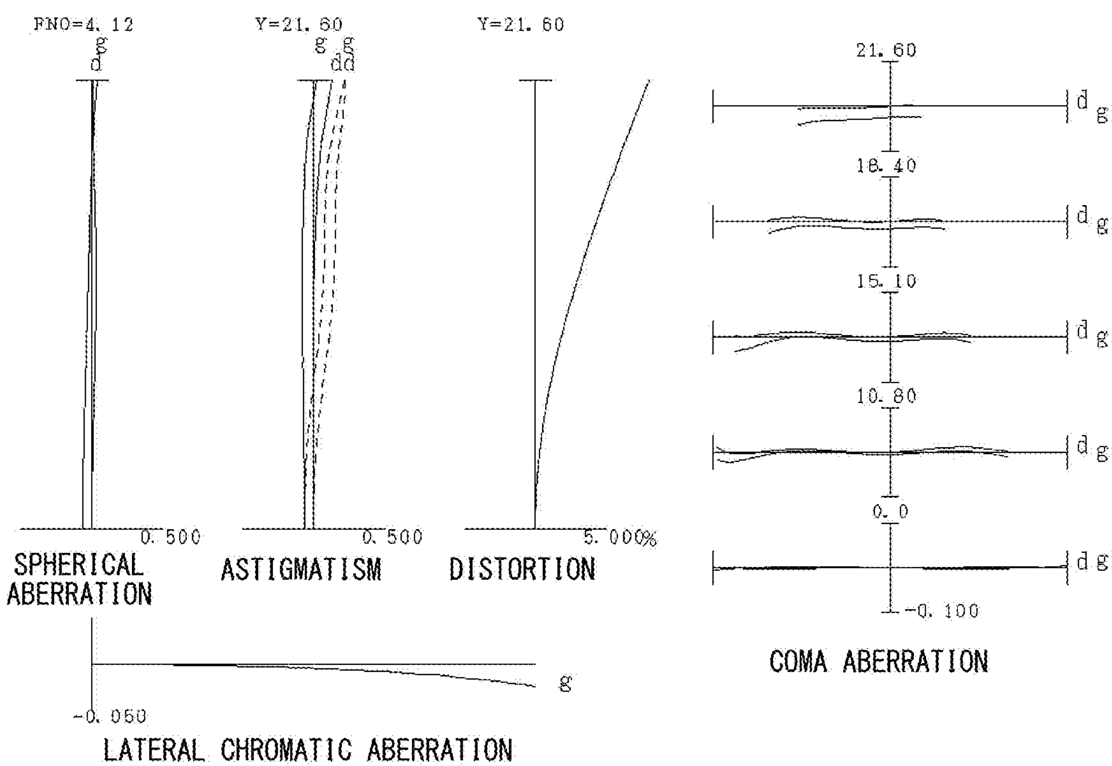
COMA ABERRATION

(b)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15. 10
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d g
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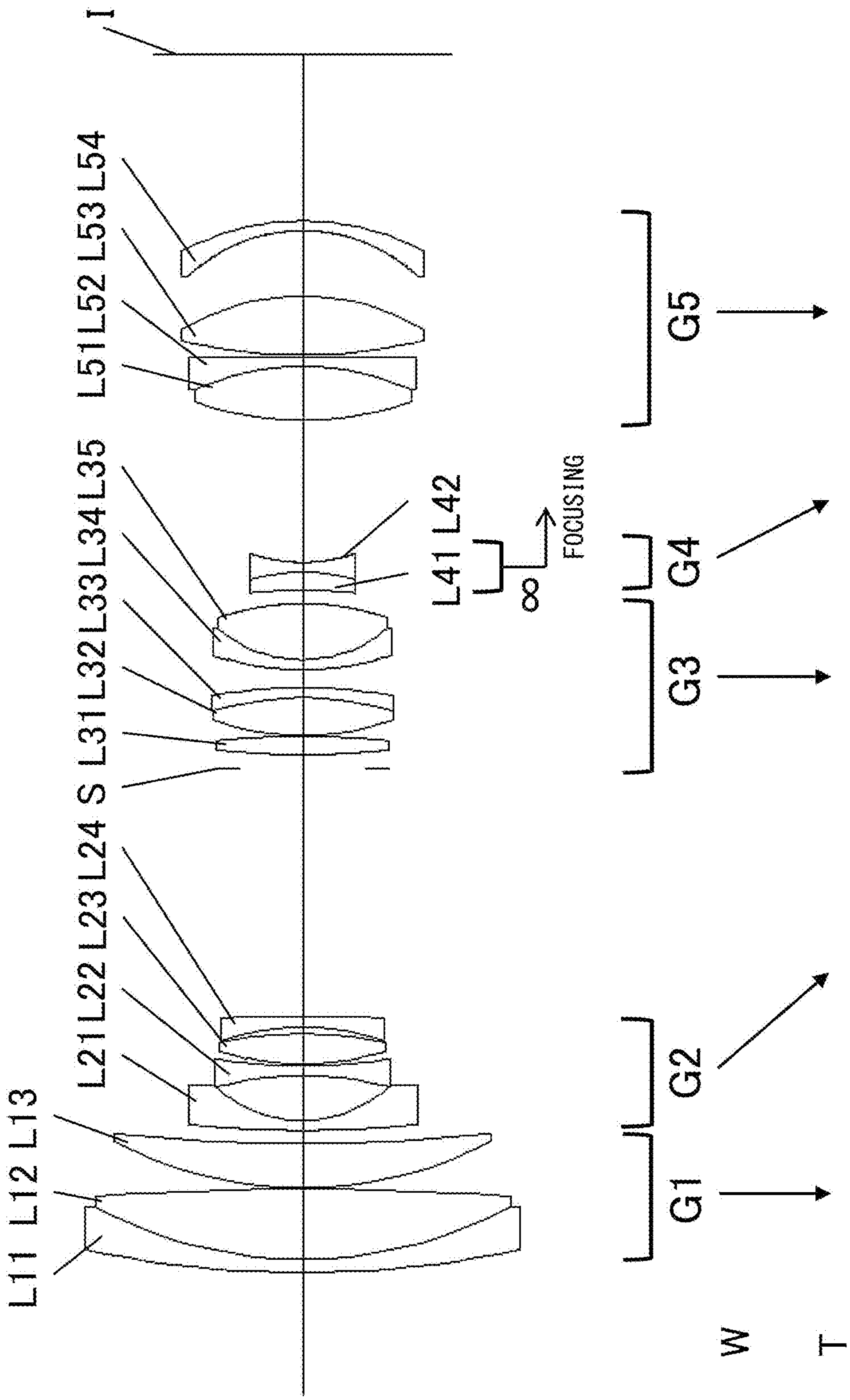
COMA ABERRATION

Fig. 3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L51 L52 L53 L54
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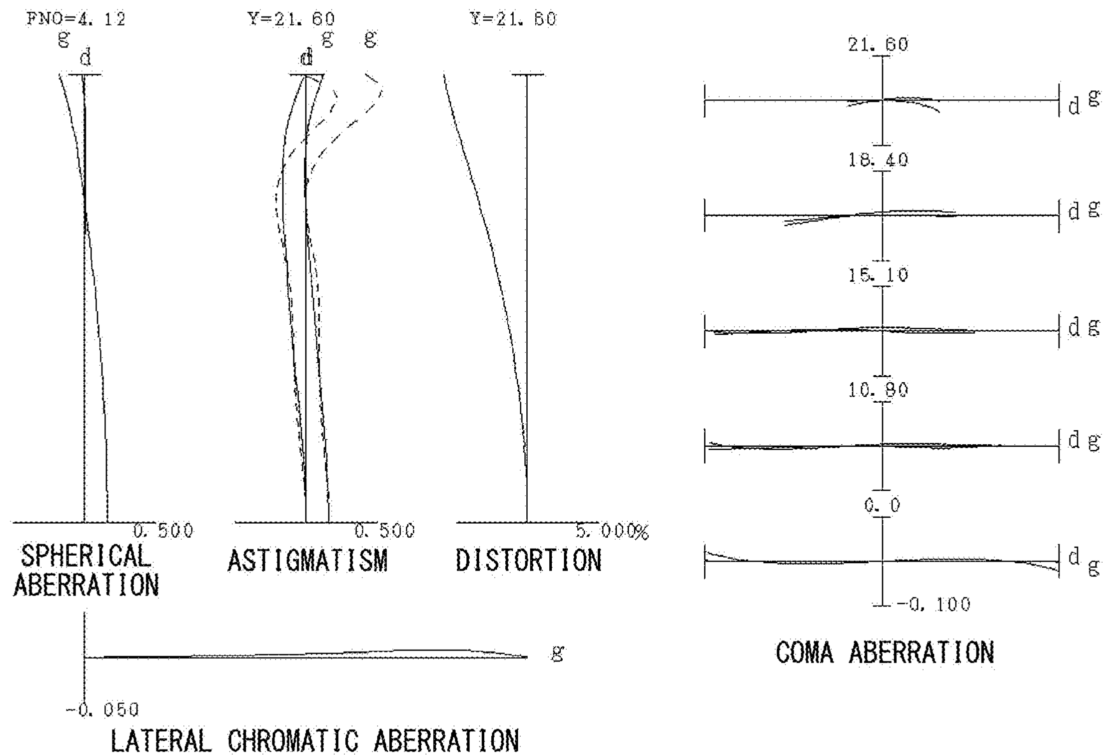
G2
G3
G4
G5
W
T

Fig. 4

(a)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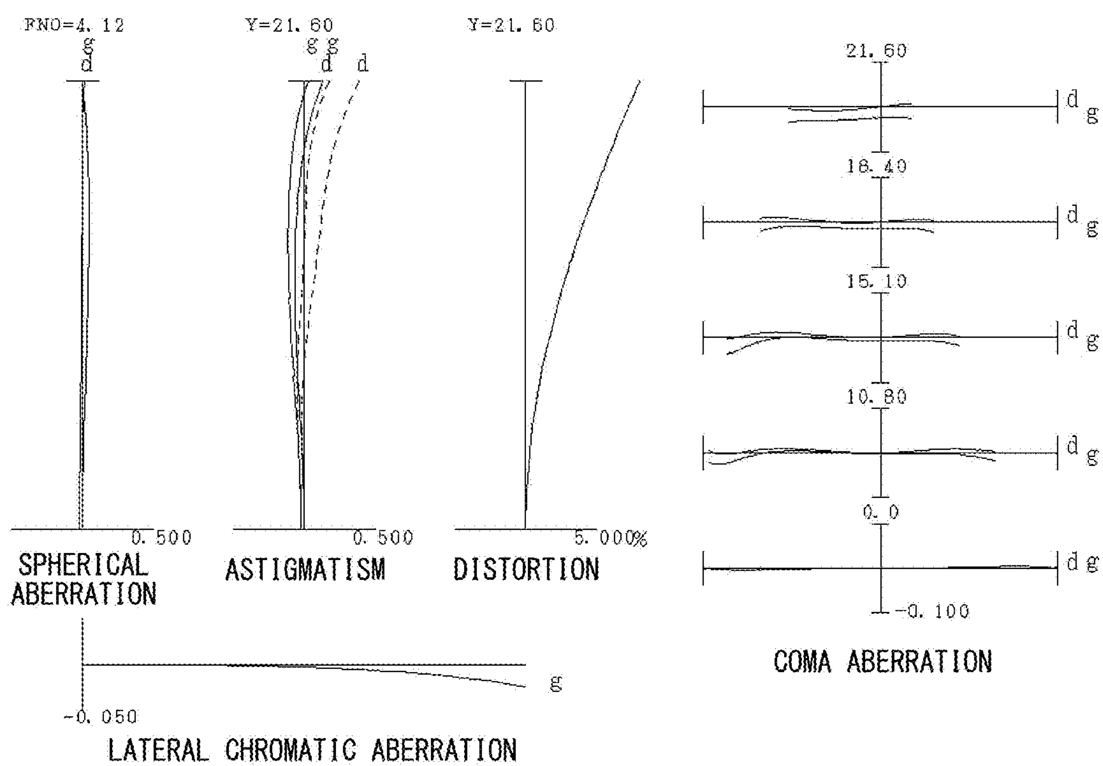
LATERAL CHROMATIC ABERRATION

(b)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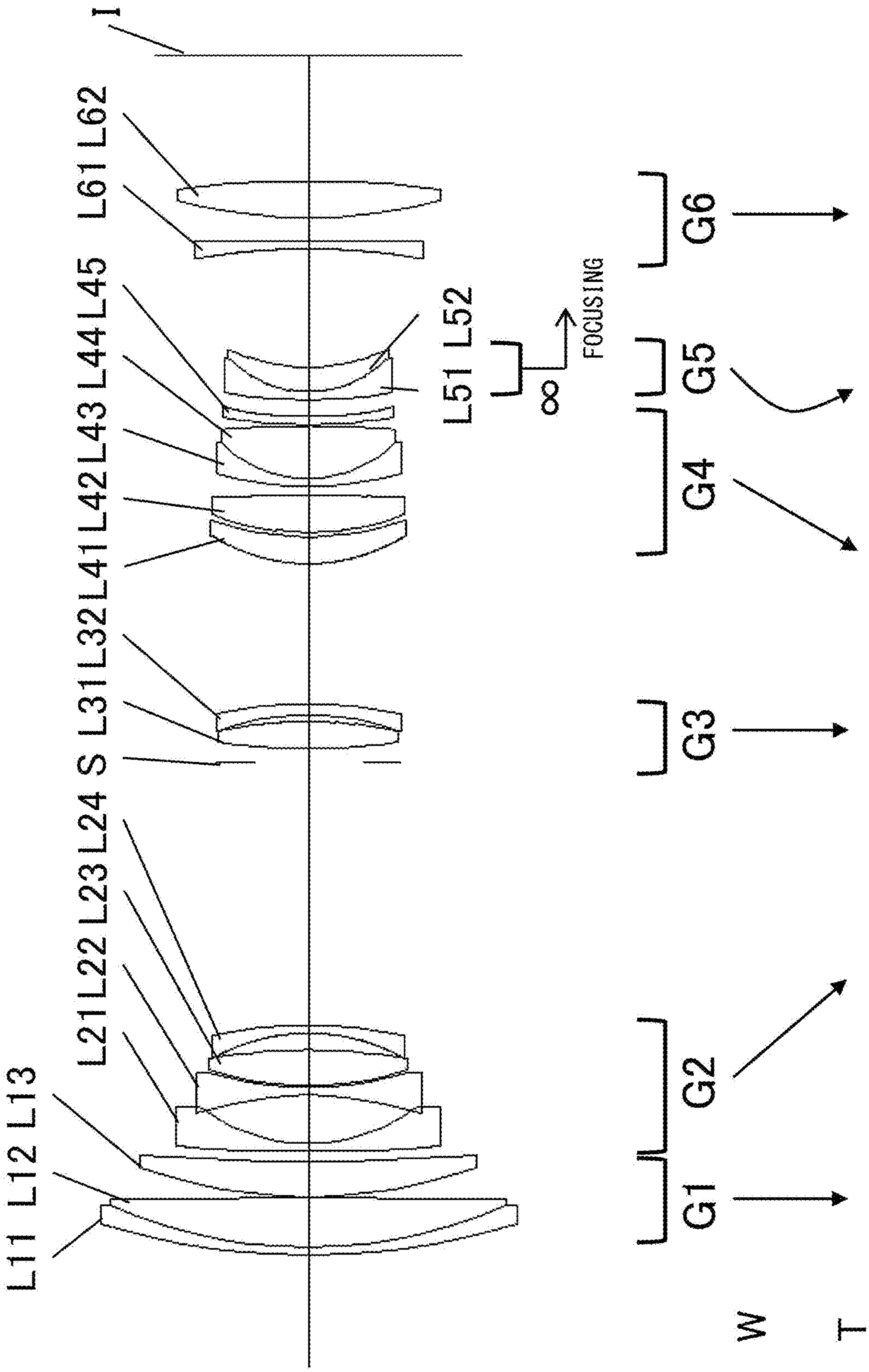
LATERAL CHROMATIC ABERRATION

Fig. 5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L13
L12
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FOCUSING
G6
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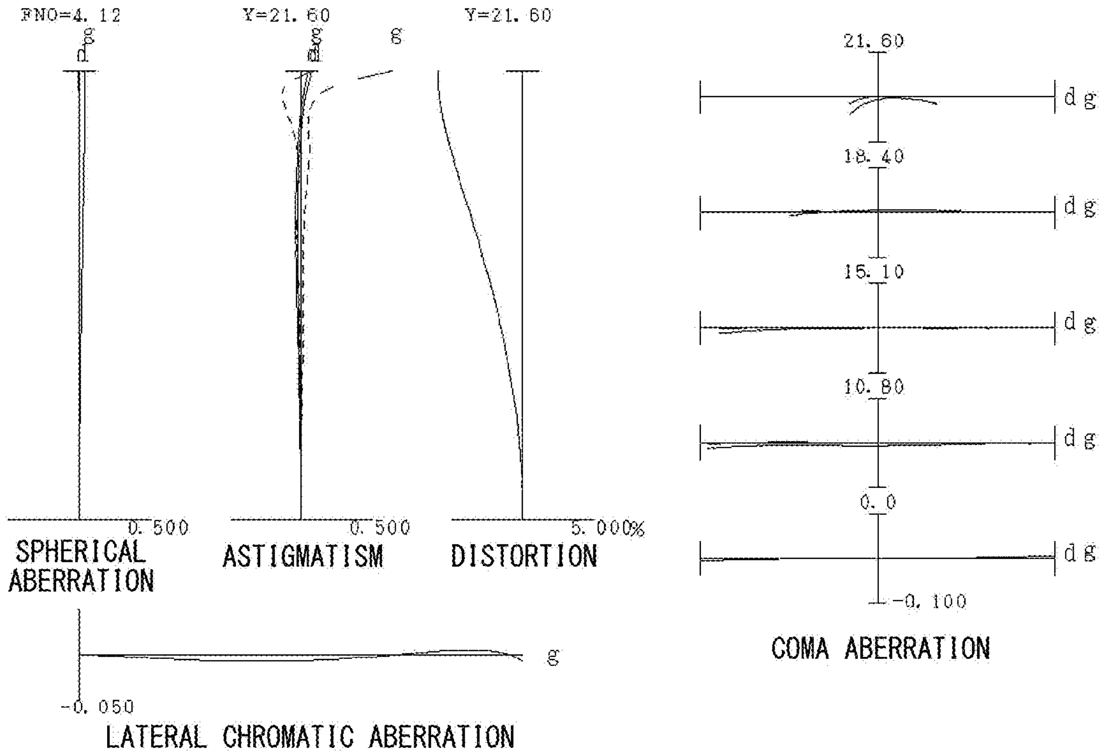
G4
G3
G2
G1
W
T

Fig. 6

(a)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LATERAL CHROMATIC ABERRATION

(b)

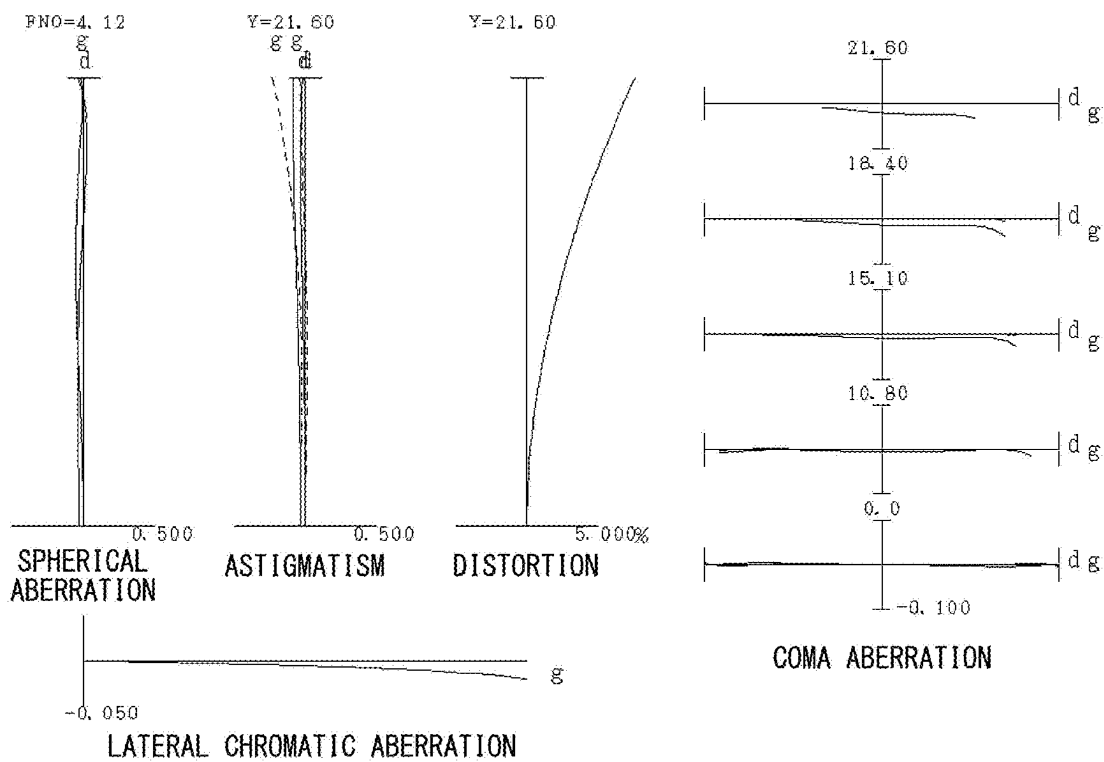
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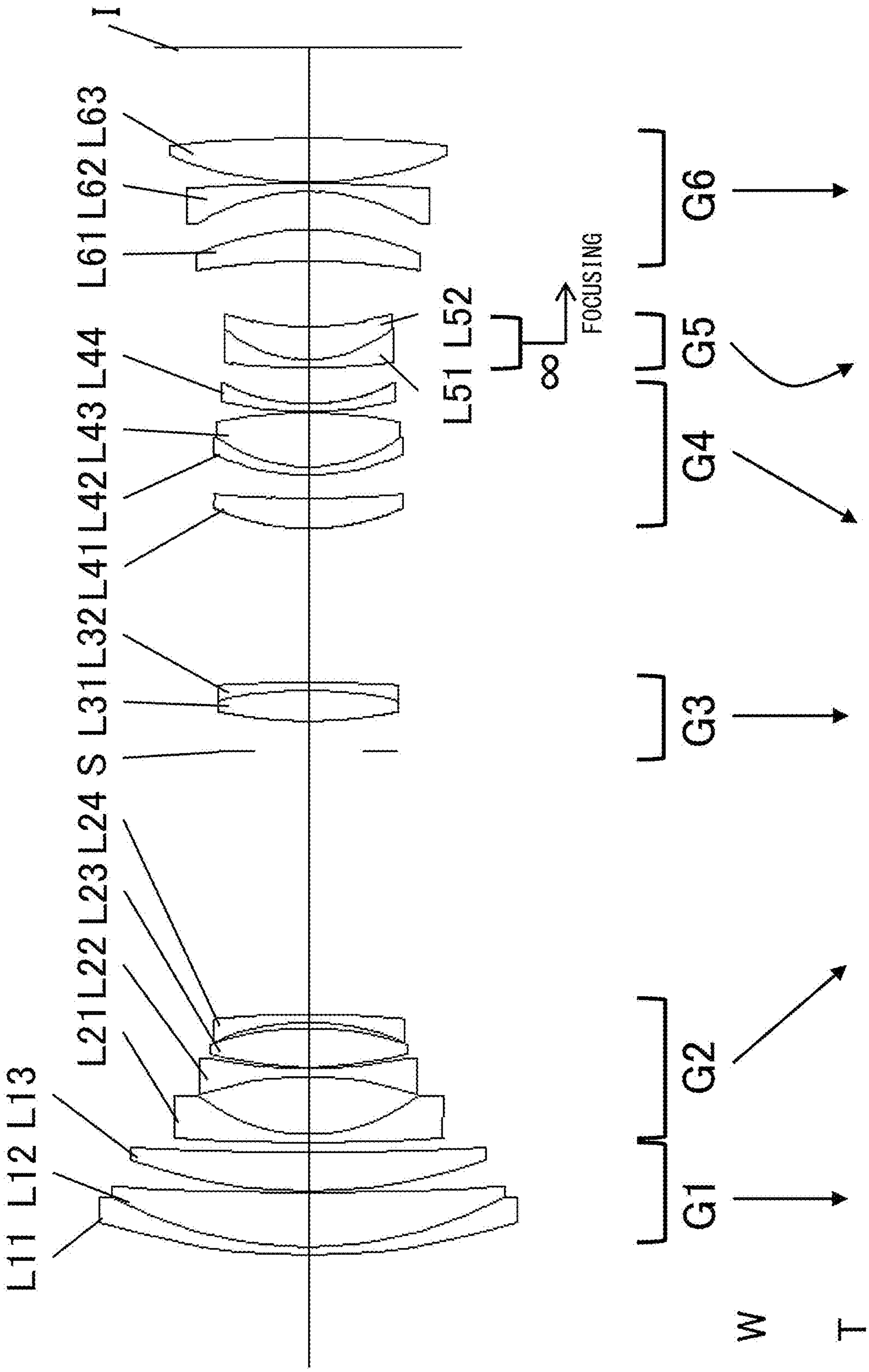
Fig. 7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L12
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∞
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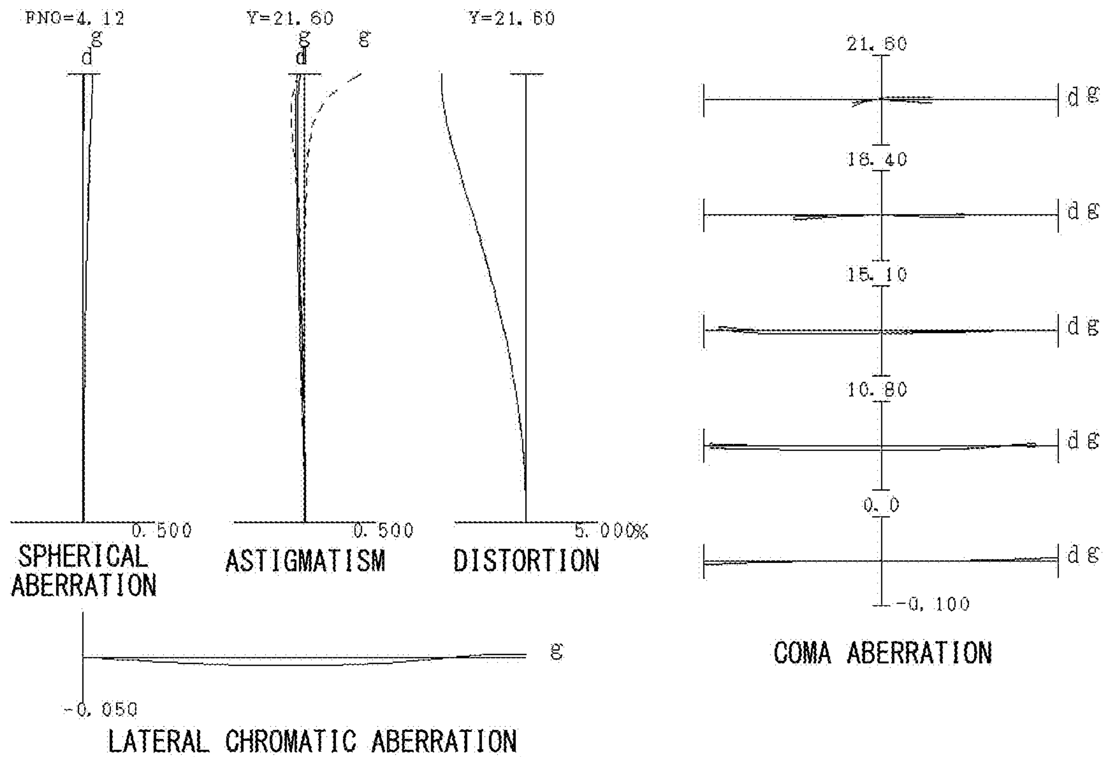
G5
G4
G3
G2
G1
W
T

Fig. 8

(a)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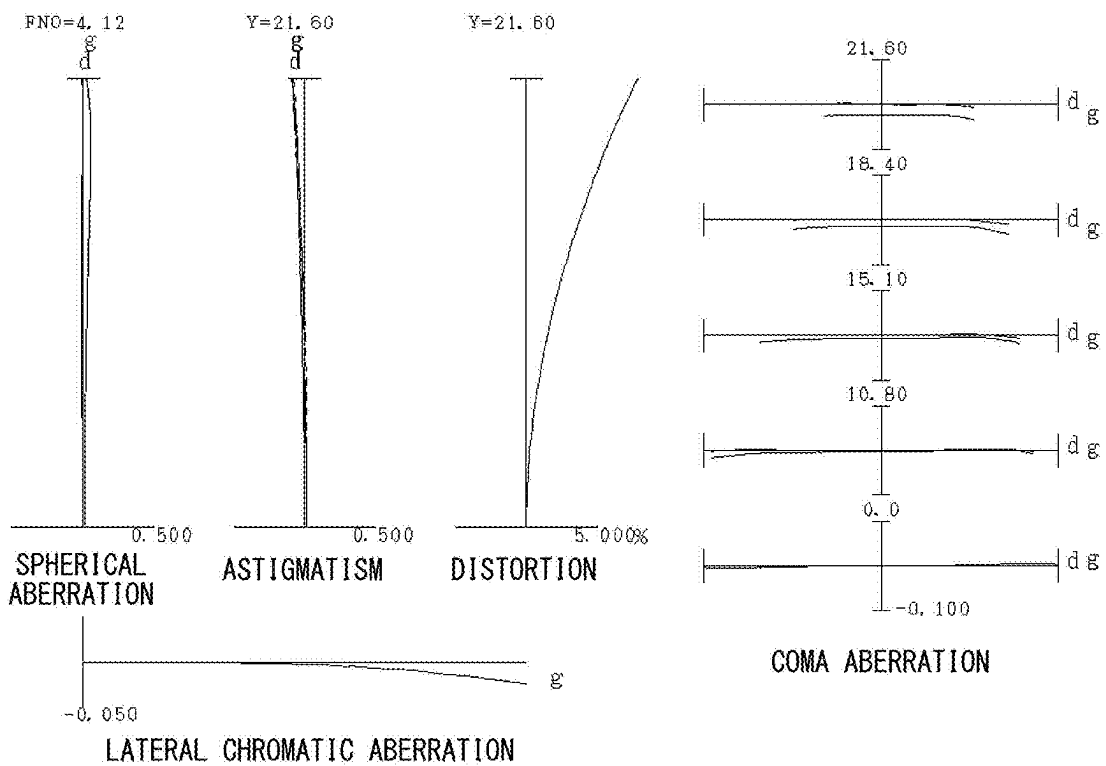
(b)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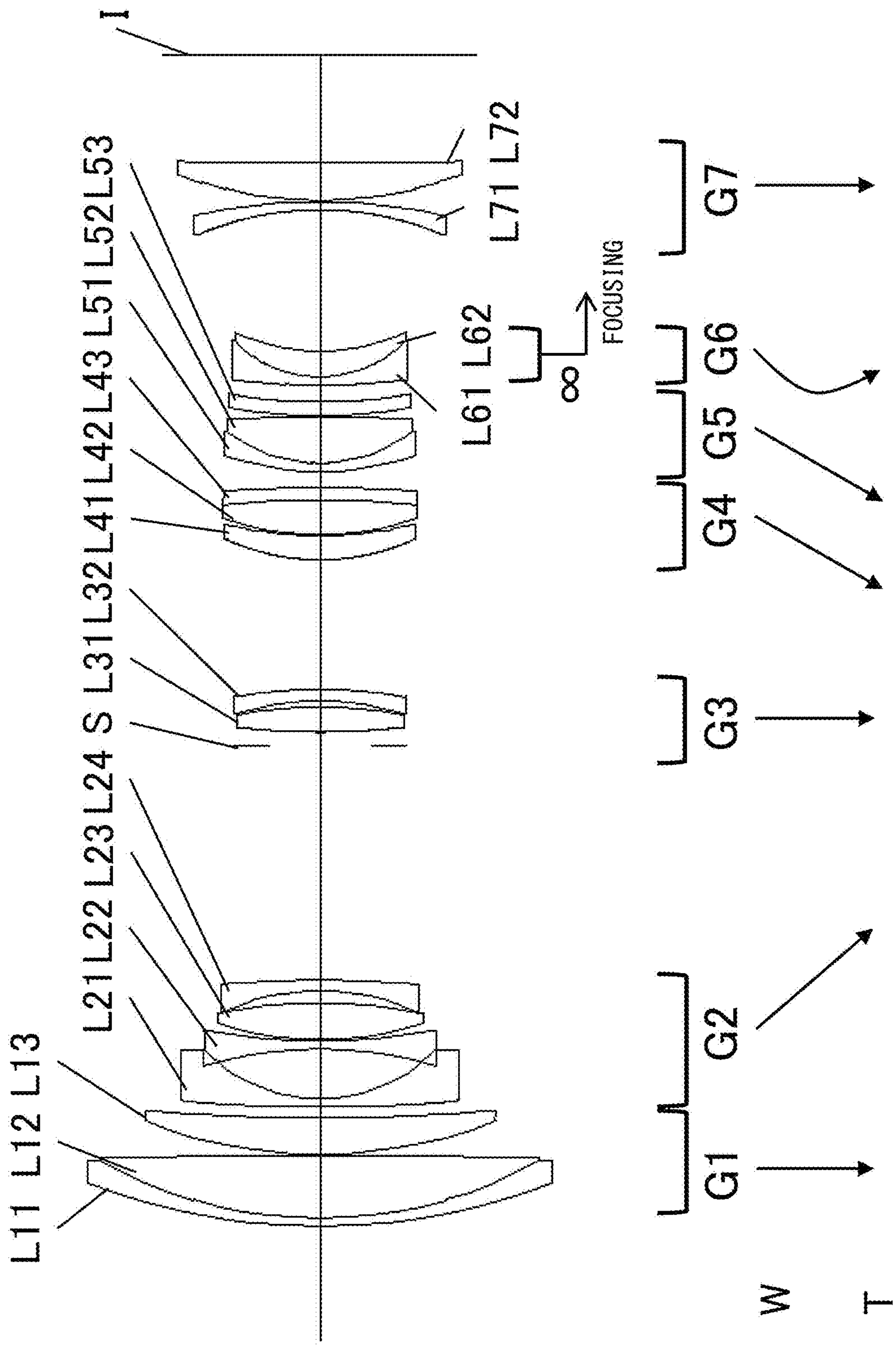
LATERAL CHROMATIC ABERRATION

Fig. 9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G1
G2
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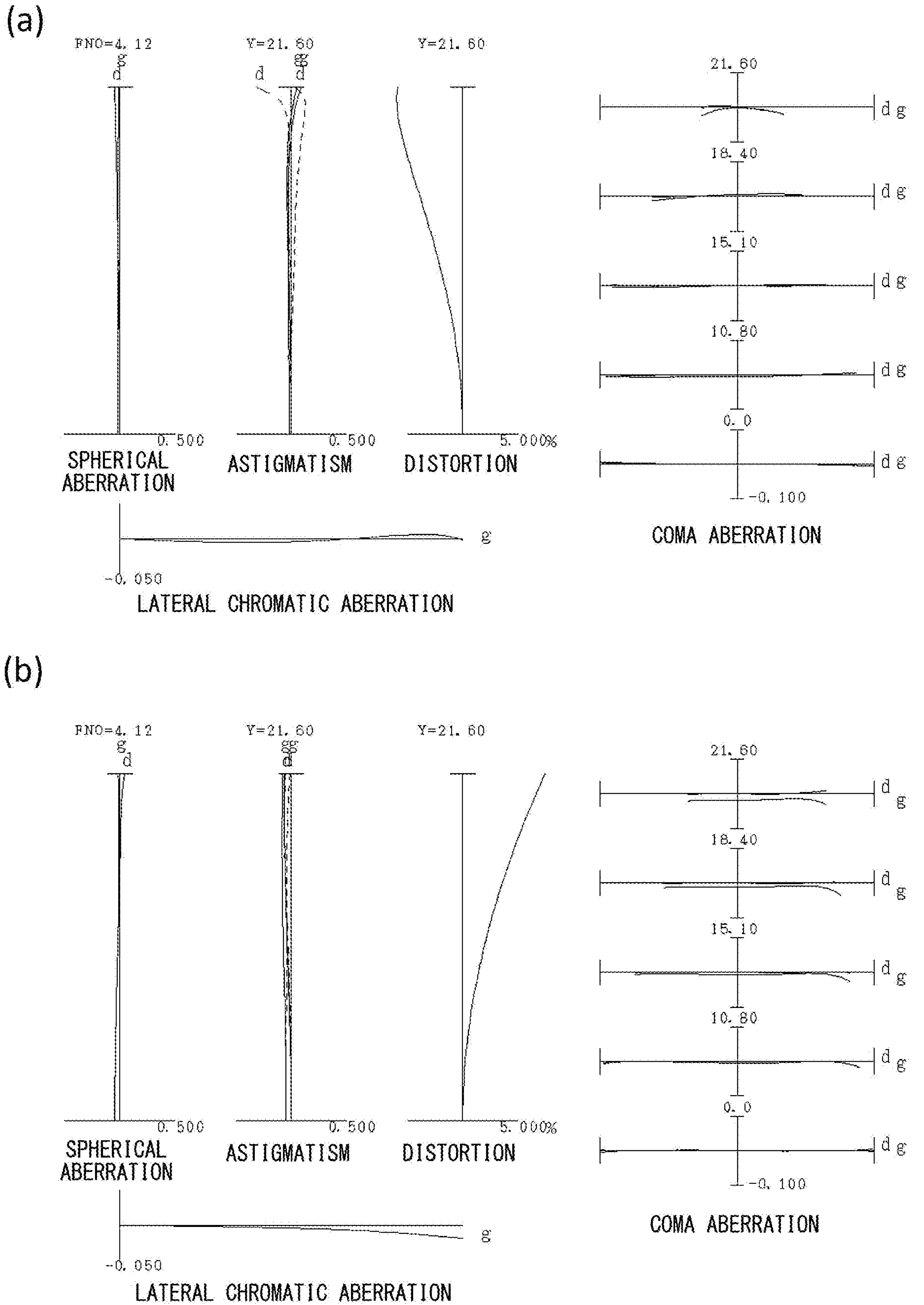
G4
G5
G6
G7
W
T

Fig. 10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(b)
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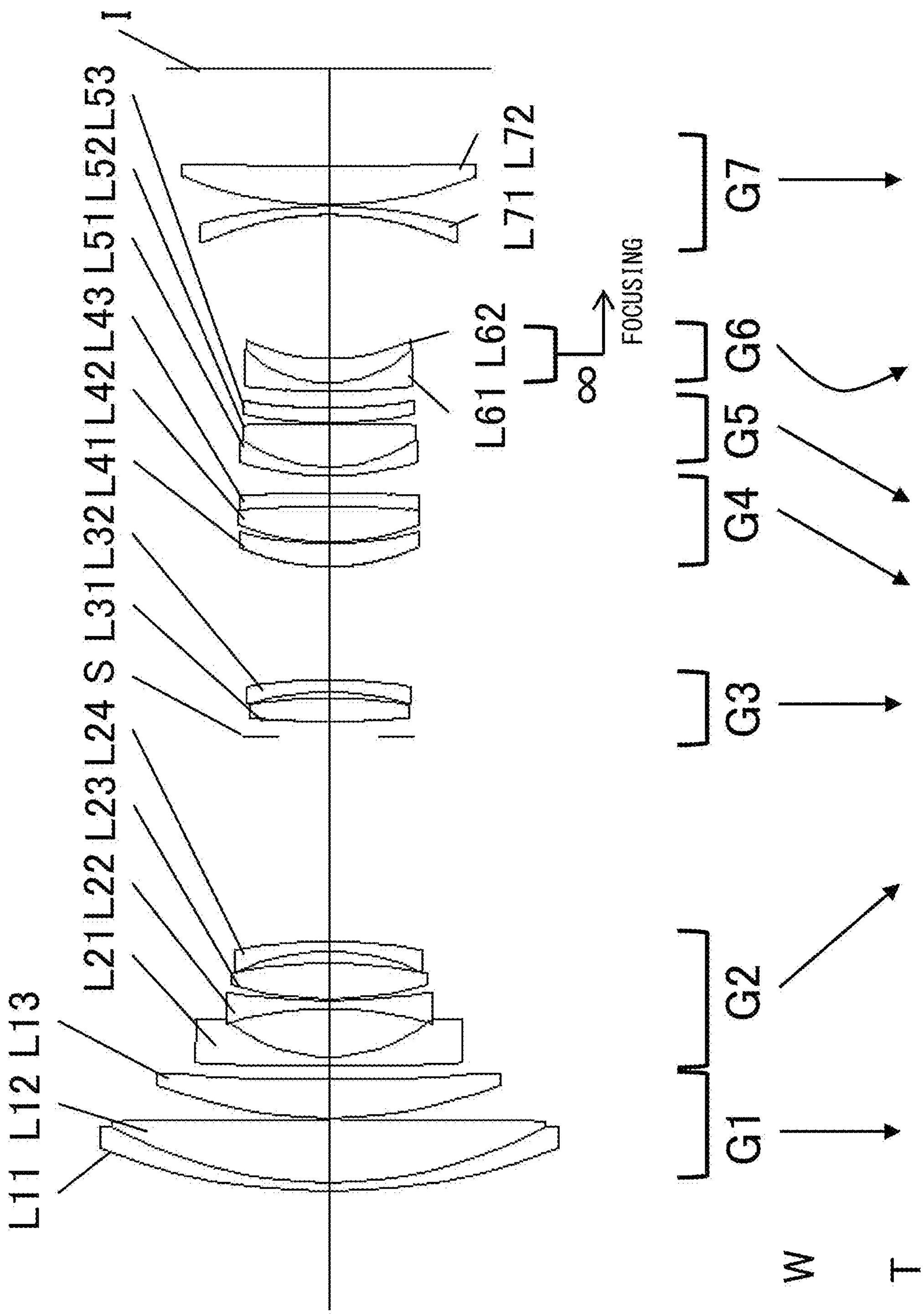
LATERAL CHROMATIC ABERRATION

Fig. 11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L61
L62
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G1
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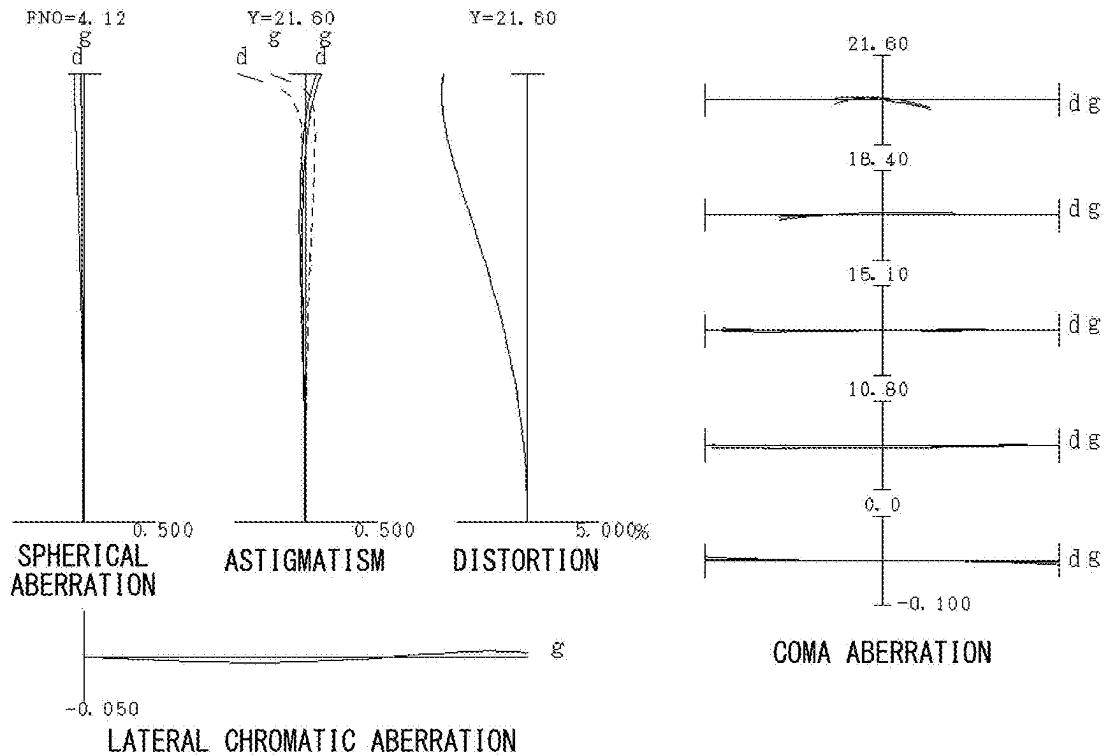
W
T

Fig. 12

(a)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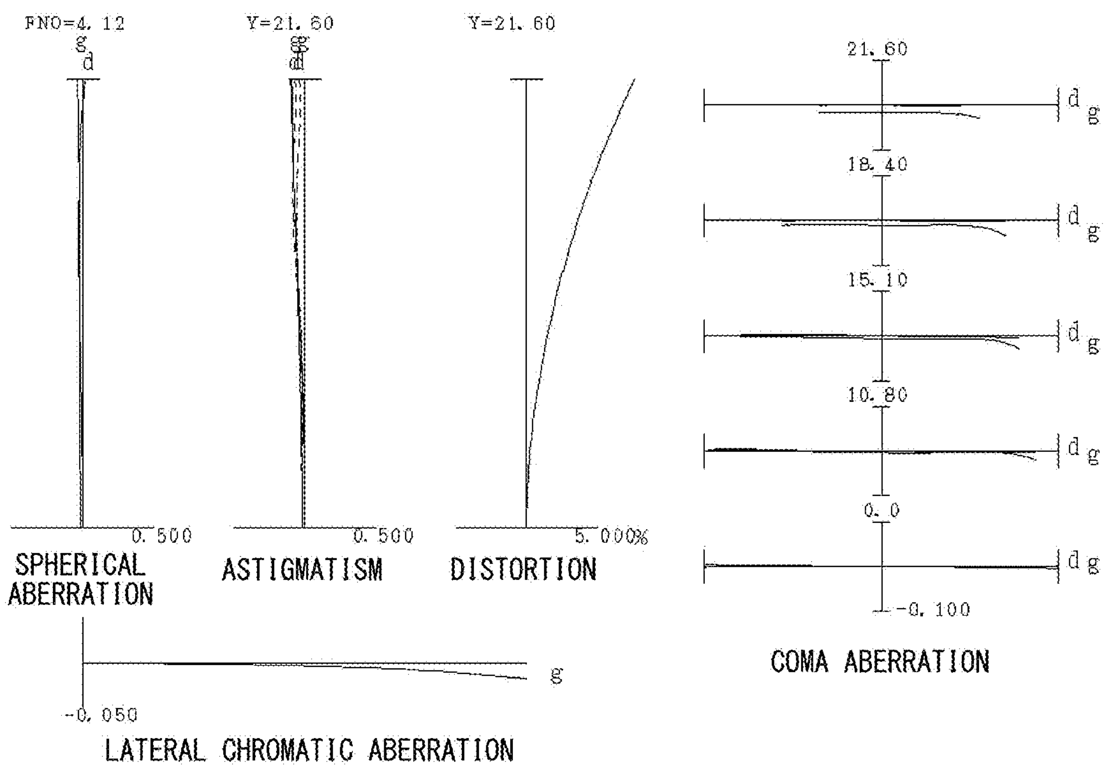
(b)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LATERAL CHROMATIC ABERRATION

Fig. 13

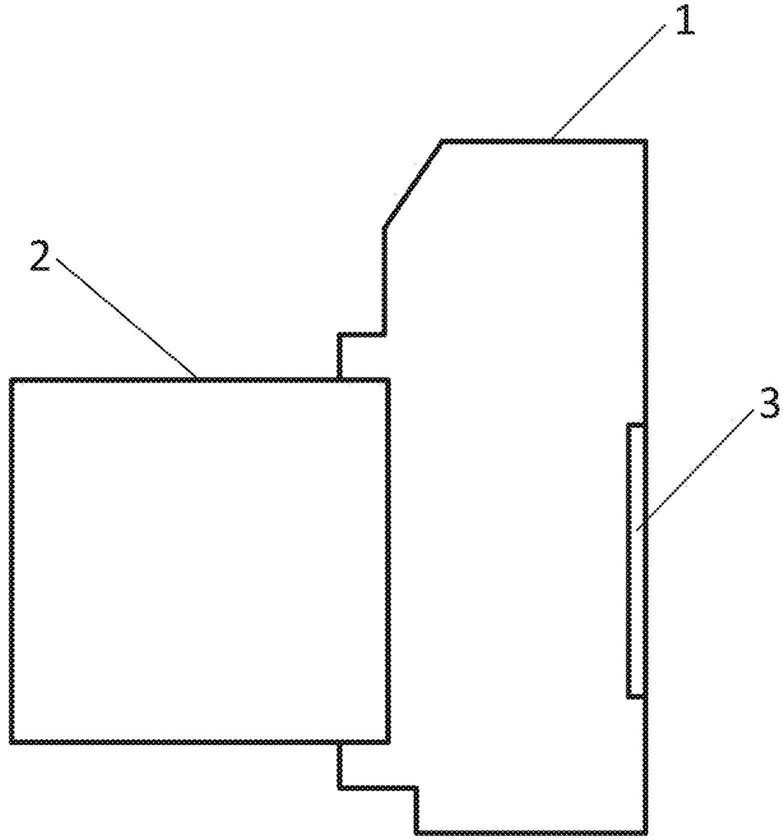
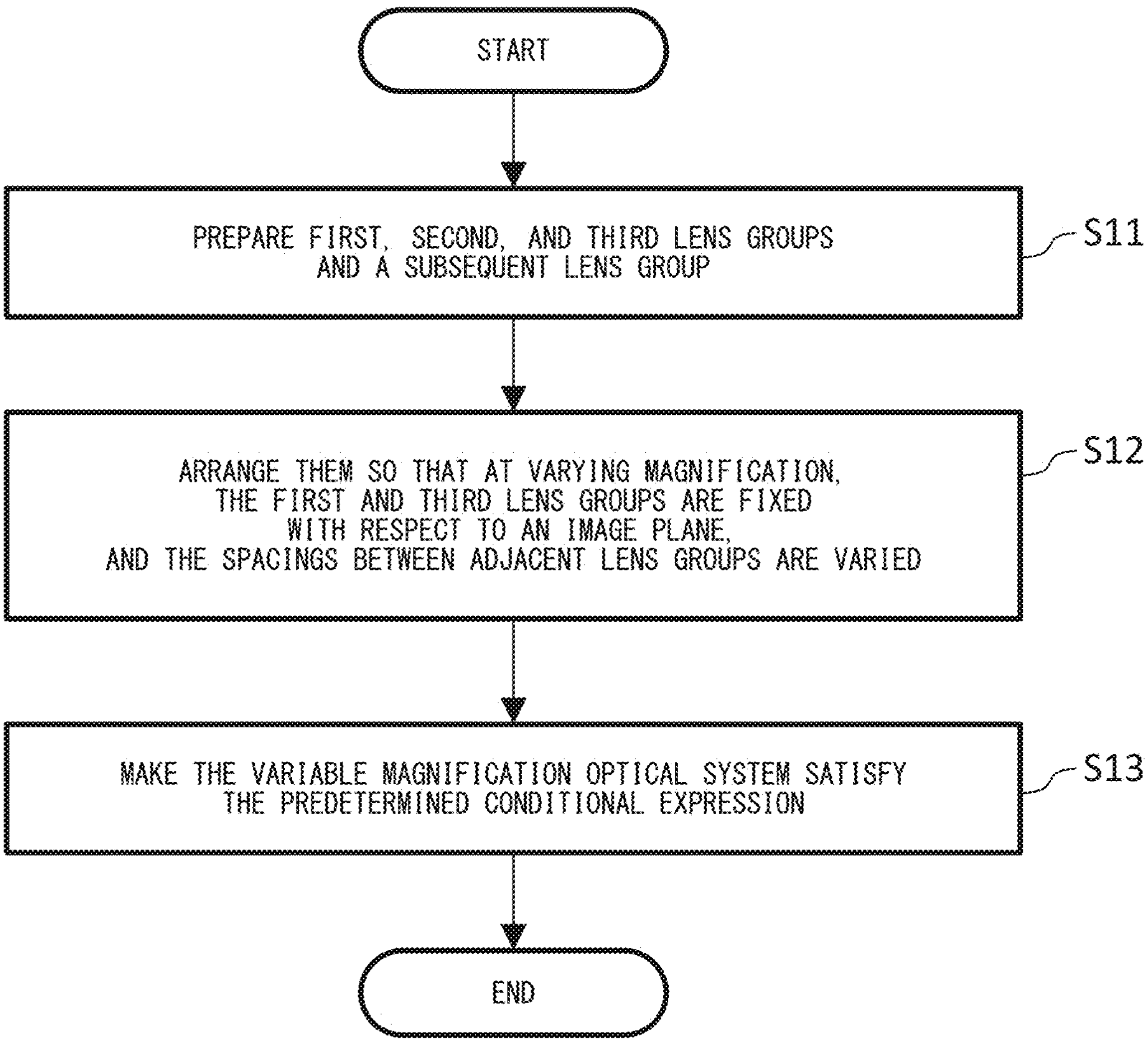


Fig. 14


START
PREPARE FIRST, SECOND, AND THIRD LENS GROUPS AND A SUBSEQUENT LENS GROUP
S11
ARRANGE THEM SO THAT AT VARYING MAGNIFICATION, THE FIRST AND THIRD LENS GROUPS ARE FIXED WITH RESPECT TO AN IMAGE PLANE, AND THE SPACINGS BETWEEN ADJACENT LENS GROUPS ARE VARIED
S12
MAKE THE VARIABLE MAGNIFICATION OPTICAL SYSTEM SATISFY THE PREDETERMINED CONDITIONAL EXPRESSION
S13
END

VARIABLE MAGNIFICATION OPTICAL SYSTEM, OPTICAL DEVICE, AND METHOD FOR MANUFACTURING VARIABLE MAGNIFICATION OPTICAL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of International Patent Application No. PCT/JP2023/038491 filed Oct. 25, 2023, which claims priority from Japanese Patent Application No. 2022-177062 filed Nov. 4, 2022, which are incorporated herein by reference.

FIELD

[0002] The present disclosure relates to a variable magnification optical system, an optical device, and a method for manufacturing a variable magnification optical system.

BACKGROUND

[0003] Variable magnification optical systems used in optical devices, such as cameras for photographs, electronic still cameras, and video cameras, have been proposed (see, e.g., Japanese Unexamined Patent Publication No. 2021-189401).

SUMMARY

[0004] A variable magnification optical system of the present disclosure includes, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups: at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied: the variable magnification optical system satisfies the following conditional expression.

$$0.24 < (TL/f1)/(ft/fw) < 0.55$$

where

[0005] TL: the distance from a lens surface closest to the object side to the image plane

[0006] f1: the focal length of the first lens group

[0007] ft: the focal length of the variable magnification optical system in a telephoto end state

[0008] fw: the focal length of the variable magnification optical system in a wide-angle end state

[0009] A method for manufacturing a variable magnification optical system of the present disclosure includes configuring a variable magnification optical system including, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups so that at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied, and that the following conditional expression is satisfied.

$$0.24<(TL/f1)/(ft/fw)<0.55$$

where

[0010] TL: the distance from a lens surface closest to the object side to the image plane

[0011] f1: the focal length of the first lens group

[0012] ft: the focal length of the variable magnification optical system in a telephoto end state

[0013] fw: the focal length of the variable magnification optical system in a wide-angle end state

BRIEF DESCRIPTION OF DRAWINGS

[0014] FIG. **1** is a cross-sectional view of a variable magnification optical system of a first example focusing on an object at infinity in the wide-angle end state.

[0015] FIG. **2**A shows aberrations of the variable magnification optical system of the first example focusing on an object at infinity in the wide-angle end state, and FIG. **2**B shows aberrations of the variable magnification optical system of the first example focusing on an object at infinity in the telephoto end state.

[0016] FIG. **3** is a cross-sectional view of a variable magnification optical system of a second example focusing on an object at infinity in the wide-angle end state.

[0017] FIG. **4**A shows aberrations of the variable magnification optical system of the second example focusing on an object at infinity in the wide-angle end state, and FIG. **4**B shows aberrations of the variable magnification optical system of the second example focusing on an object at infinity in the telephoto end state.

[0018] FIG. **5** is a cross-sectional view of a variable magnification optical system of a third example focusing on an object at infinity in the wide-angle end state.

[0019] FIG. **6**A shows aberrations of the variable magnification optical system of the third example focusing on an object at infinity in the wide-angle end state, and FIG. **6**B shows aberrations of the variable magnification optical system of the third example focusing on an object at infinity in the telephoto end state.

[0020] FIG. **7** is a cross-sectional view of a variable magnification optical system of a fourth example focusing on an object at infinity in the wide-angle end state.

[0021] FIG. **8**A shows aberrations of the variable magnification optical system of the fourth example focusing on an object at infinity in the wide-angle end state, and FIG. **8**B shows aberrations of the variable magnification optical system of the fourth example focusing on an object at infinity in the telephoto end state.

[0022] FIG. **9** is a cross-sectional view of a variable magnification optical system of a fifth example focusing on an object at infinity in the wide-angle end state.

[0023] FIG. **10**A shows aberrations of the variable magnification optical system of the fifth example focusing on an object at infinity in the wide-angle end state, and FIG. **10**B shows aberrations of the variable magnification optical system of the fifth example focusing on an object at infinity in the telephoto end state.

[0024] FIG. **11** is a cross-sectional view of a variable magnification optical system of a sixth example focusing on an object at infinity in the wide-angle end state.

[0025] FIG. **12**A shows aberrations of the variable magnification optical system of the sixth example focusing on an object at infinity in the wide-angle end state, and FIG. **12**B shows aberrations of the variable magnification optical system of the sixth example focusing on an object at infinity in the telephoto end state.

[0026] FIG. 13 schematically shows a camera including a variable magnification optical system of the embodiment.

[0027] FIG. 14 is a flowchart outlining a method for manufacturing a variable magnification optical system of the embodiment.

DESCRIPTION OF EMBODIMENTS

[0028] The following describes a variable magnification optical system, an optical device, and a method for manufacturing a variable magnification optical system of an embodiment of the present application.

[0029] A variable magnification optical system of the present embodiment includes, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups: at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied: the variable magnification optical system satisfies the following conditional expression.

$$0.24 < (TL/f1)/(ft/fw) < 0.55 \quad (1)$$

where

[0030] TL: the distance from a lens surface closest to the object side to the image plane

[0031] f1: the focal length of the first lens group

[0032] ft: the focal length of the variable magnification optical system in a telephoto end state

[0033] fw: the focal length of the variable magnification optical system in a wide-angle end state

[0034] The variable magnification optical system of the present embodiment can reduce variations in aberrations, including spherical aberration at varying magnification, by including a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups.

[0035] Conditional expression (1) restricts the ratio between the ratio of the distance from a lens surface closest to the object side to the image plane to the focal length of the first lens group and the ratio of the focal length of the variable magnification optical system in a telephoto end state to that of the variable magnification optical system in a wide-angle end state (variable power ratio). The variable magnification optical system of the present embodiment satisfying conditional expression (1) can reduce variations in aberrations, including spherical aberration at varying magnification.

[0036] If the value of conditional expression (1) exceeds the upper limit in the variable magnification optical system of the present embodiment, the first lens group will have too strong refractive power with respect to the distance from a lens surface closest to the object side to the image plane and the variable power ratio, making it difficult to reduce variations in aberrations, including spherical aberration at varying magnification.

[0037] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (1) to 0.55. To further ensure the effect of the present embodiment, the upper limit of conditional expression (1) is preferably set to 0.53, more preferably to 0.50.

[0038] If the value of conditional expression (1) is below the lower limit in the variable magnification optical system of the present embodiment, the first lens group will have too weak refractive power with respect to the distance from a lens surface closest to the object side to the image plane and the variable power ratio, making it difficult to reduce variations in aberrations, including spherical aberration at varying magnification.

[0039] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (1) to 0.24. To further ensure the effect of the present embodiment, the lower limit of conditional expression (1) is preferably set to 0.28, 0.30, or 0.33, more preferably to 0.36.

[0040] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$3.00 < f1/(-f2) < 5.80 \quad (2)$$

where

[0041] f2: the focal length of the second lens group

[0042] Conditional expression (2) restricts the ratio between the focal lengths of the first and second lens groups. The variable magnification optical system of the present embodiment satisfying conditional expression (2) can reduce variations in aberrations, including coma aberration at varying magnification.

[0043] If the value of conditional expression (2) exceeds the upper limit in the variable magnification optical system of the present embodiment, the second lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0044] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (2) to 5.80. To further ensure the effect of the present embodiment, the upper limit of conditional expression (2) is preferably set to 5.60, more preferably to 5.40.

[0045] If the value of conditional expression (2) is below the lower limit in the variable magnification optical system of the present embodiment, the first lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0046] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (2) to 3.00. To further ensure the effect of the present embodiment, the lower limit of conditional expression (2) is preferably set to 3.30, 3.50, or 3.75, more preferably to 3.90.

[0047] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$0.45 < f1/f3 < 6.00 \tag{3}$$

where

[0048] f3: the focal length of the third lens group

[0049] Conditional expression (3) restricts the ratio between the focal lengths of the first and third lens groups. The variable magnification optical system of the present embodiment satisfying conditional expression (3) can reduce variations in aberrations, including coma aberration at varying magnification.

[0050] If the value of conditional expression (3) exceeds the upper limit in the variable magnification optical system of the present embodiment, the third lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0051] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (3) to 6.00. To further ensure the effect of the present embodiment, the upper limit of conditional expression (3) is preferably set to 5.50, 5.00, 4.80, or 4.50, more preferably to 4.00.

[0052] If the value of conditional expression (3) is below the lower limit in the variable magnification optical system of the present embodiment, the first lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0053] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (3) to 0.45. To further ensure the effect of the present embodiment, the lower limit of conditional expression (3) is preferably set to 0.50 or 0.55, more preferably to 0.60.

[0054] In the variable magnification optical system of the present embodiment, the subsequent lens group preferably includes a focusing lens group having negative refractive power and moving at focusing, and the following conditional expression is preferably satisfied.

$$0.30 < f2/fF < 1.00 \tag{4}$$

where

[0055] f2: the focal length of the second lens group

[0056] fF: the focal length of the focusing lens group

[0057] The variable magnification optical system of the present embodiment can reduce variations in aberrations, including spherical aberration at focusing, by the subsequent lens group including a focusing lens group.

[0058] Conditional expression (4) restricts the ratio between the focal lengths of the second lens group and the focusing lens group. The variable magnification optical system of the present embodiment satisfying conditional expression (4) can reduce variations in aberrations, including coma aberration at varying magnification and spherical aberration at focusing.

[0059] If the value of conditional expression (4) exceeds the upper limit in the variable magnification optical system of the present embodiment, the focusing lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including spherical aberration at focusing.

[0060] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (4) to 1.00. To further ensure the effect of the present embodiment, the upper limit of conditional expression (4) is preferably set to 0.90, 0.80, or 0.75, more preferably to 0.70.

[0061] If the value of conditional expression (4) is below the lower limit in the variable magnification optical system of the present embodiment, the second lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0062] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (4) to 0.30. To further ensure the effect of the present embodiment, the lower limit of conditional expression (4) is preferably set to 0.33, more preferably to 0.35.

[0063] In the variable magnification optical system of the present embodiment, a final lens group disposed closest to the image plane in the subsequent lens group is preferably fixed with respect to the image plane at varying magnification.

[0064] Such a configuration simplifies a mechanism for moving the lens groups at varying magnification, enabling the variable magnification optical system of the present embodiment to be reduced in size and weight.

[0065] In the variable magnification optical system of the present embodiment, the subsequent lens group preferably includes a focusing lens group having negative refractive power and moving at focusing and a final lens group disposed closest to the image plane, and the following conditional expression is preferably satisfied.

$$2.00 < |fR|/(-fF) < 100.00 \tag{5}$$

where

[0066] fR: the focal length of the final lens group

[0067] fF: the focal length of the focusing lens group

[0068] Conditional expression (5) restricts the ratio between the focal lengths of the final lens group and the focusing lens group. The variable magnification optical system of the present embodiment satisfying conditional expression (5) can reduce variations in aberrations, including coma aberration at varying magnification and spherical aberration at focusing.

[0069] If the value of conditional expression (5) exceeds the upper limit in the variable magnification optical system of the present embodiment, the focusing lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including spherical aberration at focusing.

[0070] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (5) to 100.00. To further ensure the effect of the present embodiment, the upper limit of conditional expression (5) is preferably set to 80.00, 65.00, 55.00, 40.00, or 25.00, more preferably to 15.00.

[0071] If the value of conditional expression (5) is below the lower limit in the variable magnification optical system of the present embodiment, the final lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0072] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (5) to 2.00. To further ensure the effect of the present embodiment, the lower limit of conditional expression (5) is preferably set to 2.30 or 2.50, more preferably to 2.70.

[0073] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$1.5 < BFw/fw < 0.95 \tag{6}$$

where

[0074] BFw: the back focal length of the variable magnification optical system focusing on infinity in the wide-angle end state

[0075] Conditional expression (6) restricts the ratio between the focal length of the variable magnification optical system in a wide-angle end state and the back focal length of the variable magnification optical system focusing on infinity in the wide-angle end state. The variable magnification optical system of the present embodiment satisfying conditional expression (6) can correct aberrations, including coma aberration at focusing on infinity in the wide-angle end state, favorably.

[0076] If the value of conditional expression (6) exceeds the upper limit in the variable magnification optical system of the present embodiment, the back focal length will be large with respect to the focal length in the wide-angle end state, making it difficult to correct aberrations, including coma aberration at focusing on infinity in the wide-angle end state, favorably.

[0077] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (6) to 0.95. To further ensure the effect of the present embodiment, the upper limit of conditional expression (6) is preferably set to 0.92, more preferably to 0.90.

[0078] If the value of conditional expression (6) is below the lower limit in the variable magnification optical system of the present embodiment, the back focal length will be small with respect to the focal length in the wide-angle end state, making it difficult to correct aberrations, including coma aberration at focusing on infinity in the wide-angle end state, favorably.

[0079] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (6) to 0.15. To further ensure the effect of the present embodiment, the lower limit of conditional expression (6) is preferably set to 0.20, 0.30, or 0.40, more preferably to 0.45.

[0080] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$0.08 < BFt/ft < 0.24 \tag{7}$$

where

[0081] BFt: the back focal length of the variable magnification optical system focusing on infinity in the telephoto end state

[0082] Conditional expression (7) restricts the ratio between the focal length of the variable magnification optical system in a telephoto end state and the back focal length of the variable magnification optical system focusing on infinity in the telephoto end state. The variable magnification optical system of the present embodiment satisfying conditional expression (7) can correct aberrations, including coma aberration at focusing on infinity in the telephoto end state, favorably.

[0083] If the value of conditional expression (7) exceeds the upper limit in the variable magnification optical system of the present embodiment, the back focal length will be large with respect to the focal length in the telephoto end state, making it difficult to correct aberrations, including coma aberration at focusing on infinity in the telephoto end state, favorably.

[0084] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (7) to 0.24. To further ensure the effect of the present embodiment, the upper limit of conditional expression (7) is preferably set to 0.22, more preferably to 0.20.

[0085] If the value of conditional expression (7) is below the lower limit in the variable magnification optical system of the present embodiment, the back focal length will be small with respect to the focal length in the telephoto end state, making it difficult to correct aberrations, including coma aberration at focusing on infinity in the telephoto end state, favorably.

[0086] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (7) to 0.08. To further ensure the effect of the present embodiment, the lower limit of conditional expression (7) is preferably set to 0.09, more preferably to 0.10.

[0087] In the variable magnification optical system of the present embodiment, the plurality of lens groups in the subsequent lens group preferably includes at least one lens group having positive refractive power, and the following conditional expression is preferably satisfied.

$$0.70 < f1/fRP < 3.40 \tag{8}$$

where

[0088] fRP: the focal length of a lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power

[0089] The variable magnification optical system of the present embodiment can reduce variations in aberrations, including coma aberration at varying magnification by the subsequent lens group including at least one lens group having positive refractive power.

[0090] Conditional expression (8) restricts the ratio between the focal lengths of the first lens group and a lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power. The variable magnification optical system of the present embodiment satisfying conditional expression (8) can reduce variations in aberrations, including coma aberration at varying magnification.

[0091] If the value of conditional expression (8) exceeds the upper limit in the variable magnification optical system of the present embodiment, the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0092] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (8) to 3.40. To further ensure the effect of the present embodiment, the upper limit of conditional expression (8) is preferably set to 3.30, 3.20, or 3.08, more preferably to 3.00.

[0093] If the value of conditional expression (8) is below the lower limit in the variable magnification optical system of the present embodiment, the first lens group will have too strong refractive power, making it difficult to reduce variations in aberrations, including coma aberration at varying magnification.

[0094] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (8) to 0.70. To further ensure the effect of the present embodiment, the lower limit of conditional expression (8) is preferably set to 0.72, 0.80, 0.85, or 0.90, more preferably to 0.95.

[0095] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$0.50 < Gw/Gt < 1.50 \quad (9)$$

where

[0096] Gw: the distance from the lens surface closest to the object side in the variable magnification optical system in the wide-angle end state to the centroid position of the variable magnification optical system

[0097] Gt: the distance from the lens surface closest to the object side in the variable magnification optical system in the telephoto end state to the centroid position of the variable magnification optical system

[0098] Conditional expression (9) restricts the ratio of the distance from the lens surface closest to the object side in the variable magnification optical system in the wide-angle end state to the centroid position of the variable magnification optical system to the distance from the lens surface closest to the object side in the variable magnification optical system in the telephoto end state to the centroid position of the variable magnification optical system. In the variable magnification optical system of the present embodiment satisfying conditional expression (9), the change in the centroid position at varying magnification will be small, which enhances usability.

[0099] When the variable magnification optical system of the present embodiment does not satisfy conditional expression (9), the change in the centroid position at varying magnification will be large, which impairs usability.

[0100] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (9) to 1.50. To further ensure the effect of the present embodiment, the upper limit of conditional expression (9) is preferably set to 1.40, 1.30, 1.20, or 1.10, more preferably to 1.00.

[0101] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (9) to 0.50. To further ensure the effect of the present embodiment, the lower limit of conditional expression (9) is preferably set to 0.60, 0.70, or 0.80, more preferably to 0.90.

[0102] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$30.00° < \omega w \quad (10)$$

where

[0103] ωw: the semi-field angle of the variable magnification optical system in the wide-angle end state

[0104] Conditional expression (10) restricts the semi-field angle of the variable magnification optical system in the wide-angle end state. The variable magnification optical system of the present embodiment satisfying conditional expression (10) can form an image of a wide-spread subject on the image plane.

[0105] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the lower limit of conditional expression (10) to 30.00°. To further ensure the effect of the present embodiment, the lower limit of conditional expression (10) is preferably set to 34.00°, more preferably to 36.00°.

[0106] The variable magnification optical system of the present embodiment preferably satisfies the following conditional expression.

$$\omega t < 15.00° \quad (11)$$

where

[0107] ωt: the semi-field angle of the variable magnification optical system in the telephoto end state

[0108] Conditional expression (11) restricts the semi-field angle of the variable magnification optical system in the telephoto end state. The variable magnification optical system of the present embodiment satisfying conditional expression (11) can form a large image of a distant subject on the image plane.

[0109] In the variable magnification optical system of the present embodiment, the effect of the present embodiment can be ensured by setting the upper limit of conditional expression (11) to 15.00°. To further ensure the effect of the present embodiment, the upper limit of conditional expression (11) is preferably set to 13.00°, more preferably to 12.00°.

[0110] A small-sized variable magnification optical system of favorable imaging performance can be achieved by the above configurations.

[0111] An optical device of the present embodiment includes a variable magnification optical system configured as described above. This enables achieving an optical device of favorable optical performance.

[0112] A method for manufacturing a variable magnification optical system of the present embodiment includes configuring a variable magnification optical system including, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups so that at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied, and that the following conditional expression is satisfied.

$$0.24 < (TL/f1)/(ft/fw) < 0.55 \tag{1}$$

where

[0113] TL: the distance from a lens surface closest to the object side to the image plane

[0114] f1: the focal length of the first lens group

[0115] ft: the focal length of the variable magnification optical system in a telephoto end state

[0116] fw: the focal length of the variable magnification optical system in a wide-angle end state

[0117] A variable magnification optical system of favorable optical performance can be manufactured by such a method for manufacturing an optical system.

NUMERICAL EXAMPLES

[0118] Examples of the present application will be described below with reference to the drawings.

First Example

[0119] FIG. 1 is a cross-sectional view of a variable magnification optical system of a first example focusing on an object at infinity in the wide-angle end state.

[0120] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G1 having positive refractive power, a second lens group G2 having negative refractive power, a third lens group G3 having positive refractive power, a fourth lens group G4 having negative refractive power, and a fifth lens group G5 having positive refractive power.

[0121] The first lens group G1 consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L11 convex on the object side and a biconvex positive lens L12, and a meniscus-shaped positive lens L13 convex on the object side.

[0122] The second lens group G2 consists of, in order from the object side, a meniscus-shaped negative lens L21 convex on the object side, a biconcave negative lens L22, a biconvex positive lens L23, and a meniscus-shaped negative lens L24 concave on the object side.

[0123] The third lens group G3 consists of, in order from the object side, an aperture stop S, a biconvex positive lens L31, a positive cemented lens composed of a biconvex positive lens L32 and a meniscus-shaped negative lens L33 concave on the object side, and a positive cemented lens composed of a meniscus-shaped negative lens L34 convex on the object side and a biconvex positive lens L35.

[0124] The fourth lens group G4 consists of a negative cemented lens composed of a meniscus-shaped positive lens L41 concave on the object side and a biconcave negative lens L42.

[0125] The fifth lens group G5 consists of, in order from the object side, a biconvex positive lens L51, a negative cemented lens composed of a meniscus-shaped positive lens L52 concave on the object side and a biconcave negative lens L53, a positive cemented lens composed of a meniscus-shaped negative lens L54 convex on the object side and a biconvex positive lens L55, and a meniscus-shaped negative lens L56 concave on the object side.

[0126] An imaging device (not shown) constructed from CCD. CMOS, or the like is disposed on an image plane I.

[0127] The variable magnification optical system of the present example focuses by moving the fourth lens group G4 along the optical axis. When focus is shifted from infinity to a nearby object, the fourth lens group G4 moves from the object side toward the image plane side.

[0128] In the variable magnification optical system of the present example, the fourth lens group G4 and the fifth lens group G5 correspond to the subsequent lens group: the fourth lens group G4 corresponds to the focusing lens group: the fifth lens group G5 corresponds to the final lens group. The fifth lens group G5 corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0129] Table 1 below shows specifications of the variable magnification optical system of the present example.

[0130] In [General specifications]. TL is the distance from a lens surface closest to the object side to the image plane: fw is the focal length of the whole system in the wide-angle end state: ft is the focal length of the whole system in the telephoto end state: FNOw is the f-number in the wide-angle end state: FNOt is the f-number in the telephoto end state; ww is the semi-field angle (degrees) in the wide-angle end state; ωt is the semi-field angle (degrees) in the telephoto end state: Y is the maximum image height.

[0131] In [Lens specifications], m denotes the numbers of optical surfaces counted from the object side, r the radii of curvature, d the surface-to-surface distances, nd the refractive indices at d-line (wavelength 587.6 nm), and νd the Abbe numbers based on d-line. The radius of curvature r=∞ means a plane. In [Lens specifications], the optical surfaces with "*" are aspherical surfaces.

[0132] In [Aspherical surface data], m denotes the optical surfaces corresponding to aspherical surface data. K the conic constants, and A4 to A12 the aspherical coefficients.

[0133] The aspherical surfaces are expressed by expression (a) below, where y denotes the height in a direction perpendicular to the optical axis, S(y) the distance along the optical axis from the tangent plane at the vertex of an aspherical surface to the aspherical surface at height y (a sag), r the radius of curvature of a reference sphere (paraxial radius of curvature), K the conic constant, and An the nth-order aspherical coefficient. In the examples, the second-order aspherical coefficient A2 is 0. "E-n" means "$\times 10^{-n}$."

$$S(y)=(y^2/r)/\left\{1+\left(1-K\times y^2/r^2\right)^{1/2}\right\}+A4\times y^4+A6\times y^6+A8\times y^8+A10\times y^{10}+A12\times y^{12} \quad \text{(a)}$$

[0134] The unit of the focal lengths fW and fT, the radii of curvature r, and the other lengths listed in Table 1 is "mm." However, the values are not limited thereto because the optical performance of a proportionally enlarged or reduced optical system is the same as that of the original optical system.

[0135] The above reference symbols in Table 1 will also be used similarly in the tables of the other examples described below.

TABLE 1

[General specifications]

TL	185.45
fw	28.80
ft	131.00
FNOw	4.11
FNOt	4.12
ωw	38.46
ωt	8.68
Y	21.60

[lens specifications]

m	r	d	nd	vd
1)	203.5350	2.000	1.90366	31.27
2)	66.2025	10.955	1.59319	67.90
3)	−394.6700	0.200		
4)	61.5683	6.780	1.75500	52.34
5)	263.3113	D5		
*6)	180.9166	1.500	1.82098	42.50
7)	19.6183	6.756		
8)	−44.0068	1.500	1.83481	42.73
9)	82.0673	0.200		
10)	43.9489	4.902	1.80809	22.74
11)	−42.7886	0.967		
12)	−29.1485	1.500	1.81600	46.59
13)	−206.5239	D13		
14)	∞	2.000		(aperture stop)
*15)	102.6863	2.882	1.59245	66.92
16)	−108.3264	0.200		
17)	44.1156	5.502	1.59319	67.90
18)	−52.1552	1.500	1.85883	30.00
19)	−90.3268	3.621		
20)	41.9375	1.500	2.00100	29.12
21)	22.4452	7.995	1.55332	71.67
*22)	−37.7944	D22		
23)	−101.0979	2.706	1.94595	17.98
24)	−32.6426	1.500	1.77387	47.25
*25)	23.4907	D25		
26)	38.2444	9.394	1.59319	67.90
27)	−33.7518	0.200		
28)	−69.6810	7.610	1.78472	25.64
29)	−19.0000	1.500	2.00069	25.46
30)	65.6562	0.210		
31)	44.8073	1.500	1.90366	31.27
32)	23.5000	10.489	1.69895	30.13
33)	−57.9472	5.237		
*34)	−20.4734	1.500	1.74310	49.44
35)	−30.6723	D35		

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	3.202E−06	−7.029E−09	2.763E−11	−7.583E−14	1.181E−16
15)	1.0000	−8.531E−06	−1.770E−09	−7.217E−12	3.167E−14	
22)	1.0000	6.339E−06	−1.292E−08	3.068E−11	−1.100E−14	
25)	1.0000	−6.885E−06	−3.233E−09	1.766E−10	−1.843E−12	
34)	1.0000	3.056E−06	8.008E−09	1.421E−10	−4.651E−13	1.075E−15

TABLE 1-continued

[Focal length data of groups]

Groups	First surfaces	Focal lengths
G1	1	92.73
G2	6	−17.34
G3	14	24.62
G4	23	−26.67
G5	26	96.06

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	2.000	25.493	37.799	2.000	25.493	37.799
D13	37.799	14.305	2.000	37.799	14.305	2.000
D22	2.000	9.389	16.869	2.153	9.804	17.740
D25	21.523	14.134	6.655	21.370	13.720	5.783
D35	17.828	17.828	17.828	17.828	17.828	17.828

[0136] FIG. **2**A shows aberrations of the variable magnification optical system of the first example focusing on an object at infinity in the wide-angle end state: FIG. **2**B shows aberrations of the variable magnification optical system of the first example focusing on an object at infinity in the telephoto end state.

[0137] In the graphs of aberrations, FNO and Y denote f-number and image height, respectively. More specifically, the graph of spherical aberration shows the f-number corresponding to the maximum aperture: the graphs of astigmatism and distortion show the maximum of image height: the graphs of coma aberration show the values of image height. d and g denote d-line and g-line (wavelength 435.8 nm), respectively. In the graph of astigmatism, the solid lines and the broken lines show a sagittal plane and a meridional plane, respectively. The reference symbols in the graphs of aberrations of the present example will also be used in those of the other examples described below.

[0138] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

Second Example

[0139] FIG. **3** is a cross-sectional view of a variable magnification optical system of a second example focusing on an object at infinity in the wide-angle end state.

[0140] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G**1** having positive refractive power, a second lens group G**2** having negative refractive power, a third lens group G**3** having positive refractive power, a fourth lens group G**4** having negative refractive power, and a fifth lens group G**5** having positive refractive power.

[0141] The first lens group G**1** consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L**11** convex on the object side and a biconvex positive lens L**12**, and a meniscus-shaped positive lens L**13** convex on the object side.

[0142] The second lens group G**2** consists of, in order from the object side, a meniscus-shaped negative lens L**21** convex on the object side, a biconcave negative lens L**22**, a biconvex positive lens L**23**, and a meniscus-shaped negative lens L**24** concave on the object side.

[0143] The third lens group G**3** consists of, in order from the object side, an aperture stop S, a biconvex positive lens L**31**, a positive cemented lens composed of a biconvex positive lens L**32** and a meniscus-shaped negative lens L**33** concave on the object side, and a positive cemented lens composed of a meniscus-shaped negative lens L**34** convex on the object side and a biconvex positive lens L**35**.

[0144] The fourth lens group G**4** consists of a negative cemented lens composed of a meniscus-shaped positive lens L**41** concave on the object side and a biconcave negative lens L**42**.

[0145] The fifth lens group G**5** consists of, in order from the object side, a negative cemented lens composed of a biconvex positive lens L**51** and a meniscus-shaped negative lens L**52** concave on the object side, a biconvex positive lens L**53**, and a meniscus-shaped negative lens L**54** concave on the object side.

[0146] An imaging device (not shown) constructed from CCD, CMOS, or the like is disposed on an image plane I.

[0147] The variable magnification optical system of the present example focuses by moving the fourth lens group G**4** along the optical axis. When focus is shifted from infinity to a nearby object, the fourth lens group G**4** moves from the object side toward the image plane side.

[0148] In the variable magnification optical system of the present example, the fourth lens group G**4** and the fifth lens group G**5** correspond to the subsequent lens group: the fourth lens group G**4** corresponds to the focusing lens group: the fifth lens group G**5** corresponds to the final lens group. The fifth lens group G**5** corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0149] Table 2 below shows specifications of the variable magnification optical system of the present example.

TABLE 2

[General specifications]

TL	185.45
fw	28.80
ft	131.00
FNOw	4.12
FNOt	4.12
ωw	38.55
ωt	8.68
Y	21.60

[lens specifications]

m	r	d	nd	vd
1)	160.9680	2.000	1.85883	30.00
2)	66.6346	10.667	1.49782	82.57
3)	−440.7488	0.200		
4)	61.6751	6.785	1.75500	52.34
5)	270.2573	D5		
*6)	200.0407	1.500	1.82098	42.50
7)	19.4035	6.813		
8)	−50.3925	1.500	1.81600	46.59
9)	88.0073	0.200		
10)	40.5880	4.660	1.80809	22.74
11)	−61.3314	1.043		
12)	−35.5828	1.500	1.77250	49.62
13)	−1523.3790	D13		
14)	∞	2.000		(aperture stop)
*15)	89.0223	2.817	1.59245	66.92
16)	−138.8020	0.200		
17)	43.1800	5.721	1.59319	67.90
18)	−46.1385	1.500	2.00069	25.46
19)	−75.7096	2.760		
20)	42.7879	1.500	1.90265	35.77
21)	19.9289	8.552	1.55332	71.67
*22)	−37.9809	D22		
23)	−91.1448	2.782	1.94595	17.98
24)	−30.5403	1.500	1.77387	47.25
*25)	23.7535	D25		
26)	48.8085	8.210	1.49782	82.57
27)	−39.8555	1.500	2.00100	29.12
28)	−1151.4031	0.247		
29)	78.5798	9.000	1.55298	55.07
30)	−35.4446	9.937		
*31)	−25.9824	1.500	1.74310	49.44
32)	−39.1102	D32		

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	2.250E−06	−6.521E−09	2.698E−11	−8.238E−14	1.019E−16
15)	1.0000	−8.797E−06	−8.208E−11	−2.286E−11	5.285E−14	
22)	1.0000	4.616E−06	−1.129E−08	2.220E−12	2.745E−14	
25)	1.0000	−7.596E−06	3.224E−09	−2.256E−11	−6.035E−13	
31)	1.0000	−3.031E−06	−7.979E−09	7.173E−11	−2.277E−13	3.068E−16

[Focal length data of groups]

Groups	First surfaces	Focal lengths
G1	1	94.25
G2	6	−17.77
G3	14	24.74
G4	23	−26.42
G5	26	76.08

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	2.000	25.602	37.954	2.000	25.602	37.954
D13	37.954	14.352	2.000	37.954	14.352	2.000
D22	2.000	9.302	16.644	2.160	9.726	17.519

TABLE 2-continued

D25	21.625	14.323	6.981	21.465	13.899	6.106
D32	25.282	25.282	25.281	25.282	25.282	25.281

[0150] FIG. **4**A shows aberrations of the variable magnification optical system of the second example focusing on an object at infinity in the wide-angle end state; FIG. **4**B shows aberrations of the variable magnification optical system of the second example focusing on an object at infinity in the telephoto end state.

[0151] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

Third Example

[0152] FIG. **5** is a cross-sectional view of a variable magnification optical system of a third example focusing on an object at infinity in the wide-angle end state.

[0153] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G**1** having positive refractive power, a second lens group G**2** having negative refractive power, a third lens group G**3** having positive refractive power, a fourth lens group G**4** having positive refractive power, a fifth lens group G**5** having negative refractive power, and a sixth lens group G**6** having positive refractive power.

[0154] The first lens group G**1** consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L**11** convex on the object side and a biconvex positive lens L**12**, and a meniscus-shaped positive lens L**13** convex on the object side.

[0155] The second lens group G**2** consists of, in order from the object side, a meniscus-shaped negative lens L**21** convex on the object side, a biconcave negative lens L**22**, a biconvex positive lens L**23**, and a meniscus-shaped negative lens L**24** concave on the object side.

[0156] The third lens group G**3** consists of, in order from the object side, an aperture stop S, a biconvex positive lens L**31**, and a meniscus-shaped negative lens L**32** concave on the object side.

[0157] The fourth lens group G**4** consists of, in order from the object side, a meniscus-shaped positive lens L**41** convex on the object side, a biconvex positive lens L**42**, a positive cemented lens composed of a meniscus-shaped negative lens L**43** convex on the object side and a biconvex positive lens L**44**, and a meniscus-shaped negative lens L**45** convex on the object side.

[0158] The fifth lens group G**5** consists of a negative cemented lens composed of a meniscus-shaped negative lens L**51** convex on the object side and a meniscus-shaped positive lens L**52** convex on the object side.

[0159] The sixth lens group G**6** consists of, in order from the object side, a meniscus-shaped negative lens L**61** concave on the object side and a biconvex positive lens L**62**.

[0160] An imaging device (not shown) constructed from CCD, CMOS, or the like is disposed on an image plane I.

[0161] The variable magnification optical system of the present example focuses by moving the fifth lens group G**5** along the optical axis. When focus is shifted from infinity to a nearby object, the fifth lens group G**5** moves from the object side toward the image plane side.

[0162] In the variable magnification optical system of the present example, the fourth, fifth, and sixth lens groups G**4**, G**5**, and G**6** correspond to the subsequent lens group: the fifth lens group G**5** corresponds to the focusing lens group: the sixth lens group G**6** corresponds to the final lens group. The fourth lens group G**4** corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0163] Table 3 below shows specifications of the variable magnification optical system of the present example.

TABLE 3

[General specifications]

TL	178.46
fw	28.84
ft	130.95
FNOw	4.12
FNOt	4.12
ωw	38.54
ωt	8.71
Y	21.60

[lens specifications]

m	r	d	nd	νd
1)	106.2485	1.200	1.85451	25.15
2)	72.9108	7.265	1.49782	82.57
3)	−2566.3273	0.200		
4)	73.1525	5.243	1.59319	67.90
5)	311.0755	D5		
*6)	407.0508	1.200	1.85108	40.12
7)	26.2159	7.148		
8)	−51.6266	1.200	1.72916	54.61
9)	51.4576	0.200		
10)	45.6463	5.333	1.85451	25.15
11)	−83.8936	2.473		

TABLE 3-continued

*12)	−28.9700	1.200	1.49782	82.57
13)	−65.5471	D13		
14)	∞	2.000		(aperture stop)
15)	95.8245	4.041	1.59349	67.00
16)	−62.8425	0.940		
17)	−40.3456	1.651	1.87070	40.74
18)	−65.9661	D18		
*19)	25.9551	4.000	1.51680	64.14
20)	44.4253	0.645		
21)	39.9828	5.500	1.59319	67.90
22)	−391.0917	1.331		
23)	48.6465	1.200	1.90366	31.27
24)	18.3320	7.807	1.59319	67.90
25)	−171.4604	0.200		
26)	77.7825	1.200	1.69343	53.30
*27)	73.7764	D27		
28)	80.7818	1.200	1.95000	29.37
29)	16.7054	3.578	1.94595	17.98
30)	27.6369	D30		
*31)	−101.4351	1.200	1.85108	40.12
32)	−42069.7150	3.381		
33)	73.6536	5.500	1.54814	45.51
34)	−164.9703	D34		

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	2.211E−06	−1.437E−09	1.171E−11	−2.870E−14	5.008E−17
12)	1.0000	−1.225E−07	−1.735E−09	−1.015E−11		
19)	1.0000	−2.831E−06	−3.190E−09	−5.738E−12	−8.899E−15	
27)	1.0000	1.265E−05	1.948E−08	1.185E−11	2.335E−13	
31)	1.0000	−1.999E−06	2.863E−09	−3.559E−12	8.759E−15	

[Focal length data of groups]

Groups	First surfaces	Focal lengths
G1	1	105.19
G2	6	−24.34
G3	14	134.69
G4	19	35.45
G5	28	−46.01
G6	31	361.54

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	1.500	22.793	38.616	1.500	22.793	38.616
D13	39.116	17.822	2.000	39.116	17.822	2.000
D18	20.867	4.924	2.000	20.867	4.924	2.000
D27	2.529	4.659	10.992	2.905	5.282	12.275
D30	17.618	31.431	28.022	17.242	30.807	26.739
D34	18.793	18.798	18.797	18.793	18.798	18.797

[0164] FIG. **6**A shows aberrations of the variable magnification optical system of the third example focusing on an object at infinity in the wide-angle end state; FIG. **6**B shows aberrations of the variable magnification optical system of the third example focusing on an object at infinity in the telephoto end state.

[0165] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

Fourth Example

[0166] FIG. **7** is a cross-sectional view of a variable magnification optical system of a fourth example focusing on an object at infinity in the wide-angle end state.

[0167] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G**1** having positive refractive power, a second lens group G**2** having negative refractive power, a third lens group G**3** having positive refractive power, a fourth lens group G**4** having positive refractive power, a fifth lens group G**5** having negative refractive power, and a sixth lens group G**6** having negative refractive power.

[0168] The first lens group G**1** consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L**11** convex on the object side and a meniscus-shaped positive lens L**12** convex on the object side, and a meniscus-shaped positive lens L**13** convex on the object side.

[0169] The second lens group G**2** consists of, in order from the object side, a meniscus-shaped negative lens L**21** convex on the object side, a biconcave negative lens L**22**, a biconvex positive lens L**23**, and a meniscus-shaped negative lens L**24** concave on the object side.

[0170] The third lens group G**3** consists of, in order from the object side, an aperture stop S and a positive cemented lens composed of a biconvex positive lens L**31** and a meniscus-shaped negative lens L**32** concave on the object side.

[0171] The fourth lens group G**4** consists of, in order from the object side, a meniscus-shaped positive lens L**41** convex on the object side, a positive cemented lens composed of a meniscus-shaped positive lens L**42** convex on the object side and a biconvex positive lens L**43**, and a meniscus-shaped negative lens L**44** convex on the object side.

[0172] The fifth lens group G**5** consists of a negative cemented lens composed of a meniscus-shaped negative lens L**51** convex on the object side and a meniscus-shaped positive lens L**52** convex on the object side.

[0173] The sixth lens group G**6** consists of, in order from the object side, a meniscus-shaped positive lens L**61** concave on the object side, a meniscus-shaped negative lens L**62** concave on the object side, and a biconvex positive lens L**63**.

[0174] An imaging device (not shown) constructed from CCD, CMOS, or the like is disposed on an image plane I.

[0175] The variable magnification optical system of the present example focuses by moving the fifth lens group G**5** along the optical axis. When focus is shifted from infinity to a nearby object, the fifth lens group G**5** moves from the object side toward the image plane side.

[0176] In the variable magnification optical system of the present example, the fourth, fifth, and sixth lens groups G**4**, G**5**, and G**6** correspond to the subsequent lens group: the fifth lens group G**5** corresponds to the focusing lens group: the sixth lens group G**6** corresponds to the final lens group. The fourth lens group G**4** corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0177] Table 4 below shows specifications of the variable magnification optical system of the present example.

TABLE 4

[General specifications]

TL	179.47
fw	28.84
ft	130.95
FNOw	4.12
FNOt	4.12
ωw	38.54
ωt	8.69
Y	21.60

[lens specifications]

m	r	d	nd	νd
1)	100.3057	1.200	1.85451	25.15
2)	60.8344	8.099	1.53775	74.70
3)	469.7604	0.200		
4)	76.2982	5.766	1.75500	52.34
5)	445.1784	D5		
*6)	489.6863	1.200	1.85108	40.12
7)	25.8725	8.554		
8)	−50.8620	1.200	1.83481	42.72
9)	76.2098	0.200		
10)	53.6363	5.772	1.84666	23.80
11)	−47.5523	0.904		
12)	−34.9057	1.200	1.74310	49.44
*13)	−135.8499	D13		
14)	∞	4.500		(aperture stop)
*15)	63.0236	4.554	1.69343	53.30
16)	−58.8213	1.200	1.95000	29.37
17)	−207.1161	D17		
*18)	33.7325	4.500	1.59319	67.90
19)	153.6733	3.481		
20)	33.2491	1.200	1.90110	27.06
21)	23.3148	8.000	1.53775	74.70
22)	−73.6961	0.200		
23)	53.2656	1.200	1.85108	40.12
*24)	30.8637	D24		
25)	104.0299	1.200	2.00069	25.46
26)	18.9870	4.800	1.94595	17.98
27)	39.8976	D27		
*28)	−103.0331	4.657	1.69343	53.30
29)	−40.6980	5.706		
30)	−30.6104	1.200	1.91082	35.25
31)	−216.9426	0.200		
32)	55.8746	6.500	1.61266	44.46
33)	−211.7306	D33		

TABLE 4-continued

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	1.488E−06	−5.065E−10	1.818E−12	1.359E−15	
13)	1.0000	2.938E−07	−7.289E−10	1.426E−11	−2.828E−14	
15)	1.0000	−1.642E−06	9.096E−10	−2.490E−12		
18)	1.0000	9.832E−08	−5.129E−09	−2.654E−12		
24)	1.0000	1.226E−05	2.280E−08	3.207E−12	1.685E−13	
28)	1.0000	−1.332E−06	2.889E−09	2.329E−12		

[Focal length data of groups]

Groups	First surfaces	Focal lengths
G1	1	97.13
G2	6	−23.47
G3	14	89.27
G4	18	44.88
G5	25	−60.88
G6	28	−3286.39

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	500	23.030	37.587	1.500	23.030	37.587
D13	39.087	17.557	3.000	39.087	17.557	3.000
D17	22.857	6.314	2.000	22.857	6.314	2.000
D24	5.350	6.250	11.401	6.000	7.252	13.341
D27	9.813	25.456	24.618	9.162	24.454	22.679
D33	13.468	13.469	13.458	13.468	13.469	13.458

[0178] FIG. **8**A shows aberrations of the variable magnification optical system of the fourth example focusing on an object at infinity in the wide-angle end state: FIG. **8**B shows aberrations of the variable magnification optical system of the fourth example focusing on an object at infinity in the telephoto end state.

[0179] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

Fifth Example

[0180] FIG. **9** is a cross-sectional view of a variable magnification optical system of a fifth example focusing on an object at infinity in the wide-angle end state.

[0181] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G**1** having positive refractive power, a second lens group G**2** having negative refractive power, a third lens group G**3** having positive refractive power, a fourth lens group G**4** having positive refractive power, a fifth lens group G**5** having positive refractive power, a sixth lens group G**6** having negative refractive power, and a seventh lens group G**7** having positive refractive power.

[0182] The first lens group G**1** consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L**11** convex on the object side and a biconvex positive lens L**12**, and a meniscus-shaped positive lens L**13** convex on the object side.

[0183] The second lens group G**2** consists of, in order from the object side, a meniscus-shaped negative lens L**21** convex on the object side, a biconcave negative lens L**22**, a biconvex positive lens L**23**, and a meniscus-shaped negative lens L**24** concave on the object side.

[0184] The third lens group G**3** consists of, in order from the object side, an aperture stop S, a biconvex positive lens L**31**, and a meniscus-shaped negative lens L**32** concave on the object side.

[0185] The fourth lens group G**4** consists of, in order from the object side, a meniscus-shaped positive lens L**41** convex on the object side and a positive cemented lens composed of a biconvex positive lens L**42** and a meniscus-shaped negative lens L**43** concave on the object side.

[0186] The fifth lens group G**5** consists of a positive cemented lens composed of a meniscus-shaped negative lens L**51** convex on the object side and a biconvex positive lens L**52**, and a meniscus-shaped positive lens L**53** convex on the object side.

[0187] The sixth lens group G**6** consists of a negative cemented lens composed of a meniscus-shaped negative lens L**61** convex on the object side and a meniscus-shaped positive lens L**62** convex on the object side.

[0188] The seventh lens group G**7** consists of, in order from the object side, a meniscus-shaped negative lens L**71** concave on the object side and a meniscus-shaped positive lens L**72** convex on the object side.

[0189] An imaging device (not shown) constructed from CCD, CMOS, or the like is disposed on an image plane I.

[0190] The variable magnification optical system of the present example focuses by moving the sixth lens group G**6** along the optical axis. When focus is shifted from infinity to a nearby object, the sixth lens group G**6** moves from the object side toward the image plane side.

[0191] In the variable magnification optical system of the present example, the fourth, fifth, sixth, and seventh lens groups G**4**, G**5**, G**6**, and G**7** correspond to the subsequent lens group; the sixth lens group G**6** corresponds to the focusing lens group; the seventh lens group G**7** corresponds to the final lens group. The fourth lens group G**4** corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0192] Table 5 below shows specifications of the variable magnification optical system of the present example.

TABLE 5

[General specifications]

TL	169.45
fw	28.84
ft	116.40
FNOw	4.12
FNOt	4.12
ωw	38.52
ωt	9.80
Y	21.60

[lens specifications]

m	r	d	nd	νd
1)	93.2961	1.200	1.85451	25.15
2)	64.7090	8.994	1.49782	82.57
3)	−1632.1248	0.200		
4)	69.0153	5.266	1.59319	67.90
5)	278.2695	D5		
*6)	315.4615	1.200	1.77387	47.25
7)	23.3642	7.183		
8)	−56.9381	1.200	1.83481	42.73
9)	89.0147	0.200		
10)	48.2552	5.210	1.84666	23.80
11)	−77.2530	1.839		
12)	−33.1241	1.500	1.59319	67.90
13)	−166.5029	D13		
14)	∞	2.000		(aperture stop)
*15)	103.5679	3.610	1.69343	53.30
16)	−65.2717	0.920		
17)	−38.6388	1.605	1.80100	34.92
18)	−75.8947	D18		
*19)	32.3007	3.500	1.51680	64.14
20)	59.0298	0.200		
21)	42.1175	5.000	1.59319	67.90
22)	−136.2064	1.741	1.72047	34.71
23)	−228.7783	D23		
24)	41.7423	1.200	1.85451	25.15
25)	21.6999	6.682	1.49782	82.57
26)	−240.2934	0.200		
27)	76.7885	2.000	1.85108	40.12
*28)	108.2756	D28		
29)	111.2012	1.200	1.95000	29.37
30)	17.1778	3.739	1.94595	17.98
31)	29.4041	D31		
*32)	−46.3988	1.200	1.85108	40.12
33)	−80.8980	0.200		
34)	57.3607	5.500	1.57501	41.50
35)	1745.7962	D35		

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	1.519E−06	−2.184E−10	1.352E−12	−1.201E−15	9.425E−18
15)	1.0000	−6.645E−07	1.393E−09	−3.960E−12		
19)	1.0000	−2.186E−07	−1.597E−09	−1.186E−12		
28)	1.0000	1.109E−05	1.403E−08	8.343E−12	1.499E−13	
32)	1.0000	−1.684E−06	8.599E−10	3.075E−12	6.087E−16	

TABLE 5-continued

[Focal length data of groups]		
Groups	First surfaces	Focal lengths
G1	1	96.71
G2	6	−23.18
G3	14	136.52
G4	19	43.42
G5	24	105.09
G6	29	−43.14
G7	32	469.29

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	1.619	20.213	32.811	1.619	20.213	32.811
D13	33.925	15.331	2.733	33.925	15.331	2.733
D17	18.781	3.212	2.000	18.781	3.212	2.000
D24	2.382	2.449	2.000	2.382	2.449	2.000
D27	2.394	4.128	8.760	2.777	4.750	9.887
D33	20.417	34.186	31.215	20.035	33.564	30.087
D35	15.440	15.449	15.451	15.440	15.449	15.451

[0193] FIG. **10**A shows aberrations of the variable magnification optical system of the fifth example focusing on an object at infinity in the wide-angle end state: FIG. **10**B shows aberrations of the variable magnification optical system of the fifth example focusing on an object at infinity in the telephoto end state.

[0194] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

Sixth Example

[0195] FIG. **11** is a cross-sectional view of a variable magnification optical system of a sixth example focusing on an object at infinity in the wide-angle end state.

[0196] The variable magnification optical system of the present example includes, in order from the object side, a first lens group G**1** having positive refractive power, a second lens group G**2** having negative refractive power, a third lens group G**3** having positive refractive power, a fourth lens group G**4** having positive refractive power, a fifth lens group G**5** having positive refractive power, a sixth lens group G**6** having negative refractive power, and a seventh lens group G**7** having positive refractive power.

[0197] The first lens group G**1** consists of, in order from the object side, a positive cemented lens composed of a meniscus-shaped negative lens L**11** convex on the object side and a biconvex positive lens L**12**, and a meniscus-shaped positive lens L**13** convex on the object side.

[0198] The second lens group G**2** consists of, in order from the object side, a meniscus-shaped negative lens L**21** convex on the object side, a biconcave negative lens L**22**, a biconvex positive lens L**23**, and a meniscus-shaped negative lens L**24** concave on the object side.

[0199] The third lens group G**3** consists of, in order from the object side, an aperture stop S, a biconvex positive lens L**31**, and a meniscus-shaped negative lens L**32** concave on the object side.

[0200] The fourth lens group G**4** consists of, in order from the object side, a meniscus-shaped positive lens L**41** convex on the object side and a positive cemented lens composed of a biconvex positive lens L**42** and a meniscus-shaped negative lens L**43** concave on the object side.

[0201] The fifth lens group G**5** consists of a positive cemented lens composed of a meniscus-shaped negative lens L**51** convex on the object side and a biconvex positive lens L**52**, and a meniscus-shaped positive lens L**53** convex on the object side.

[0202] The sixth lens group G**6** consists of a negative cemented lens composed of a meniscus-shaped negative lens L**61** convex on the object side and a meniscus-shaped positive lens L**62** convex on the object side.

[0203] The seventh lens group G**7** consists of, in order from the object side, a meniscus-shaped negative lens L**71** concave on the object side and a meniscus-shaped positive lens L**72** convex on the object side.

[0204] An imaging device (not shown) constructed from CCD, CMOS, or the like is disposed on an image plane I.

[0205] The variable magnification optical system of the present example focuses by moving the sixth lens group G**6** along the optical axis. When focus is shifted from infinity to a nearby object, the sixth lens group G**6** moves from the object side toward the image plane side.

[0206] In the variable magnification optical system of the present example, the fourth, fifth, sixth, and seventh lens groups G**4**, G**5**, G**6**, and G**7** correspond to the subsequent lens group; the sixth lens group G**6** corresponds to the focusing lens group: the seventh lens group G**7** corresponds to the final lens group. The fourth lens group G**4** corresponds to the lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power.

[0207] Table 6 below shows specifications of the variable magnification optical system of the present example.

TABLE 6

[General specifications]

TL	157.46
fw	28.84
ft	101.85
FNOw	4.12
FNOt	4.12
ωw	38.51
ωt	11.15
Y	21.60

[lens specifications]

m	r	d	nd	νd
1)	89.9694	1.200	1.85451	25.15
2)	61.8344	8.870	1.49782	82.57
3)	−1810.4849	0.200		
4)	64.2354	5.370	1.59319	67.90
5)	290.2968	D5		
*6)	5724.0693	1.200	1.77387	47.25
7)	22.3009	6.722		
8)	−51.4759	1.200	1.87070	40.74
9)	89.5799	0.200		
10)	48.1451	4.981	1.84666	23.80
11)	−65.5885	1.692		
12)	−29.8981	1.362	1.59319	67.90
13)	−78.5606	D13		
14)	∞	2.000		(aperture stop)
*15)	120.1934	3.278	1.74310	49.44
16)	−65.7245	0.960		
17)	−35.0667	1.651	1.85026	32.35
18)	−62.4547	D18		
*19)	29.6539	3.262	1.51680	64.14
20)	48.4068	0.200		
21)	35.8637	5.000	1.59319	67.90
22)	−160.1358	1.853	1.80000	29.84
23)	−240.2036	D23		
24)	41.9624	1.200	1.85451	25.15
25)	21.1993	6.047	1.49782	82.57
26)	−424.5511	0.200		
27)	68.6284	2.079	1.85108	40.12
*28)	114.7292	D28		
29)	89.8202	1.200	1.95000	29.37
30)	16.6762	3.424	1.94595	17.98
31)	26.9989	D31		
*32)	−40.8570	1.200	1.85108	40.12
33)	−66.9608	0.200		
34)	54.9466	5.500	1.54814	45.79
35)	1434.5246	D35		

[Aspherical surface data]

m	K	A4	A6	A8	A10	A12
6)	1.0000	2.611E−06	−9.668E−10	4.188E−13	1.205E−14	−8.027E−18
15)	1.0000	−3.471E−07	1.740E−09	−3.975E−12		
19)	1.0000	−3.712E−07	−1.673E−09	−2.490E−12		
28)	1.0000	1.466E−05	2.424E−08	2.676E−12	3.610E−13	
32)	1.0000	−1.048E−06	5.180E−09	−4.595E−12	1.454E−14	

[Focal length data of groups]

Groups	First surfaces	Focal lengths
G1	1	90.07
G2	6	−22.46
G3	14	140.83
G4	19	40.35
G5	24	101.24
G6	29	−41.95
G7	32	557.85

TABLE 6-continued

[Variable spacing data]

	At focusing on infinity			At focusing nearby		
	Wide-angle	Midpoint	Telephoto	Wide-angle	Midpoint	Telephoto
D5	1.995	19.531	28.874	1.995	19.531	28.874
D13	28.880	11.344	2.000	28.880	11.344	2.000
D18	15.834	2.061	2.000	15.834	2.061	2.000
D23	2.490	2.378	2.000	2.490	2.378	2.000
D28	2.241	4.303	7.661	2.633	4.962	8.708
D31	20.172	31.996	29.078	19.781	31.337	28.030
D35	13.601	13.592	13.628	13.601	13.592	13.628

[0208] FIG. **12**A shows aberrations of the variable magnification optical system of the sixth example focusing on an object at infinity in the wide-angle end state; FIG. **12**B shows aberrations of the variable magnification optical system of the sixth example focusing on an object at infinity in the telephoto end state.

[0209] The graphs of aberrations suggest that the variable magnification optical system of the present example corrects aberrations appropriately and has high optical performance.

[0210] A variable magnification optical system of favorable optical performance can be achieved according to the above examples.

[0211] Values for the conditional expressions of the examples are listed below.

[0212] TL is the distance from a lens surface closest to the object side to the image plane: fw is the focal length of the variable magnification optical system in a wide-angle end state: ft is the focal length of the variable magnification optical system in a telephoto end state. f1, f2, and f3 are the focal lengths of the first, second, and third lens groups, respectively. fF is the focal length of the focusing lens group: fR is the focal length of the final lens group: fRP is the focal length of a lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power. BFw is the back focal length of the variable magnification optical system focusing on infinity in the wide-angle end state: BFt is the back focal length of the variable magnification optical system focusing on infinity in the telephoto end state. Gw is the distance from the lens surface closest to the object side in the variable magnification optical system in the wide-angle end state to the centroid position of the variable magnification optical system: Gt is the distance from the lens surface closest to the object side in the variable magnification optical system in the telephoto end state to the centroid position of the variable magnification optical system. ωw is the semi-field angle of the variable magnification optical system in the wide-angle end state; ωt is the semi-field angle of the variable magnification optical system in the telephoto end state.

[Values for Conditional Expressions]

Conditional expressions	First	Second	Third	Fourth	Fifth	Sixth
(1) (TL/f1)/(ft/fw)	0.440	0.433	0.374	0.407	0.434	0.495
(2) f1/(−f2)	5.348	5.304	4.321	4.138	4.172	4.011
(3) f1/f3	3.767	3.809	0.781	1.088	0.708	0.640
(4) f2/fF	0.650	0.673	0.529	0.386	0.537	0.535

-continued

Conditional expressions	First	Second	Third	Fourth	Fifth	Sixth
(5) |fR|/(−fF)	3.602	2.880	7.858	53.979	10.878	13.297
(6) BFw/fw	0.619	0.878	0.652	0.467	0.535	0.472
(7) BFt/ft	0.136	0.193	0.144	0.103	0.133	0.134
(8) f1/fRP	0.965	1.239	2.967	2.164	2.227	2.232
(9) Gw/Gt	0.937	0.913	0.917	0.939	0.925	0.937
(10) ωw	38.458°	38.547°	38.544°	38.541°	38.523°	38.515°
(11) ωt	8.677°	8.678°	8.715°	8.694°	9.795°	11.148°

[0213] The above examples are specific examples of the present invention, and the present invention is not limited thereto. The following features can be appropriately employed unless the optical performance of the variable magnification optical system of the embodiment of the present application is compromised.

[0214] In the variable magnification optical system of the present embodiment, the third lens group need not necessarily include an aperture stop. The position of the aperture stop in the variable magnification optical system of the present embodiment is not limited to any of the positions of the aperture stops S in the variable magnification optical systems of the above examples. The aperture stop in the variable magnification optical system of the present embodiment may be disposed between lenses in the third lens group.

[0215] The variable magnification optical system of the present embodiment may include an optical member, such as a filter, between the image plane and a lens surface closest to the image plane.

[0216] The variable magnification optical system of the present embodiment may include a vibration reduction lens group configured to make a movement including a component in a direction perpendicular to the optical axis to correct an image blur caused by shaky hands. The vibration reduction lens group may be a lens group or a lens subgroup consisting of one or more lens components included in a lens group.

[0217] In the variable magnification optical system of the present embodiment, lens surfaces may be spherical, plane, or aspherical surfaces. Spherical or plane lens surfaces are preferable because they facilitate lens machining, assembling, and adjustment and prevent a decrease in optical performance caused by errors in machining, assembling, and adjustment and because depiction performance does not decrease much when the image plane is shifted.

[0218] An aspherical lens surface may be formed by grinding glass or glass molding with a mold having an aspherical shape, or formed on the surface of resin bonded on a glass surface. In the variable magnification optical system of the present embodiment, lens surfaces may be diffractive surfaces, and lenses may be graded index lenses (GRIN lenses) or plastic lenses.

[0219] Next, a camera including the variable magnification optical system of the present embodiment will be described with reference to FIG. **13**.

[0220] FIG. **13** schematically shows a camera including the variable magnification optical system of the present embodiment.

[0221] The camera **1** is a "mirror-less camera" of an interchangeable lens type including the optical system of the first example as an imaging lens **2**.

[0222] In the camera **1**, light from an object (subject) (not shown) is condensed by the imaging lens **2** and reaches an imaging device **3**. The imaging device **3** converts the light from the subject to image data. When a release button (not shown) is pressed by a user who takes a photograph, the image data is stored in a memory (not shown). In this way, the user can take a picture of the subject with the camera **1**.

[0223] The variable magnification optical system of the first example included in the camera **1** as the imaging lens **2** is a variable magnification optical system of favorable optical performance. Thus the camera **1** can achieve favorable optical performance. A camera configured by including any of the variable magnification optical systems of the second to sixth examples as the imaging lens **2** can have the same effect as the camera **1**.

[0224] Finally, a method for manufacturing a variable magnification optical system of the present embodiment will be outlined with reference to FIG. **14**.

[0225] FIG. **14** is a flowchart outlining a method for manufacturing a variable magnification optical system of the present embodiment. The method for manufacturing a variable magnification optical system of the present embodiment shown in FIG. **14** includes steps S**11** to S**13** below.

[0226] Step S**11**: first, second, and third lens groups and a subsequent lens group are prepared.

[0227] Step S**12**: they are arranged so that at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied.

[0228] Step S**13**: the variable magnification optical system is made to satisfy the following conditional expression.

$$0.24 < (TL/f1)/(ft/fw) < 0.55 \tag{1}$$

where

[0229] TL: the distance from a lens surface closest to the object side to the image plane

[0230] f1: the focal length of the first lens group

[0231] ft: the focal length of the variable magnification optical system in a telephoto end state

[0232] fw: the focal length of the variable magnification optical system in a wide-angle end state

[0233] An optical system of favorable imaging performance can be manufactured by the method for manufacturing a variable magnification optical system of the present embodiment.

[0234] It should be noted that those skilled in the art can make various changes, substitutions, and modifications without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A variable magnification optical system comprising, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups,

at varying magnification, the first and third lens groups being fixed with respect to an image plane, and the spacings between adjacent lens groups being varied,

the variable magnification optical system satisfying the following conditional expression.

$$0.24 < (TL/f1)/(ft/fw) < 0.55$$

where

TL: the distance from a lens surface closest to the object side to the image plane

f1: the focal length of the first lens group

ft: the focal length of the variable magnification optical system in a telephoto end state

fw: the focal length of the variable magnification optical system in a wide-angle end state

2. The variable magnification optical system according to claim **1**, wherein the following conditional expression is satisfied.

$$3.00 < f1/(-f2) < 5.80$$

where

f2: the focal length of the second lens group

3. The variable magnification optical system according to claim **1**, wherein the following conditional expression is satisfied.

$$0.45 < f1/f3 < 6.00$$

where

f3: the focal length of the third lens group

4. The variable magnification optical system according to claim **1**, wherein the subsequent lens group includes a focusing lens group having negative refractive power and moving at focusing, and the following conditional expression is satisfied.

$$0.30 < f2/fF < 1.00$$

where

f2: the focal length of the second lens group

fF: the focal length of the focusing lens group

5. The variable magnification optical system according to claim **1**, wherein a final lens group disposed closest to the image plane in the subsequent lens group is fixed with respect to the image plane at varying magnification.

6. The variable magnification optical system according to claim **1**, wherein the subsequent lens group includes a focusing lens group having negative refractive power and moving at focusing and a final lens group disposed closest to the image plane, and

the following conditional expression is satisfied.

$$2.00 < |fR|/(-fF) < 100.00$$

where

fR: the focal length of the final lens group

fF: the focal length of the focusing lens group

7. The variable magnification optical system according to claim **1**, wherein the following conditional expression is satisfied.

$$0.15 < BFw/fw < 0.95$$

where

BFw: the back focal length of the variable magnification optical system focusing on infinity in the wide-angle end state

8. The variable magnification optical system according to claim **1**, wherein the following conditional expression is satisfied.

$$0.08 < BFt/ft < 0.24$$

where

BFt: the back focal length of the variable magnification optical system focusing on infinity in the telephoto end state

9. The variable magnification optical system according to claim **1**, wherein the subsequent lens group includes at least one lens group having positive refractive power, and the following conditional expression is satisfied.

$$0.70 < f1/fRP < 3.40$$

where

fRP: the focal length of a lens group having the strongest refractive power of lens groups included in the subsequent lens group and having positive refractive power

10. The variable magnification optical system according to claim **1**, wherein the following conditional expression is satisfied.

$$0.50 < Gw/Gt < 1.50$$

where

Gw: the distance from the lens surface closest to the object side in the variable magnification optical system in the wide-angle end state to the centroid position of the variable magnification optical system

Gt: the distance from the lens surface closest to the object side in the variable magnification optical system in the telephoto end state to the centroid position of the variable magnification optical system

11. An optical device comprising the variable magnification optical system according to claim **1**.

12. A method for manufacturing a variable magnification optical system, the method comprising configuring a variable magnification optical system including, in order from an object side, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a subsequent lens group including a plurality of lens groups so that

at varying magnification, the first and third lens groups are fixed with respect to an image plane, and the spacings between adjacent lens groups are varied, and

the following conditional expression is satisfied.

$$0.24 < (TL/f1)/(ft/fw) < 0.55$$

where

TL: the distance from a lens surface closest to the object side to the image plane

f1: the focal length of the first lens group

ft: the focal length of the variable magnification optical system in a telephoto end state

fw: the focal length of the variable magnification optical system in a wide-angle end state

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