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IMAGING OPTICAL SYSTEM, AND IMAGE CAPTURE DEVICE AND CAMERA SYSTEM INCLUDING THE SAME

Abstract

An imaging optical system includes: a first lens group having positive power; a second lens group having negative power; a third lens group having positive power; a fourth lens group having positive power; a fifth lens group having negative power; and a sixth lens group having power. The first, second, third, fourth, fifth, and sixth lens groups are arranged in this order such that the first lens group is located closest to an object and that the sixth lens group is located closest to an image plane. An interval between each pair of lens groups that are adjacent to each other changes as at least the first, second, third, fourth, fifth, and sixth lens groups move in an optical axis direction aligned with an optical axis of the imaging optical system while the imaging optical system is zooming.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS
[0001] The present application is based upon, and claims the benefit of priority to, Japanese Patent Application No. 2024-023382, filed on Feb. 20, 2024, the entire contents of which are hereby incorporated by reference.
TECHNICAL FIELD
[0002] The present disclosure relates to an imaging optical system having the ability to compensate for various types of aberrations sufficiently over the entire zoom range, and also relates to an image capture device and interchangeable lens unit including such an imaging optical system.
BACKGROUND ART
[0003] JP 2023-104137 A discloses a zoom lens including a first lens group L**1** having positive refractive power, a second lens group L**2** having negative refractive power, a third lens group L**3** having positive refractive power, a fourth lens group L**4** having positive refractive power, and an N.sup.th lens group LN having negative refractive power. The first, second, third, fourth, and N.sup.th lens groups L**1**, L**2**, L**3**, L**4**, and LN are arranged in this order such that the first lens group L**1** is located closer to an object than any of the other second, third, fourth, and N.sup.th lens groups is, and that the N.sup.th lens group is located closer to an image plane than any of the other first, second, third, and fourth lens groups is. In the zoom lens, the interval between adjacent lens groups changes while the zoom lens system is zooming.
SUMMARY
[0004] The present disclosure provides an imaging optical system having the ability to compensate for various types of aberrations sufficiently over the entire zoom range and an image capture device and interchangeable lens unit including such an imaging optical system. An imaging optical system according to the present disclosure includes: a first lens group having positive power; a second lens group having negative power; a third lens group having positive power; a fourth lens group having positive power; a fifth lens group having negative power; and a sixth lens group having power. The first, second, third, fourth, fifth, and sixth lens groups are arranged in this order such that the first lens group is located closer to an object than any of the second, third, fourth, fifth or sixth lens group is, and that the sixth lens group is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group is. An interval between each pair of lens groups that are adjacent to each other changes as at least the first, second, third, fourth, fifth, and sixth lens groups move in an optical axis direction aligned with an optical axis of the imaging optical system while the imaging optical system is zooming.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0005] The figures depict one or more implementations in accordance with the present teaching, by way of example only, not by way of limitations. In the figures, like reference numerals refer to the same or similar elements.
[0006] FIG. **1**A illustrates lens arrangements showing an infinity in-focus state of an imaging optical system according to a first embodiment (corresponding to a first example of numerical

values);
[0007] FIG. **1**B illustrates longitudinal aberration diagrams showing the infinity in-focus state of the imaging optical system in the first example of numerical values;
[0008] FIG. **1**C illustrates lateral aberration diagrams showing a basic state where the imaging optical system is making no image blur compensation and an image blur compensated state where the imaging optical system is making image blur compensation, respectively, at a telephoto end in the first example of numerical values;
[0009] FIG. **2**A illustrates lens arrangements showing an infinity in-focus state of an imaging optical system according to a second embodiment (corresponding to a second example of numerical values);
[0010] FIG. **2**B illustrates longitudinal aberration diagrams showing the infinity in-focus state of the imaging optical system in the second example of numerical values;
[0011] FIG. **2**C illustrates lateral aberration diagrams showing a basic state where the imaging optical system is making no image blur compensation and an image blur compensated state where the imaging optical system is making image blur compensation, respectively, at a telephoto end in the second example of numerical values;
[0012] FIG. **3**A illustrates lens arrangements showing an infinity in-focus state of an imaging optical system according to a third embodiment (corresponding to a third example of numerical values);
[0013] FIG. **3**B illustrates longitudinal aberration diagrams showing the infinity in-focus state of the imaging optical system in the third example of numerical values;
[0014] FIG. **3**C illustrates lateral aberration diagrams showing a basic state where the imaging optical system is making no image blur compensation and an image blur compensated state where the imaging optical system is making image blur compensation, respectively, at a telephoto end in the third example of numerical values;
[0015] FIG. **4**A illustrates lens arrangements showing an infinity in-focus state of an imaging optical system according to a fourth embodiment (corresponding to a fourth example of numerical values);
[0016] FIG. **4**B illustrates longitudinal aberration diagrams showing the infinity in-focus state of the imaging optical system in the fourth example of numerical values;
[0017] FIG. **4**C illustrates lateral aberration diagrams showing a basic state where the imaging optical system is making no image blur compensation and an image blur compensated state where the imaging optical system is making image blur compensation, respectively, at a telephoto end in the fourth example of numerical values;
[0018] FIG. **5**A illustrates lens arrangements showing an infinity in-focus state of an imaging optical system according to a fifth embodiment (corresponding to a fifth example of numerical values);
[0019] FIG. **5**B illustrates longitudinal aberration diagrams showing the infinity in-focus state of the imaging optical system in the fifth example of numerical values;
[0020] FIG. **5**C illustrates lateral aberration diagrams showing a basic state where the imaging optical system is making no image blur compensation and an image blur compensated state where the imaging optical system is making image blur compensation, respectively, at a telephoto end in the fifth example of numerical values;
[0021] FIG. **6** illustrates a schematic configuration for an image capture device according to the first embodiment; and
[0022] FIG. **7** illustrates a schematic configuration for a camera system according to the first embodiment.

DETAILED DESCRIPTION

[0023] Embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings as needed. Note that unnecessarily detailed description will be omitted.

For example, detailed description of already well-known matters and redundant description of substantially the same configuration will be omitted. This is done to avoid making the following description overly redundant and thereby help one of ordinary skill in the art understand the present disclosure easily.

[0024] In addition, note that the accompanying drawings and the following description are provided to help one of ordinary skill in the art understand the present disclosure fully and should not be construed as limiting the scope of the present disclosure, which is defined by the appended claims.

First to Fifth Embodiments

[0025] Imaging optical systems according to first to fifth embodiments will now be described on an individual basis with reference to the accompanying drawings.

[0026] FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A illustrate lens arrangements of imaging optical systems according to first to fifth embodiments, respectively. In each of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the imaging optical system is in an infinity in-focus state.

[0027] In FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, portion (a) illustrates a lens arrangement at a wide-angle end (which is a state with the shortest focal length fw); portion (d) illustrates a lens arrangement at a middle position (which is a state with a middle focal length fM=√(fw*fT)); and portion (e) illustrates a lens arrangement at a telephoto end (which is a state with the longest focal length fT). Note that portions (a), (d), and (e) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A have the same aspect ratio.

[0028] Furthermore, in portion (a) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the asterisk (*) attached to a surface of a particular lens indicates that the surface is an aspheric surface. Note that in the lenses shown in portion (a) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, an object-side surface or an image-side surface having no asterisks is a spherical surface.

[0029] Also, in FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the polygon arrows shown in portion (c) thereof each connect together the respective positions of the lens groups at the wide-angle end (WIDE), middle position (MID), and telephoto end (TELE) from top to bottom. Note that these polygon arrows just connect the wide-angle end to the middle position and the middle position to the telephoto end with the lines, and do not indicate the actual movement of the lens groups.

[0030] Furthermore, in portion (b) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the respective lens groups are designated by the reference signs G**1**-G**6** (or G**1**-G**7**) corresponding to their respective positions shown in portion (a).

[0031] Furthermore, the signs (+) and (−) added to the reference signs G**1**-G**7** of the respective lens groups in portion (b) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A indicate the powers of the respective lens groups G**1**-G**7**. That is to say, the positive sign (+) indicates positive power, and the negative sign (−) indicates negative power.

[0032] Also, the arrows added to the lens groups in portion (b) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A each indicate focusing to make a transition from the infinity in-focus state toward the close-object in-focus state. Note that in FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the reference signs of respective lens groups are shown under the respective lens groups in portion (a) thereof, and therefore, an arrow indicating focusing is shown under the sign of each lens group for convenience's sake. In each zooming state, the directions of movement of the respective lens groups during focusing will be described more specifically later with respect to each of the first through fifth embodiments.

[0033] Furthermore, in portions (a), (d), and (e) of FIGS. **1**A, **2**A, **3**A, **4**A, and **5**A, the straight line drawn at the right end indicates the position of the image plane S (i.e., a surface, facing the object, of the image sensor). Therefore, the left end of the drawings corresponds to the object side. Furthermore, a parallel plate P such as a low-pass filter or cover glass is disposed between the lens group on the last stage, facing the image plane S, of the imaging optical system and the image plane S.

[0034] Note that the "optical axis" as used herein refers to the "optical axis of the imaging optical system" unless otherwise stated.

First Embodiment

[0035] FIG. **1**A illustrates an imaging optical system according to a first embodiment.

[0036] The imaging optical system includes: a first lens group G**1** having positive power; a second lens group G**2** having negative power; a third lens group G**3** having positive power; a fourth lens group G**4** having positive power; a fifth lens group G**5** having negative power; and a sixth lens group G**6** having negative power. The first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** are arranged in this order such that the first lens group G**1** is located closer to an object than any of the second, third, fourth, fifth, or sixth lens group G**2**, G**3**, G**4**, G**5**, G**6** is and that the sixth lens group G**6** is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group G**1**, G**2**, G**3**, G**4**, G**5** is.

[0037] The imaging optical system forms an image at a point on the image plane S.

[0038] The first lens group G**1** is made up of: a first lens L**1** having negative power; a second lens L**2** having positive power; and a third lens L**3** having positive power. The first lens L**1**, the second lens L**2**, and the third lens L**3** are arranged in this order such that the first lens L**1** is located closer to the object than any other member of this first lens group G**1** is and that the third lens L**3** is located closer to the image plane than any other member of this first lens group G**1** is. The first lens L**1** and the second lens L**2** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the first lens L**1** and the second lens L**2**.

[0039] The second lens group G**2** is made up of: a fourth lens L**4** having negative power; a fifth lens L**5** having negative power; a sixth lens L**6** having positive power; and a seventh lens L**7** having negative power. The fourth, fifth, sixth, and seventh lenses L**4**, L**5**, L**6**, L**7** are arranged in this order such that the fourth lens L**4** is located closer to the object than any other member of this second lens group G**2** is and that the seventh lens L**7** is located closer to the image plane than any other member of this second lens group G**2** is. The fifth lens L**5** and the sixth lens L**6** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifth lens L**5** and the sixth lens L**6**.

[0040] The third lens group G**3** is made up of: an aperture stop A; an eighth lens L**8** having positive power; a ninth lens L**9** having negative power; a tenth lens L**10** having positive power; and an eleventh lens L**11** having negative power. The aperture stop A and the eighth, ninth, tenth, and eleventh lenses L**8**, L**9**, L**10**, L**11** are arranged in this order such that the aperture stop A is located closer to the object than any other member of this third lens group G**3** is and that the eleventh lens L**11** is located closer to the image plane than any other member of this third lens group G**3** is. The ninth lens L**9** and the tenth lens L**10** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the ninth lens L**9** and the tenth lens L**10**.

[0041] The fourth lens group G**4** is made up of a twelfth lens L**12** having positive power and a thirteenth lens L**13** having positive power. The twelfth lens L**12** is located closer to the object than the thirteenth lens L**13** is. The thirteenth lens L**13** is located closer to the image plane than the twelfth lens L**12** is.

[0042] The fifth lens group G**5** is made up of: a fourteenth lens L**14** having positive power; and a fifteenth lens L**5** having negative power. The fourteenth lens L**14** is located closer to the object than the fifteenth lens L**15** is. The fifteenth lens L**15** is located closer to the image plane than the fourteenth lens L**14** is. The fourteenth lens L**14** and the fifteenth lens L**15** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fourteenth lens L**14** and the fifteenth lens L**15**.

[0043] The sixth lens group G**6** is made up of a sixteenth lens L**16** having negative power and a seventeenth lens L**17** having positive power. The sixteenth lens L**16** is located closer to the object than the seventeenth lens L**17** is. The seventeenth lens L**17** is located closer to the image plane than the sixteenth lens L**16** is.

[0044] The respective lenses will be described.

[0045] First, the respective lenses that form the first lens group G**1** will be described. The first lens

L**1** is a meniscus lens having a convex surface facing the object. The second lens L**2** is a biconvex lens. The third lens L**3** is a meniscus lens having a convex surface facing the object.
[0046] Next, the respective lenses that form the second lens group G**2** will be described. The fourth lens L**4** is a meniscus lens having a convex surface facing the object. The fifth lens L**5** is a biconcave lens. The sixth lens L**6** is a biconvex lens. The seventh lens L**7** is a biconcave lens.
[0047] Next, the respective lenses that form the third lens group G**3** will be described. The eighth lens L**8** is a biconvex lens. The ninth lens L**9** is a meniscus lens having a convex surface facing the object. The tenth lens L**10** is a biconvex lens. The eleventh lens L**11** is a meniscus lens having a convex surface facing the image plane. In this case, the eighth lens L**8** is an example of the lens LG**3**F**1**. The eighth lens L**8** is an example of the group of fixed lenses G**3**Obj configured not to move perpendicularly to the optical axis during image stabilization. The ninth lens L**9** is an example of the lens LG**3**F**2**. The ninth lens L**9** and the tenth lens L**10** are an example of a group of image stabilizer lenses that move perpendicularly to the optical axis during the image stabilization. The eleventh lens L**11** is an example of the lens LG**3**R**1**. The eleventh lens L**11** is an example of a group of fixed lenses G**3**Img that does not move perpendicularly to the optical axis during the image stabilization.
[0048] Next, the respective lenses that form the fourth lens group G**4** will be described. The twelfth lens L**12** is a meniscus lens having a convex surface facing the object. The thirteenth lens L**13** is a biconvex lens. The object-side and image-side surfaces of the thirteenth lens L**13** are aspheric surfaces. In this case, the twelfth lens L**12** is an example of the lens LG**4**F**1**. The twelfth lens L**12** is an example of the lens LG**4**Fp**1**. The thirteenth lens L**13** is an example of the lens LG**4**F**2**.
[0049] Next, the respective lenses that form the fifth lens group G**5** will be described. The fourteenth lens L**14** is a biconvex lens. The fifteenth lens L**15** is a biconcave lens.
[0050] Next, the respective lenses that form the sixth lens group G**6** will be described. The sixteenth lens L**16** is a meniscus lens having a convex surface facing the image plane. The seventeenth lens L**17** is a biconvex lens.
[0051] While the imaging optical system according to the first embodiment is zooming from the wide-angle end toward the telephoto end during a shooting session, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** all move toward the object with respect to the image plane S. In the meantime, as the imaging optical system is zooming, the first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** move along the optical axis such that the interval between the first lens group G**1** and the second lens group G**2** increases, the interval between the second lens group G**2** and the third lens group G**3** decreases, the interval between the third lens group G**3** and the fourth lens group G**4** decreases, the interval between the fourth lens group G**4** and the fifth lens group G**5** increases, and the interval between the fifth lens group G**5** and the sixth lens group G**6** increases.
[0052] While the imaging optical system according to the first embodiment is focusing to make a transition from the infinity in-focus state toward the close-object in-focus state, the fifth lens group G**5** moves along the optical axis toward the image plane.
[0053] When any camera shake or any vibration caused by external force during a shooting session is detected by a gyrosensor provided for at least one of an interchangeable lens unit holding the imaging optical system or an image capture device to which the interchangeable lens unit is attached, the ninth lens L**9** and the tenth lens L**10** (forming the group of image stabilizer lenses) which belong to the third lens group G**3** move perpendicularly to the optical axis (i.e., in a direction in which the image blur is reduced) to optically compensate for the image blur that may be caused by the camera shake or the vibration due to external force. These image blur compensation lenses (namely, the ninth lens L**9** and the tenth lens L**10**) allow the imaging optical system to compensate for the shift of the image point due to the vibration of the overall system. That is to say, this allows the imaging optical system to optically compensate for the image blur due to camera shake,

vibrations, and other disturbances.

Second Embodiment

[0054] FIG. **2**A illustrates an imaging optical system according to a second embodiment.

[0055] The imaging optical system includes: a first lens group G**1** having positive power; a second lens group G**2** having negative power; a third lens group G**3** having positive power; a fourth lens group G**4** having positive power; a fifth lens group G**5** having negative power; and a sixth lens group G**6** having negative power. The first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** are arranged in this order such that the first lens group G**1** is located closer to an object than any of the second, third, fourth, fifth, or sixth lens group G**2**, G**3**, G**4**, G**5**, G**6** is and that the sixth lens group G**6** is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group G**1**, G**2**, G**3**, G**4**, G**5** is.

[0056] The imaging optical system forms an image at a point on the image plane S.

[0057] The first lens group G**1** is made up of: a first lens L**1** having negative power; a second lens L**2** having positive power; and a third lens L**3** having positive power. The first lens L**1**, the second lens L**2**, and the third lens L**3** are arranged in this order such that the first lens L**1** is located closer to the object than any other member of this first lens group G**1** is and that the third lens L**3** is located closer to the image plane than any other member of this first lens group G**1** is. The first lens L**1** and the second lens L**2** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the first lens L**1** and the second lens L**2**.

[0058] The second lens group G**2** is made up of: a fourth lens L**4** having negative power; a fifth lens L**5** having negative power; a sixth lens L**6** having positive power; and a seventh lens L**7** having negative power. The fourth, fifth, sixth, and seventh lenses L**4**, L**5**, L**6**, L**7** are arranged in this order such that the fourth lens L**4** is located closer to the object than any other member of this second lens group G**2** is and that the seventh lens L**7** is located closer to the image plane than any other member of this second lens group G**2** is. The fifth lens L**5** and the sixth lens L**6** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifth lens L**5** and the sixth lens L**6**.

[0059] The third lens group G**3** is made up of: an aperture stop A; an eighth lens L**8** having positive power; a ninth lens L**9** having negative power; a tenth lens L**10** having positive power, and an eleventh lens L**11** having negative power. The aperture stop A and the eighth, ninth, tenth, and eleventh lenses L**8**, L**9**, L**10**, L**11** are arranged in this order such that the aperture stop A is located closer to the object than any other member of this third lens group G**3** is and that the eleventh lens L**11** is located closer to the image plane than any other member of this third lens group G**3** is. The ninth lens L**9** and the tenth lens L**10** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the ninth lens L**9** and the tenth lens L**10**.

[0060] The fourth lens group G**4** is made up of a twelfth lens L**12** having positive power and a thirteenth lens L**13** having positive power. The twelfth lens L**12** is located closer to the object than the thirteenth lens L**13** is. The thirteenth lens L**13** is located closer to the image plane than the twelfth lens L**12** is.

[0061] The fifth lens group G**5** is made up of: a fourteenth lens L**14** having positive power; and a fifteenth lens L**5** having negative power. The fourteenth lens L**14** is located closer to the object than the fifteenth lens L**15** is. The fifteenth lens L**15** is located closer to the image plane than the fourteenth lens L**14** is. The fourteenth lens L**14** and the fifteenth lens L**15** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fourteenth lens L**14** and the fifteenth lens L**15**.

[0062] The sixth lens group G**6** is made up of a sixteenth lens L**16** having negative power and a seventeenth lens L**17** having positive power. The sixteenth lens L**16** is located closer to the object than the seventeenth lens L**17** is. The seventeenth lens L**17** is located closer to the image plane than the sixteenth lens L**16** is.

[0063] The respective lenses will be described.

[0064] First, the respective lenses that form the first lens group G**1** will be described. The first lens L**1** is a meniscus lens having a convex surface facing the object. The second lens L**2** is a biconvex lens. The third lens L**3** is a meniscus lens having a convex surface facing the object.
[0065] Next, the respective lenses that form the second lens group G**2** will be described. The fourth lens L**4** is a meniscus lens having a convex surface facing the object. The fifth lens L**5** is a biconcave lens. The sixth lens L**6** is a biconvex lens. The seventh lens L**7** is a biconcave lens.
[0066] Next, the respective lenses that form the third lens group G**3** will be described. The eighth lens L**8** is a biconvex lens. The ninth lens L**9** is a meniscus lens having a convex surface facing the object. The tenth lens L**10** is a biconvex lens. The eleventh lens L**11** is a biconcave lens. In this case, the eighth lens L**8** is an example of the lens LG**3**F**1**. The eighth lens L**8** is an example of the group of fixed lenses G**3**Obj configured not to move perpendicularly to the optical axis during image stabilization. The ninth lens L**9** is an example of the lens LG**3**F**2**. The ninth lens L**9** and the tenth lens L**10** are an example of a group of image stabilizer lenses that move perpendicularly to the optical axis during the image stabilization. The eleventh lens L**11** is an example of the lens LG**3**R**1**. The eleventh lens L**11** is an example of a group of fixed lenses G**3**Img that does not move perpendicularly to the optical axis during the image stabilization.
[0067] Next, the respective lenses that form the fourth lens group G**4** will be described. The twelfth lens L**12** is a biconvex lens. The thirteenth lens L**13** is a biconvex lens. The object-side and image-side surfaces of the thirteenth lens L**13** are aspheric surfaces. In this case, the twelfth lens L**12** is an example of the lens LG**4**F**1**. The twelfth lens L**12** is an example of the lens LG**4**Fp**1**. The thirteenth lens L**13** is an example of the lens LG**4**F**2**.
[0068] Next, the respective lenses that form the fifth lens group G**5** will be described. The fourteenth lens L**14** is a meniscus lens having a convex surface facing the image plane. The fifteenth lens L**15** is a biconcave lens.
[0069] Next, the respective lenses that form the sixth lens group G**6** will be described. The sixteenth lens L**16** is a meniscus lens having a convex surface facing the image plane. The seventeenth lens L**17** is a biconvex lens.
[0070] While the imaging optical system according to the second embodiment is zooming from the wide-angle end toward the telephoto end during a shooting session, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** all move toward the object with respect to the image plane S. In the meantime, as the imaging optical system is zooming, the first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** move along the optical axis such that the interval between the first lens group G**1** and the second lens group G**2** increases, the interval between the second lens group G**2** and the third lens group G**3** decreases, the interval between the third lens group G**3** and the fourth lens group G**4** decreases, the interval between the fourth lens group G**4** and the fifth lens group G**5** increases from the wide-angle end through a middle position but decreases from the middle position through the telephoto end, and the interval between the fifth lens group G**5** and the sixth lens group G**6** decreases from the wide-angle end through the middle position but increases from the middle position through the telephoto end.
[0071] While the imaging optical system according to the second embodiment is focusing to make a transition from the infinity in-focus state toward the close-object in-focus state, the fifth lens group G**5** moves along the optical axis toward the image plane.
[0072] Meanwhile, the ninth lens L**9** and the tenth lens L**10** (forming the group of image stabilizer lenses) which belong to the third lens group G**3** move perpendicularly to the optical axis to optically compensate for the image blur. These image blur compensation lenses (namely, the ninth lens L**9** and the tenth lens L**10**) allow the imaging optical system to compensate for the shift of the image point due to the vibration of the overall system. That is to say, this allows the imaging optical system to optically compensate for the image blur due to camera shake, vibrations, and other disturbances.

Third Embodiment

[0073] FIG. **3**A illustrates an imaging optical system according to a third embodiment.

[0074] The imaging optical system includes: a first lens group G**1** having positive power; a second lens group G**2** having negative power; a third lens group G**3** having positive power; a fourth lens group G**4** having positive power; a fifth lens group G**5** having negative power; and a sixth lens group G**6** having negative power. The first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** are arranged in this order such that the first lens group G**1** is located closer to an object than any of the second, third, fourth, fifth, or sixth lens group G**2**, G**3**, G**4**, G**5**, G**6** is and that the sixth lens group G**6** is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group G**1**, G**2**, G**3**, G**4**, G**5** is.

[0075] The imaging optical system forms an image at a point on the image plane S.

[0076] The first lens group G**1** is made up of: a first lens L**1** having negative power; a second lens L**2** having positive power; and a third lens L**3** having positive power. The first lens L**1**, the second lens L**2**, and the third lens L**3** are arranged in this order such that the first lens L**1** is located closer to the object than any other member of this first lens group G**1** is and that the third lens L**3** is located closer to the image plane than any other member of this first lens group G**1** is. The first lens L**1** and the second lens L**2** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the first lens L**1** and the second lens L**2**. The second lens group G**2** is made up of: a fourth lens L**4** having negative power; a fifth lens L**5** having negative power; a sixth lens L**6** having positive power; and a seventh lens L**7** having negative power. The fourth, fifth, sixth, and seventh lenses L**4**, L**5**, L**6**, L**7** are arranged in this order such that the fourth lens L**4** is located closer to the object than any other member of this second lens group G**2** is and that the seventh lens L**7** is located closer to the image plane than any other member of this second lens group G**2** is. The fifth lens L**5** and the sixth lens L**6** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifth lens L**5** and the sixth lens L**6**.

[0077] The third lens group G**3** is made up of: an aperture stop A; an eighth lens L**8** having positive power; a ninth lens L**9** having negative power; a tenth lens L**10** having positive power; and an eleventh lens L**11** having negative power. The aperture stop A and the eighth, ninth, tenth, and eleventh lenses L**8**, L**9**, L**10**, L**11** are arranged in this order such that the aperture stop A is located closer to the object than any other member of this third lens group G**3** is and that the eleventh lens L**11** is located closer to the image plane than any other member of this third lens group G**3** is. The ninth lens L**9** and the tenth lens L**10** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the ninth lens L**9** and the tenth lens L**10**.

[0078] The fourth lens group G**4** is made up of a twelfth lens L**12** having positive power and a thirteenth lens L**13** having positive power. The twelfth lens L**12** is located closer to the object than the thirteenth lens L**13** is. The thirteenth lens L**13** is located closer to the image plane than the twelfth lens L**12** is.

[0079] The fifth lens group G**5** is made up of: a fourteenth lens L**14** having positive power; and a fifteenth lens L**5** having negative power. The fourteenth lens L**14** is located closer to the object than the fifteenth lens L**15** is. The fifteenth lens L**15** is located closer to the image plane than the fourteenth lens L**14** is. The fourteenth lens L**14** and the fifteenth lens L**15** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fourteenth lens L**14** and the fifteenth lens L**15**.

[0080] The sixth lens group G**6** is made up of a sixteenth lens L**16** having negative power and a seventeenth lens L**17** having positive power. The sixteenth lens L**16** is located closer to the object than the seventeenth lens L**17** is. The seventeenth lens L**17** is located closer to the image plane than the sixteenth lens L**16** is.

[0081] The respective lenses will be described.

[0082] First, the respective lenses that form the first lens group G**1** will be described. The first lens

L**1** is a meniscus lens having a convex surface facing the object. The second lens L**2** is a biconvex lens. The third lens L**3** is a meniscus lens having a convex surface facing the object.
[0083] Next, the respective lenses that form the second lens group G**2** will be described. The fourth lens L**4** is a meniscus lens having a convex surface facing the object. The fifth lens L**5** is a biconcave lens. The sixth lens L**6** is a biconvex lens. The seventh lens L**7** is a biconcave lens.
[0084] Next, the respective lenses that form the third lens group G**3** will be described. The eighth lens L**8** is a biconvex lens. The ninth lens L**9** is a meniscus lens having a convex surface facing the object. The tenth lens L**10** is a biconvex lens. The eleventh lens L**11** is a meniscus lens having a convex surface facing the image plane. In this case, the eighth lens L**8** is an example of the lens LG**3**F**1**. The eighth lens L**8** is an example of the group of fixed lenses G**3**Obj configured not to move perpendicularly to the optical axis during image stabilization. The ninth lens L**9** is an example of the lens LG**3**F**2**. The ninth lens L**9** and the tenth lens L**10** are an example of a group of image stabilizer lenses that move perpendicularly to the optical axis during the image stabilization. The eleventh lens L**11** is an example of the lens LG**3**R**1**. The eleventh lens L**11** is an example of a group of fixed lenses G**3**Img that does not move perpendicularly to the optical axis during the image stabilization.
[0085] Next, the respective lenses that form the fourth lens group G**4** will be described. The twelfth lens L**12** is a meniscus lens having a convex surface facing the object. The thirteenth lens L**13** is a biconvex lens. The object-side and image-side surfaces of the thirteenth lens L**13** are aspheric surfaces. In this case, the twelfth lens L**12** is an example of the lens LG**4**F**1**. The twelfth lens L**12** is an example of the lens LG**4**Fp**1**. The thirteenth lens L**13** is an example of the lens LG**4**F**2**.
[0086] Next, the respective lenses that form the fifth lens group G**5** will be described. The fourteenth lens L**14** is a biconvex lens. The fifteenth lens L**15** is a biconcave lens.
[0087] Next, the respective lenses that form the sixth lens group G**6** will be described. The sixteenth lens L**16** is a meniscus lens having a convex surface facing the image plane. The seventeenth lens L**17** is a biconvex lens.
[0088] While the imaging optical system according to the third embodiment is zooming from the wide-angle end toward the telephoto end during a shooting session, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** all move toward the object with respect to the image plane S. In the meantime, as the imaging optical system is zooming, the first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** move along the optical axis such that the interval between the first lens group G**1** and the second lens group G**2** increases, the interval between the second lens group G**2** and the third lens group G**3** decreases, the interval between the third lens group G**3** and the fourth lens group G**4** decreases, the interval between the fourth lens group G**4** and the fifth lens group G**5** increases from the wide-angle end through a middle position but decreases from the middle position through the telephoto end, and the interval between the fifth lens group G**5** and the sixth lens group G**6** increases.
[0089] While the imaging optical system according to the third embodiment is focusing to make a transition from the infinity in-focus state toward the close-object in-focus state, the fifth lens group G**5** moves along the optical axis toward the image plane.
[0090] Meanwhile, the ninth lens L**9** and the tenth lens L**10** (forming the group of image stabilizer lenses) which belong to the third lens group G**3** move perpendicularly to the optical axis to optically compensate for the image blur. These image blur compensation lenses (namely, the ninth lens L**9** and the tenth lens L**10**) allow the imaging optical system to compensate for the shift of the image point due to the vibration of the overall system. That is to say, this allows the imaging optical system to optically compensate for the image blur due to camera shake, vibrations, and other disturbances.
Fourth Embodiment
[0091] FIG. **4**A illustrates an imaging optical system according to a fourth embodiment.

[0092] The imaging optical system includes: a first lens group G**1** having positive power; a second lens group G**2** having negative power; a third lens group G**3** having positive power; a fourth lens group G**4** having positive power; a fifth lens group G**5** having negative power; a sixth lens group G**6** having negative power; and a seventh lens group G**7** having negative power. The first, second, third, fourth, fifth, sixth, and seventh lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6**, G**7** are arranged in this order such that the first lens group G**1** is located closer to an object than any of the second, third, fourth, fifth, sixth, or seventh lens group G**2**, G**3**, G**4**, G**5**, G**6**, G**7** is and that the seventh lens group G**7** is located closer to an image plane than any of the first, second, third, fourth, fifth, or sixth lens group G**1**, G**2**, G**3**, G**4**, G**5**, G**6** is.
[0093] The imaging optical system forms an image at a point on the image plane S.
[0094] The first lens group G**1** is made up of: a first lens L**1** having negative power; a second lens L**2** having positive power; and a third lens L**3** having positive power. The first lens L**1**, the second lens L**2**, and the third lens L**3** are arranged in this order such that the first lens L**1** is located closer to the object than any other member of this first lens group G**1** is and that the third lens L**3** is located closer to the image plane than any other member of this first lens group G**1** is. The first lens L**1** and the second lens L**2** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the first lens L**1** and the second lens L**2**.
[0095] The second lens group G**2** is made up of: a fourth lens L**4** having negative power; a fifth lens L**5** having negative power; a sixth lens L**6** having positive power; and a seventh lens L**7** having negative power. The fourth, fifth, sixth, and seventh lenses L**4**, L**5**, L**6**, L**7** are arranged in this order such that the fourth lens L**4** is located closer to the object than any other member of this second lens group G**2** is and that the seventh lens L**7** is located closer to the image plane than any other member of this second lens group G**2** is. The fifth lens L**5** and the sixth lens L**6** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifth lens L**5** and the sixth lens L**6**.
[0096] The third lens group G**3** is made up of: an aperture stop A; an eighth lens L**8** having positive power; a ninth lens L**9** having negative power; a tenth lens L**10** having positive power; and an eleventh lens L**11** having negative power. The aperture stop A and the eighth, ninth, tenth, and eleventh lenses L**8**, L**9**, L**10**, L**11** are arranged in this order such that the aperture stop A is located closer to the object than any other member of this third lens group G**3** is and that the eleventh lens L**11** is located closer to the image plane than any other member of this third lens group G**3** is. The ninth lens L**9** and the tenth lens L**10** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the ninth lens L**9** and the tenth lens L**10**.
[0097] The fourth lens group G**4** is made up of a twelfth lens L**12** having positive power and a thirteenth lens L**13** having positive power. The twelfth lens L**12** is located closer to the object than the thirteenth lens L**13** is. The thirteenth lens L**13** is located closer to the image plane than the twelfth lens L**12** is.
[0098] The fifth lens group G**5** is made up of: a fourteenth lens L**14** having positive power; and a fifteenth lens L**5** having negative power. The fourteenth lens L**14** is located closer to the object than the fifteenth lens L**15** is. The fifteenth lens L**15** is located closer to the image plane than the fourteenth lens L**14** is. The fourteenth lens L**14** and the fifteenth lens L**15** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fourteenth lens L**14** and the fifteenth lens L**15**.
[0099] The sixth lens group G**6** is made up of a sixteenth lens L**16** having negative power and a seventeenth lens L**17** having positive power. The sixteenth lens L**16** is located closer to the object than the seventeenth lens L**17** is. The seventeenth lens L**17** is located closer to the image plane than the sixteenth lens L**16** is.
[0100] The seventh lens group G**7** consists of an eighteenth lens L**18** having negative power.
[0101] The respective lenses will be described.
[0102] First, the respective lenses that form the first lens group G**1** will be described. The first lens

L**1** is a meniscus lens having a convex surface facing the object. The second lens L**2** is a biconvex lens. The third lens L**3** is a meniscus lens having a convex surface facing the object.
[0103] Next, the respective lenses that form the second lens group G**2** will be described. The fourth lens L**4** is a meniscus lens having a convex surface facing the object. The fifth lens L**5** is a biconcave lens. The sixth lens L**6** is a biconvex lens. The seventh lens L**7** is a biconcave lens.
[0104] Next, the respective lenses that form the third lens group G**3** will be described. The eighth lens L**8** is a biconvex lens. The ninth lens L**9** is a meniscus lens having a convex surface facing the object. The tenth lens L**10** is a biconvex lens. The eleventh lens L**11** is a biconcave lens. In this case, the eighth lens L**8** is an example of the lens LG**3**F**1**. The eighth lens L**8** is an example of the group of fixed lenses G**3**Obj configured not to move perpendicularly to the optical axis during image stabilization. The ninth lens L**9** is an example of the lens LG**3**F**2**. The ninth lens L**9** and the tenth lens L**10** are an example of a group of image stabilizer lenses that move perpendicularly to the optical axis during the image stabilization. The eleventh lens L**11** is an example of the lens LG**3**R**1**. The eleventh lens L**11** is an example of a group of fixed lenses G**3**Img that does not move perpendicularly to the optical axis during the image stabilization.
[0105] Next, the respective lenses that form the fourth lens group G**4** will be described. The twelfth lens L**12** is a biconvex lens. The thirteenth lens L**13** is a biconvex lens. The object-side and image-side surfaces of the thirteenth lens L**13** are aspheric surfaces. In this case, the twelfth lens L**12** is an example of the lens LG**4**F**1**. The twelfth lens L**12** is an example of the lens LG**4**Fp**1**. The thirteenth lens L**13** is an example of the lens LG**4**F**2**.
[0106] Next, the respective lenses that form the fifth lens group G**5** will be described. The fourteenth lens L**14** is a biconvex lens. The fifteenth lens L**15** is a biconcave lens.
[0107] Next, the respective lenses that form the sixth lens group G**6** will be described. The sixteenth lens L**16** is a meniscus lens having a convex surface facing the image plane. The seventeenth lens L**17** is a biconvex lens.
[0108] Next, the lens that forms the seventh lens group G**7** will be described. The eighteenth lens L**18** is a meniscus lens having a convex surface facing the image plane.
[0109] While the imaging optical system according to the fourth embodiment is zooming from the wide-angle end toward the telephoto end during a shooting session, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, the sixth lens group G**6**, and the seventh lens group G**7** all move toward the object with respect to the image plane S. In the meantime, as the imaging optical system is zooming, the first, second, third, fourth, fifth, sixth, and seventh lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6**, G**7** move along the optical axis such that the interval between the first lens group G**1** and the second lens group G**2** increases, the interval between the second lens group G**2** and the third lens group G**3** decreases, the interval between the third lens group G**3** and the fourth lens group G**4** decreases, the interval between the fourth lens group G**4** and the fifth lens group G**5** increases from the wide-angle end through a middle position but decreases from the middle position through the telephoto end, the interval between the fifth lens group G**5** and the sixth lens group G**6** decreases from the wide-angle end through the middle position but increases from the middle position through the telephoto end, and the interval between the sixth lens group G**6** and the seventh lens group G**7** increases from the wide-angle end through the middle position but decreases from the middle position through the telephoto end.
[0110] While the imaging optical system according to the fourth embodiment is focusing to make a transition from the infinity in-focus state toward the close-object in-focus state, the fifth lens group G**5** moves along the optical axis toward the image plane.
[0111] Meanwhile, the ninth lens L**9** and the tenth lens L**10** (forming the group of image stabilizer lenses) which belong to the third lens group G**3** move perpendicularly to the optical axis to optically compensate for the image blur. These image blur compensation lenses (namely, the ninth lens L**9** and the tenth lens L**10**) allow the imaging optical system to compensate for the shift of the

image point due to the vibration of the overall system. That is to say, this allows the imaging optical system to optically compensate for the image blur due to camera shake, vibrations, and other disturbances.

Fifth Embodiment

[0112] FIG. **5**A illustrates an imaging optical system according to a fifth embodiment.

[0113] The imaging optical system includes: a first lens group G**1** having positive power; a second lens group G**2** having negative power; a third lens group G**3** having positive power; a fourth lens group G**4** having positive power; a fifth lens group G**5** having negative power; and a sixth lens group G**6** having negative power. The first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** are arranged in this order such that the first lens group G**1** is located closer to an object than any of the second, third, fourth, fifth, or sixth lens group G**2**, G**3**, G**4**, G**5**, G**6** is and that the sixth lens group G**6** is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group G**1**, G**2**, G**3**, G**4**, G**5** is.

[0114] The imaging optical system forms an image at a point on the image plane S.

[0115] The first lens group G**1** is made up of: a first lens L**1** having negative power; a second lens L**2** having positive power; and a third lens L**3** having positive power. The first lens L**1**, the second lens L**2**, and the third lens L**3** are arranged in this order such that the first lens L**1** is located closer to the object than any other member of this first lens group G**1** is and that the third lens L**3** is located closer to the image plane than any other member of this first lens group G**1** is. The first lens L**1** and the second lens L**2** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the first lens L**1** and the second lens L**2**.

[0116] The second lens group G**2** is made up of: a fourth lens L**4** having negative power; a fifth lens L**5** having negative power; a sixth lens L**6** having positive power; and a seventh lens L**7** having negative power. The fourth, fifth, sixth, and seventh lenses L**4**, L**5**, L**6**, L**7** are arranged in this order such that the fourth lens L**4** is located closer to the object than any other member of this second lens group G**2** is and that the seventh lens L**7** is located closer to the image plane than any other member of this second lens group G**2** is. The fifth lens L**5** and the sixth lens L**6** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifth lens L**5** and the sixth lens L**6**.

[0117] The third lens group G**3** is made up of: an aperture stop A; an eighth lens L**8** having positive power; a ninth lens L**9** having negative power; a tenth lens L**10** having positive power; and an eleventh lens L**11** having negative power. The aperture stop A and the eighth, ninth, tenth, and eleventh lenses L**8**, L**9**, L**10**, L**11** are arranged in this order such that the aperture stop A is located closer to the object than any other member of this third lens group G**3** is and that the eleventh lens L**11** is located closer to the image plane than any other member of this third lens group G**3** is. The ninth lens L**9** and the tenth lens L**10** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the ninth lens L**9** and the tenth lens L**10**.

[0118] The fourth lens group G**4** is made up of a twelfth lens L**12** having positive power, a thirteenth lens L**13** having positive power, and a fourteenth lens L**14** having positive power. The twelfth lens L**12** is located closer to the object than the thirteenth lens L**13** or the fourteenth lens L**14** is. The fourteenth lens L**14** is located closer to the image plane than the twelfth lens L**12** or the thirteenth lens L**13** is.

[0119] The fifth lens group G**5** is made up of: a fifteenth lens L**15** having positive power; and a sixteenth lens L**16** having negative power. The fifteenth lens L**15** is located closer to the object than the sixteenth lens L**16** is. The sixteenth lens L**16** is located closer to the image plane than the fifteenth lens L**15** is. The fifteenth lens L**15** and the sixteenth lens L**16** are bonded together with an adhesive, for example, to form a bonded lens. That is to say, the bonded lens includes the fifteenth lens L**15** and the sixteenth lens L**16**.

[0120] The sixth lens group G**6** is made up of a seventeenth lens L**17** having negative power and an eighteenth lens L**18** having positive power. The seventeenth lens L**17** is located closer to the object than the eighteenth lens L**18** is. The eighteenth lens L**18** is located closer to the image plane than the seventeenth lens L**17** is.

[0121] The respective lenses will be described.

[0122] First, the respective lenses that form the first lens group G**1** will be described. The first lens L**1** is a meniscus lens having a convex surface facing the object. The second lens L**2** is a biconvex lens. The third lens L**3** is a meniscus lens having a convex surface facing the object.

[0123] Next, the respective lenses that form the second lens group G**2** will be described. The fourth lens L**4** is a meniscus lens having a convex surface facing the object. The fifth lens L**5** is a biconcave lens. The sixth lens L**6** is a biconvex lens. The seventh lens L**7** is a biconcave lens.

[0124] Next, the respective lenses that form the third lens group G**3** will be described. The eighth lens L**8** is a biconvex lens. The ninth lens L**9** is a meniscus lens having a convex surface facing the object. The tenth lens L**10** is a biconvex lens. The eleventh lens L**11** is a biconcave lens. In this case, the eighth lens L**8** is an example of the lens LG**3**F**1**. The eighth lens L**8** is an example of the group of fixed lenses G**3**Obj configured not to move perpendicularly to the optical axis during image stabilization. The ninth lens L**9** is an example of the lens LG**3**F**2**. The ninth lens L**9** and the tenth lens L**10** are an example of a group of image stabilizer lenses that move perpendicularly to the optical axis during the image stabilization. The eleventh lens L**11** is an example of the lens LG**3**R**1**. The eleventh lens L**11** is an example of a group of fixed lenses G**3**Img that does not move perpendicularly to the optical axis during the image stabilization.

[0125] Next, the respective lenses that form the fourth lens group G**4** will be described. The twelfth lens L**12** is a meniscus lens having a convex surface facing the object. The thirteenth lens L**13** is a meniscus lens having a convex surface facing the image plane. The fourteenth lens L**14** is a biconvex lens. The object-side and image-side surfaces of the fourteenth lens L**14** are aspheric surfaces. In this case, the twelfth lens L**12** is an example of the lens LG**4**F**1**. The twelfth lens L**12** is an example of the lens LG**4**Fp**1**. The thirteenth lens L**13** is an example of the lens LG**4**F**2**.

[0126] Next, the respective lenses that form the fifth lens group G**5** will be described. The fifteenth lens L**15** is a biconvex lens. The sixteenth lens L**16** is a biconcave lens.

[0127] Next, the respective lenses that form the sixth lens group G**6** will be described. The seventeenth lens L**17** is a meniscus lens having a convex surface facing the image plane. The eighteenth lens L**18** is a biconvex lens.

[0128] While the imaging optical system according to the fifth embodiment is zooming from the wide-angle end toward the telephoto end during a shooting session, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** all move toward the object with respect to the image plane S. In the meantime, as the imaging optical system is zooming, the first, second, third, fourth, fifth, and sixth lens groups G**1**, G**2**, G**3**, G**4**, G**5**, G**6** move along the optical axis such that the interval between the first lens group G**1** and the second lens group G**2** increases, the interval between the second lens group G**2** and the third lens group G**3** decreases, the interval between the third lens group G**3** and the fourth lens group G**4** decreases, the interval between the fourth lens group G**4** and the fifth lens group G**5** increases, and the interval between the fifth lens group G**5** and the sixth lens group G**6** increases.

[0129] While the imaging optical system according to the fifth embodiment is focusing to make a transition from the infinity in-focus state toward the close-object in-focus state, the fifth lens group G**5** moves along the optical axis toward the image plane.

[0130] Meanwhile, the ninth lens L**9** and the tenth lens L**10** (forming the group of image stabilizer lenses) which belong to the third lens group G**3** move perpendicularly to the optical axis to optically compensate for the image blur. These image blur compensation lenses (namely, the ninth lens L**9** and the tenth lens L**10**) allow the imaging optical system to compensate for the shift of the image point due to the vibration of the overall system. That is to say, this allows the imaging optical system to optically compensate for the image blur due to camera shake, vibrations, and other disturbances.

Other Embodiments

[0131] The first, second, third, fourth, and fifth embodiments have been described as exemplary embodiments of the present disclosure. Note that the embodiments described above are only examples of the present disclosure and should not be construed as limiting. Rather, each of these embodiments may be readily modified, replaced, combined with other embodiments, provided with some additional components, or partially omitted without departing from the scope of the present disclosure.

[0132] For example, in the first to fifth embodiments described above, the imaging optical system is supposed to be used in the entire zoom range from the wide-angle end through the telephoto end. However, the imaging optical system does not have to be used in the entire zoom range. Alternatively, the imaging optical system may also be used selectively only in an extracted range where optical performance is ensured according to the desired zoom range, for example. That is to say, the imaging optical system may also be used as an imaging optical system with lower zoom power than the imaging optical system to be described for the first, second, third, fourth, and fifth examples of numerical values corresponding to the first, second, third, fourth, and fifth embodiments, respectively. Optionally, the imaging optical system may also be used selectively as a single-focus lens system only at an extracted focal length where optical performance is ensured according to the desired zoom position.

[0133] In addition, the number of the lens groups and the number of the lenses that form each lens group are substantial numbers. Optionally, a lens having substantially no power may be added to any of the lens groups described above.

[0134] In the embodiments described above, the image blur is compensated for by moving the image blur compensation lenses perpendicularly to the optical axis. However, the image blur may be compensated for as long as the lenses are moved such that each of those lenses has a vertical direction component. For example, the image blur may also be compensated for by pivoting the image blur compensation lenses around a center of rotation on the optical axis (i.e., with the lenses tilted such that the axis of each of these lenses intersects with the optical axis of the imaging optical system) if the lens barrel is allowed to have a complicated structure.

(Conditions and Advantages)

[0135] Next, conditions that may be satisfied by the imaging optical systems according to the first to fifth embodiments, for example, will be described. A plurality of possible conditions may be defined for the imaging optical system according to each of the first to fifth embodiments. In that case, an imaging optical system, of which the configuration satisfies all of these possible conditions, is most advantageous. Alternatively, an imaging optical system that achieves its expected advantages by satisfying any of the individual conditions to be described below may also be provided.

[0136] An imaging optical system according to each of the first to fifth embodiments described above includes: a first lens group having positive power; a second lens group having negative power; a third lens group having positive power; a fourth lens group having positive power; a fifth lens group having negative power; and a sixth lens group having power. The first, second, third, fourth, fifth, and sixth lens groups are arranged in this order such that the first lens group is located closer to an object than any of the second, third, fourth, fifth or sixth lens group is, and that the sixth lens group is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group is. An interval between each pair of lens groups that are adjacent to each other changes as at least the first, second, third, fourth, fifth, and sixth lens groups move in an optical axis direction while the imaging optical system is zooming. The optical axis direction is a direction aligned with an optical axis of the imaging optical system. This configuration will be hereinafter referred to as a “basic configuration.”

[0137] The imaging optical system with the basic configuration has a configuration that may be

used effectively to reduce the overall size of the zoom lens. This allows the imaging optical system to compensate for various types of aberrations that occur to the respective lens groups during zooming. Consequently, this allows for providing an imaging optical system having the ability to compensate for various types of aberrations sufficiently over the entire zoom range.
[0138] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; and a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization.
[0139] The imaging optical system preferably satisfies the following inequality (1):
[00001] $0.06 < Th\_IS\_Obj / Th\_G3 < 0.50 \quad (1)$ [0140] where Th_IS_Obj is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Obj, and
[0141] Th_G**3** is the thickness of the third lens group G**3** on the optical axis.
[0142] The condition expressed by this inequality (1) defines the ratio of an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Obj to the thickness of the third lens group G**3** on the optical axis (i.e., a thickness measured on the optical axis from the object-side surface of a lens located closer to the object than any other lens belonging to the third lens group G**3** is to the image-side surface of a lens located closer to the image plane than any other lens belonging to the third lens group G**3** is).
[0143] If the Th_IS_Obj/Th_G**3** ratio were less than the lower limit set by the inequality (1), then the spherical aberration would be too positively biased (i.e., toward the positive side of the spherical aberration diagram to be referred to later) over the entire zoom range and the image plane would be too negatively biased (i.e., toward the negative side of the spherical aberration diagram to be referred to later) over the entire zoom range, which is not beneficial.
[0144] Conversely, if the Th_IS_Obj/Th_G**3** ratio were greater than the upper limit set by the inequality (1), then the spherical aberration would be too negatively biased over the entire zoom range and the image plane would be too positively biased over the entire zoom range, which is not beneficial, either.
[0145] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (1a) and (1b) is/are preferably satisfied:
[00002] $0.08 < Th\_IS\_Obj / Th\_G3 \quad (1a) \quad Th\_IS\_Obj / Th\_G3 < 0.30. \quad (1b)$
[0146] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (1c) and (1d) is/are satisfied:
[00003] $0.1 < Th\_IS\_Obj / Th\_G3 \quad (1c) \quad Th\_IS\_Obj / Th\_G3 < 0.25. \quad (1d)$
[0147] Even more preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (1) and (1f) is/are satisfied:
[00004] $0.12 < Th\_IS\_Obj / Th\_G3 \quad (1e) \quad Th\_IS\_Obj / Th\_G3 < 0.2. \quad (1f)$
[0148] For example, in the imaging optical system, the fourth lens group G**4** preferably includes at least two lenses.
[0149] The imaging optical system preferably satisfies the following inequality (2):
[00005] $0.05 < Th\_G4\_Air / Th\_G4 < 0.80 \quad (2)$
where Th_G**4** Air is a maximum value of an air gap on the optical axis between adjacent lenses included in at least two lenses that form the fourth lens group G**4**; and [0150] Th_G**4** is the thickness of the fourth lens group G**4** on the optical axis.
[0151] The condition expressed by the inequality (2) defines the ratio of a maximum value of an air gap between adjacent lenses included in at least two lenses which form part of the fourth lens group G**4** to the thickness of the fourth lens group G**4** on the optical axis.

[0152] If the Th_G**4**_Air/Th_G**4** ratio were less than the lower limit set by the inequality (2), then the spherical aberration would be too positively biased (i.e., toward the positive side of the spherical aberration diagram to be referred to later) on the telephoto side and the image plane would be too negatively biased (i.e., toward the negative side of the spherical aberration diagram to be referred to later) on the telephoto side, which is not beneficial.
[0153] Conversely, if the Th_G**4**_Air/Th_G**4** ratio were greater than the upper limit set by the inequality (2), then the spherical aberration would be too negatively biased on the telephoto side and the image plane would be too positively biased on the telephoto side, which is not beneficial, either.
[0154] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (2a) and (2b) is/are preferably satisfied:
[00006] $0.075 < \text{Th\_G4\_Air} / \text{Th\_G4} \quad (2a) \quad \text{Th\_G4\_Air} / \text{Th\_G4} < 0.70. \quad (2b)$
[0155] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (2c) and (2d) is/are satisfied:
[00007] $0.100 < \text{Th\_G4\_Air} / \text{Th\_G4} \quad (2c) \quad \text{Th\_G4\_Air} / \text{Th\_G4} < 0.60. \quad (2d)$
[0156] Even more preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (2e) and (2f) is/are satisfied:
[00008] $0.150 < \text{Th\_G4\_Air} / \text{Th\_G4} \quad (2e) \quad \text{Th\_G4\_Air} / \text{Th\_G4} < 0.50. \quad (2f)$
[0157] Particularly preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (2g) and (2h) is/are satisfied:
[00009] $0.190 < \text{Th\_G4\_Air} / \text{Th\_G4} \quad (2g) \quad \text{Th\_G4\_Air} / \text{Th\_G4} < 0.40. \quad (2h)$
[0158] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during an image stabilization; and a group of fixed lenses G**3**Img located closer to the image plane than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization.
[0159] This may reduce the chances of the group of image stabilizer lenses moving during the image stabilization. Consequently, the aberrations may be compensated for sufficiently even when the group of image stabilizer lenses moves perpendicularly to the optical axis.
[0160] For example, in the imaging optical system, an object-side surface of a lens LG**3**R**1** located closer to the image plane than any of other negative lenses that form part of the third lens group G**3** preferably has a convex surface facing the image plane.
[0161] This allows the spherical aberration occurring in the third lens group G**3** having positive power to be compensated for sufficiently over the entire zoom range.
[0162] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; and a group of fixed lenses G**3**Img located closer to the image plane than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis.
[0163] The imaging optical system preferably satisfies the following inequality (3):
[00010] $0.05 < \text{Th\_IS\_Img} / \text{Th\_G3} < 0.80 \quad (3)$
where Th_IS_Img is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Img, and [0164] Th G**3** is the thickness of the third lens group G**3** on the optical axis.
[0165] The condition expressed by the inequality (3) defines the ratio of an air gap on the optical

axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Img to the thickness of the third lens group G**3** on the optical axis (i.e., a thickness measured on the optical axis from the object-side surface of a lens located closer to the object than any other lens belonging to the third lens group G**3** is to the image-side surface of a lens located closer to the image plane than any other lens belonging to the third lens group G**3** is).

[0166] If the Th_IS_Img/Th_G**3** ratio were less than the lower limit set by the inequality (3), then the spherical aberration would be too positively biased (i.e., toward the positive side of the spherical aberration diagram to be referred to later) over the entire zoom range, which is not beneficial.

[0167] Conversely, if the Th_IS_Img/Th_G**3** ratio were greater than the upper limit set by the inequality (3), then the spherical aberration would be too negatively biased (i.e., toward the negative side of the spherical aberration diagram to be referred to later) over the entire zoom range, which is not beneficial, either.

[0168] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (3a) and (3b) is/are preferably satisfied:

[00011] $0.075 < Th\_IS\_Img / Th\_G3 \quad (3a) \quad Th\_IS\_Img / Th\_G3 < 0.4. \quad (3b)$

[0169] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (3c) and (3d) is/are satisfied:

[00012] $0.12 < Th\_IS\_Img / Th\_G3 \quad (3c) \quad Th\_IS\_Img / Th\_G3 < 0.2. \quad (3d)$

[0170] For example, the imaging optical system preferably satisfies the following inequality (4):

[00013] $0. < (R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2) < 1. \quad (4)$

where R**2**_LG**3**F**1** is a radius of curvature of an image-side surface of a lens LG**3**F**1** located closer to the object than any other lens belonging to the third lens group G**3** is, and [0171] R**1**_LG**3**F**2** is a radius of curvature of an object-side surface of a lens LG**3**F**2** located adjacent to the lens LG**3**F**1** and closer to the image plane than the lens LG**3**F**1** is.

[0172] The condition expressed by the inequality (4) defines the ratio of the sum of a radius of curvature of an image-side surface of a lens LG**3**F**1** located closer to the object than any other lens belonging to the third lens group and a radius of curvature of an object-side surface of a lens LG**3**F**2** located adjacent to the lens LG**3**F**1** and closer to the image plane than the lens LG**3**F**1** is to the difference between the former and latter radii of curvature.

[0173] If the ratio were less than the lower limit set by the inequality (4), then the spherical aberration would be too positively biased (i.e., toward the positive side of the spherical aberration diagram to be referred to later) on the telephoto side, which is not beneficial. In addition, the image plane would be too positively biased (i.e., toward the positive side of the spherical aberration diagram to be referred to later) over the entire zoom range, which is not beneficial, either.

[0174] Conversely, if the ratio were greater than the upper limit set by the inequality (4), then the spherical aberration would be too negatively biased (i.e., toward the negative side of the spherical aberration diagram to be referred to later) on the telephoto side, which is not beneficial. In addition, the image plane would be too negatively biased (i.e., toward the negative side of the spherical aberration diagram to be referred to later) over the entire zoom range, which is not beneficial, either.

[0175] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (4a) and (4b) is/are preferably satisfied:

[00014] $(R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2) < 0.97 \quad (4a)$

$0.65 < (R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2). \quad (4b)$

[0176] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (4c) and (4d) is/are satisfied:

[00015] $(R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2) < 0.95 \quad (4c)$

$0.8 < (R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2).\quad (4d)$

[0177] For example, in the imaging optical system, an image-side surface of a positive lens LG**4**Fp**1** located closer to the object than any other lens belonging to the fourth lens group G**4** is preferably has a convex surface facing the object.

[0178] This allows the planarity of the image plane S to be corrected sufficiently over the entire zoom range.

[0179] For example, the imaging optical system preferably satisfies the following inequality (5):

[00016] $-10.0 < (R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2) < 1.\quad (5)$

where R**2**_LG**4**F**1** is a radius of curvature of an image-side surface of a lens LG**4**F**1** located closer to the object than any other lens belonging to the fourth lens group G**4** is, and [0180] R**1**_LG**4**F**2** is a radius of curvature of an object-side surface of a lens LG**4**F**2** located adjacent to the lens LG**4**F**1** and closer to the image plane than the lens LG**4**F**1** is.

[0181] The condition expressed by the inequality (5) defines the ratio of the sum of a radius of curvature of an image-side surface of a lens LG**4**F**1** located closer to the object than any other lens belonging to the fourth lens group G**4** is and a radius of curvature of an object-side surface of a lens LG**4**F**2** located adjacent to the lens LG**4**F**1** and closer to the image plane than the lens LG**4**F**1** is to the difference between the former and latter radii of curvature.

[0182] If the ratio were less than the lower limit set by the inequality (5), then the image plane would be too negatively biased (i.e., toward the negative side of the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial.

[0183] Conversely, if the ratio were greater than the upper limit set by the inequality (5), then the image plane would be too positively biased (i.e., toward the positive side of the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial, either.

[0184] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (5a) and (5b) is/are preferably satisfied:

[00017] $(R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2) < 0.75\quad (5a)$

$-8. < (R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2).\quad (5b)$

[0185] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (5c) and (5d) is/are satisfied:

[00018] $(R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2) < 0.50\quad (5c)$

$-6. < (R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2).\quad (5d)$

[0186] For example, the imaging optical system preferably satisfies the following inequality (6):

[00019] $nd\_LG4Fp1 < 1.6\quad (6)$

where nd_LG**4**Fp**1** is a refractive index of a positive lens LG**4**Fp**1** located closer to the object than any other lens belonging to the fourth lens group G**4** is.

[0187] The condition expressed by the inequality (6) defines the refractive index of a positive lens LG**4**Fp**1** located closer to the object than any other lens belonging to the fourth lens group G**4** is.

[0188] If the refractive index were greater than the upper limit set by the inequality (6), then the spherical aberration would be too positively biased (i.e., toward the positive side of the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial.

[0189] To enhance the advantage described above, the condition expressed by the following inequality (6a) is preferably satisfied:

[00020] $nd\_LG4Fp1 < 1.55.\quad (6a)$

[0190] More preferably, to further enhance the advantage described above, the imaging optical system satisfies the condition expressed by the following inequality (6b):

[00021] $1.4 < nd\_LG4Fp1.\quad (6b)$

[0191] If the refractive index were less than the lower limit set by the inequality (6b), then the

spherical aberration might be too negatively biased (i.e., toward the negative side of the astigmatism diagram to be referred to later).
[0192] For example, in the imaging optical system, the fifth lens group G**5** is preferably configured to move toward the image plane while the imaging optical system is focusing from an infinity in-focus object toward a close-object in-focus state.
[0193] This ensures good focus performance while the imaging optical system is focusing.
[0194] For example, the imaging optical system preferably satisfies the following inequality (7):
[00022] $0.1 < ThwG5\_G6 / fw < 0.8 \quad (7)$
where ThwG**5**_G**6** is an interval measured on the optical axis between the fifth lens group G**5** and the sixth lens group G**6** in the imaging optical system at a wide-angle end; and [0195] fw is a focal length of the imaging optical system at the wide-angle end.
[0196] The condition expressed by the inequality (7) defines the ratio of an interval measured on the optical axis between the fifth lens group G**5** and the sixth lens group G**6** in the imaging optical system at a wide-angle end to a focal length of the imaging optical system at the wide-angle end.
[0197] If the ThwG**5**_G**6**/fw ratio were less than the lower limit set by the inequality (7), the magnitude of movement of the fifth lens group G**5** toward the image plane while the imaging optical system is focusing from the infinity in-focus state toward the close-object in-focus state would decrease to the point of causing a decline in focusing accuracy, which is not beneficial.
[0198] Conversely, if the ThwG**5**_G**6**/fw ratio were greater than the upper limit set by the inequality (7), the magnitude of movement of the fifth lens group G**5** toward the image plane while the imaging optical system is focusing from the infinity in-focus state toward the close-object in-focus state would increase to the point of making the total optical length too long, which is not beneficial, either.
[0199] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (7a) and (7b) is/are preferably satisfied:
[00023] $0.2 < ThwG5\_G6 / fw \quad (7a) \quad ThwG5\_G6 / fw < 0.7. \quad (7b)$
[0200] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (7c) and (7d) is/are satisfied:
[00024] $0.32 < ThwG5\_G6 / fw \quad (7c) \quad ThwG5\_G6 / fw < 0.6. \quad (7d)$
[0201] For example, the imaging optical system preferably satisfies the following inequality (8):
[00025] $0.2 < fG1 / fT < 1. \quad (8)$
where fG**1** is a focal length of the first lens group G**1**, and [0202] fT is a focal length of the imaging optical system at a telephoto end.
[0203] The condition expressed by the inequality (8) defines the ratio of a focal length of the first lens group G**1** to a focal length of the imaging optical system at a telephoto end.
[0204] If the fG**1**/fT ratio were less than the lower limit set by the inequality (8), then the focal length of the first lens group G**1** would be so short as to make it difficult to increase the focal length of the imaging optical system at the telephoto end, which is not beneficial.
[0205] Conversely, if the fG**1**/fT ratio were greater than the upper limit set by the inequality (8), then the focal length of the first lens group G**1** would be so long as to make the magnitude of movement of the first lens group G**1** too much while the imaging optical system is zooming, which is not beneficial, either.
[0206] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (8a) and (8b) is/are preferably satisfied:
[00026] $0.25 < fG1 / fT \quad (8a) \quad fG1 / fT < 0.8. \quad (8b)$
[0207] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (8c) and (8d) is/are satisfied:
[00027] $0.3 < fG1 / fT \quad (8c) \quad fG1 / fT < 0.5. \quad (8d)$

[0208] The imaging optical system preferably satisfies the following inequality (9):

[00028] $-2.5 < fG5 / fw < -1. \quad (9)$

where fG**5** is a focal length of the fifth lens group G**5**, and [0209] fw is a focal length of the imaging optical system at a wide-angle end.

[0210] The condition set by the inequality (9) defines the ratio of a focal length of the fifth lens group G**5** to a focal length of the imaging optical system at a wide-angle end.

[0211] If the fG**5**/fw ratio were less than the lower limit set by the inequality (9), then the focal length of the fifth lens group G**5** would be so short as to make it difficult to reduce the variation in aberration from the wide-angle end through the telephoto end while the imaging optical system is zooming, which is not beneficial.

[0212] Conversely, if the fG**5**/fw ratio were greater than the upper limit set by the inequality (9), then the focal length of the fifth lens group G**5** would be so long as to make the magnitude of movement too much while the imaging optical system is focusing, which is not beneficial, either.

[0213] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (9a) and (9b) is/are preferably satisfied:

[00029] $-2.25 < fG5 / fw \quad (9a) \quad fG5 / fw < -1.5. \quad (9b)$

[0214] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (9c) and (9d) is/are satisfied:

[00030] $-1.9 < fG5 / fw \quad (9c) \quad fG5 / fw < -1.8. \quad (9d)$

[0215] For example, the imaging optical system preferably satisfies the following inequality (10):

[00031] $0.5 < Th\_G2\_G3 / Yw < 3. \quad (10)$

where Th_G**2**_G**3** is an air gap measured on the optical axis between the second lens group G**2** and the third lens group G**3** in the imaging optical system at a wide-angle end, and [0216] Yw is a maximum image height of the imaging optical system at the wide-angle end.

[0217] The condition expressed by the inequality (10) defines the ratio of an air gap measured on the optical axis between the second lens group G**2** and the third lens group G**3** in the imaging optical system at a wide-angle end (i.e., the gap measured on the optical axis between an image-side surface of a lens located closer to the image plane than any other lens belonging to the second lens group G**2** to an object-side surface of lens located closer to the object than any other lens belonging to the third lens group G**3**) to a maximum image height of the imaging optical system at the wide-angle end. In a camera system or an image capture device including an imaging optical system, the maximum image height of the imaging optical system at the wide-angle end may be regarded as a diagonal length, measured on an image sensor, of an imaging point corresponding to the angle of view at the wide-angle end.

[0218] If the Th_G**2**_G**3**/Yw ratio were less than the lower limit set by the inequality (10), then the interval would change so little while the imaging optical system is zooming as to make it difficult to compensate for aberrations at the time of zooming, which is not beneficial.

[0219] Conversely, if the Th_G**2**_G**3**/Yw ratio were greater than the upper limit set by the inequality (10), then the interval would change so much while the imaging optical system is zooming as to make it difficult to arrange a mechanism for causing either the second lens group G**2** or the third lens group G**3** to move, which is not beneficial, either.

[0220] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (10a) and (10b) is/are preferably satisfied:

[00032] $0.75 < Th\_G2\_G3 / Yw \quad (10a) \quad Th\_G2\_G3 / Yw < 2.. \quad (10b)$

[0221] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (10c) and (10d) is/are satisfied:

[00033] $0.85 < Th\_G2\_G3 / Yw \quad (10c) \quad Th\_G2\_G3 / Yw < 1.. \quad (10d)$

[0222] For example, the imaging optical system preferably satisfies the following inequality (11):

[00034] $0.3 < BFw / Yw < 3.$ (11)

where BFw is a back focus of the imaging optical system at a wide-angle end; and [0223] Yw is a maximum image height of the imaging optical system at the wide-angle end.

[0224] The condition expressed by the inequality (11) defines the ratio of a back focus of the imaging optical system at a wide-angle end (i.e., the interval measured on the optical axis from a lens located closest to the image plane to the image plane S in the imaging optical system at a wide-angle end) to a maximum image height of the imaging optical system at the wide-angle end. In a camera system or an image capture device including an imaging optical system, the maximum image height of the imaging optical system at the wide-angle end may be regarded as a diagonal length, measured on an image sensor, of an imaging point corresponding to the angle of view at the wide-angle end.

[0225] If the BFw/Yw ratio were less than the lower limit set by the inequality (11), then the back focus would be so narrow as to make it difficult to arrange a member for use to couple the imaging optical system to an image sensor placed on the image plane S, which is not beneficial.

[0226] Conversely, if the BFw/Yw ratio were greater than the upper limit set by the inequality (11), then the back focus would be so wide as to make the overall size of the imaging optical system too large, which is not beneficial, either.

[0227] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (11a) and (11b) is/are preferably satisfied:

[00035] $0.4 < BFw / Yw$ $(11a)$ $BFw / Yw < 2.4.$ $(11b)$

[0228] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (11c) and (11d) is/are satisfied:

[00036] $0.5 < BFw / Yw$ $(11c)$ $BFw / Yw < 1.2.$ $(11d)$

[0229] Even more preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (11e) and (11f) is/are satisfied:

[00037] $0.75 < BFw / Yw$ $(11e)$ $BFw / Yw < 0.9.$ $(11f)$

[0230] For example, the imaging optical system preferably satisfies the following inequality (12):

[00038] $2. < TTLw / Yw < 10.0$ (12)

where TTLw is a total optical length of the imaging optical system at a wide-angle end; and [0231] Yw is a maximum image height of the imaging optical system at the wide-angle end.

[0232] The condition expressed by the inequality (12) defines the ratio of a total optical length of the imaging optical system at a wide-angle end (i.e., the interval measured from an object-side surface of a lens located closest to the object to the image plane S in the imaging optical system) to a maximum image height of the imaging optical system at the wide-angle end. In a camera system or an image capture device including an imaging optical system, the maximum image height of the imaging optical system at the wide-angle end may be regarded as a diagonal length, measured on an image sensor, of an imaging point corresponding to the angle of view at the wide-angle end.

[0233] If the TTLw/Yw ratio were less than the lower limit set by the inequality (12), then the total optical length of the imaging optical system at the wide-angle end would be so short as to make it difficult to compensate for aberrations sufficiently, which is not beneficial.

[0234] Conversely, if the TTLw/Yw ratio were greater than the upper limit set by the inequality (12), then the total optical length of the imaging optical system at the wide-angle end would be too long, which is not beneficial, either.

[0235] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (12a) and (12b) is/are preferably satisfied:

[00039] $3. < TTLw / Yw$ $(12a)$ $TTLw / Yw < 8..$ $(12b)$

[0236] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (12c) and (12d) is/are satisfied:

[00040] $4. < TTLw / Yw \quad (12c) \quad TTLw / Yw < 5.5. \quad (12d)$

[0237] For example, the imaging optical system preferably satisfies the following inequality (13):

[00041] $0.1 < (TTLt - TTLw) / TTLt < 0.5 \quad (13)$

where TTLt is a total optical length of the imaging optical system at a telephoto end; and [0238] TTLw is a total optical length of the imaging optical system at a wide-angle end.

[0239] The condition expressed by the inequality (13) defines the ratio of the difference between the total optical length of the imaging optical system at the telephoto end and the total optical length of the imaging optical system at the wide-angle end to the total optical length of the imaging optical system at the telephoto end. Note that the total optical length of the imaging optical system is the interval from an object-side surface of a lens located closest to the object in the imaging optical system to the image plane S.

[0240] If the (TTLt−TTLw)/TTLt ratio were less than the lower limit set by the inequality (13), then the total optical length would change so little while the imaging optical system is zooming as to make it difficult to ensure a sufficient zoom ratio, which is not beneficial.

[0241] Conversely, if the (TTLt−TTLw)/TTLt ratio were greater than the upper limit set by the inequality (13), then the total optical length would change so much while the imaging optical system is zooming as to make it difficult to arrange a mechanism for causing the lens groups to move, which is not beneficial, either.

[0242] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (13a) and (13b) is/are preferably satisfied:

[00042] $0.2 < (TTLt - TTLw) / TTLt \quad (13a) \quad (TTLt - TTLw) / TTLt < 0.4. \quad (13b)$

[0243] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (13c) and (13d) is/are satisfied:

[00043] $0.25 < (TTLt - TTLw) / TTLt \quad (13c) \quad (TTLt - TTLw) / TTLt < 0.3. \quad (13d)$

[0244] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses that move perpendicularly to the optical axis during the image stabilization; and a negative lens LG**3***n* that does not move perpendicularly to the optical axis during the image stabilization. In the first to fifth embodiments, the negative lens LG**3***n* may be, for example, the eleventh lens L**11**.

[0245] This allows for reducing the movement of the group of image stabilizer lenses during the image stabilization. This allows, even when the group of image stabilizer lenses moves perpendicularly to the optical axis, the aberrations to be compensated for sufficiently.

[0246] For example, in the imaging optical system, the third lens group G**3** is preferably made up of at least four and at most six lenses.

[0247] This allows, even when the group of image stabilizer lenses moves perpendicularly to the optical axis, the aberrations caused by the group of image stabilizer lenses to be compensated for sufficiently.

[0248] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses that move perpendicularly to the optical axis during the image stabilization; and a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and not moving perpendicularly to the optical axis during image stabilization.

[0249] The imaging optical system preferably satisfies the following inequality (14):

[00044] $0.01 < Th\_IS\_Obj / Yw < 1. \quad (14)$

where Th_IS_Obj is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Obj, and [0250] Yw is a maximum image height of the imaging optical system at a wide-angle end.

[0251] The condition expressed by the inequality (14) defines the ratio of an air gap on the optical

axis between a group of image stabilizer lenses and a group of fixed lenses G**3**Obj to a maximum image height of the imaging optical system at a wide-angle end. In a camera system or an image capture device including an imaging optical system, the maximum image height of the imaging optical system at the wide-angle end may be regarded as a diagonal length, measured on an image sensor, of an imaging point corresponding to the angle of view at the wide-angle end.
[0252] If the Th_IS_Obj/Yw ratio were less than the lower limit set by the inequality (14), then the spherical aberration would be significantly positively biased (i.e., toward the positive side in the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial.
[0253] Conversely, if the Th_IS_Obj/Yw ratio were greater than the upper limit set by the inequality (14), then the spherical aberration would be significantly negatively biased (i.e., toward the negative side in the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial, either.
[0254] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (14a) and (14b) is/are preferably satisfied:
[00045] $0.05 < Th\_IS\_Obj / Yw \quad (14a) \quad Th\_IS\_Obj / Yw < 0.75. \quad (14b)$
[0255] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (14c) and (14d) is/are satisfied:
[00046] $0.08 < Th\_IS\_Obj / Yw \quad (14c) \quad Th\_IS\_Obj / Yw < 0.25 \quad (14d)$
[0256] For example, in the imaging optical system, the third lens group G**3** preferably includes: a group of image stabilizer lenses consisting of a plurality of lenses that move perpendicularly to the optical axis during the image stabilization; and a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and not moving perpendicularly to the optical axis during image stabilization.
[0257] The imaging optical system preferably satisfies the following inequality (15):
[00047] $0.02 < Th\_IS\_Img / Yw < 1. \quad (15)$
where Th_IS_Img is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Img, and [0258] Yw is a maximum image height of the imaging optical system at a wide-angle end.
[0259] The condition expressed by the inequality (15) defines the ratio of an air gap on the optical axis between a group of image stabilizer lenses and the group of fixed lenses G**3**Img to a maximum image height of the imaging optical system at a wide-angle end. In a camera system or an image capture device including an imaging optical system, the maximum image height of the imaging optical system at the wide-angle end may be regarded as a diagonal length, measured on an image sensor, of an imaging point corresponding to the angle of view at the wide-angle end.
[0260] If the Th_IS_Img/Yw ratio were less than the lower limit set by the inequality (15), then the spherical aberration would be significantly positively biased (i.e., toward the positive side in the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial.
[0261] Conversely, if the Th_IS_Img/Yw ratio were greater than the upper limit set by the inequality (15), then the spherical aberration would be significantly negatively biased (i.e., toward the negative side in the astigmatism diagram to be referred to later) over the entire zoom range, which is not beneficial, either.
[0262] To enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (15a) and (15b) is/are preferably satisfied:
[00048] $0.05 < Th\_IS\_Img / Yw \quad (15a) \quad Th\_IS\_Img / Yw < 0.50. \quad (15b)$
[0263] More preferably, to further enhance the advantage described above, the condition(s) expressed by one or both of the following inequalities (15c) and (15d) is/are satisfied:
[00049] $0.08 < Th\_IS\_Img / Yw \quad (15c) \quad Th\_IS\_Img / Yw < 0.15. \quad (15d)$
[0264] In the first to fifth embodiments described above, an imaging optical system which includes

an aperture stop A located closer to the object than any other member of the third lens group G**3** and moving along with the lenses of the third lens group G**3** while the imaging optical system is zooming has been described as an exemplary arrangement in which the third lens group G**3** includes the aperture stop A. However, this is only an example and should not be construed as limiting. Alternatively, the third lens group G**3** may include the aperture stop A located closer to the image plane than any other member of the third lens group G**3** is and moving along with the lenses of the third lens group G**3** while the imaging optical system is zooming. Still alternatively, the second lens group G**2** may include the aperture stop A located closer to the image plane than any other member of the second lens group G**2** is and moving along with the lenses of the second lens group G**2** while the imaging optical system is zooming. Yet alternatively, the aperture stop A may also be provided between the second lens group G**2** and the third lens group G**3** to move independently of the second lens group G**2** and the third lens group G**3** while the imaging optical system is zooming.

[0265] Nevertheless, providing the third lens group G**3** with the aperture stop A located closer to the object than any other member of the third lens group G**3** is and moving along with the lenses of the third lens group G**3** while the imaging optical system is zooming may reduce the chances of the effective diameter of the frontend lens (i.e., the first lens L**1**) increasing too much.

[0266] Optionally, if the complexity of a cam mechanism for use to make zooming is allowable, then controlling the aperture stop A to move independently of the second lens group G**2** and the third lens group G**3** also reduces the chances of the effective diameter of the frontend lens (i.e., the first lens L**1**) increasing too much.

Schematic Configuration for Image Capture Device to which First Embodiment is Applied

[0267] FIG. **6** illustrates a schematic configuration for an image capture device, to which the imaging optical system of the first embodiment is applied. Alternatively, the imaging optical system according to the second, third, fourth, or fifth embodiment is also applicable to the image capture device.

[0268] The image capture device **100** includes a housing **104**, an image sensor **102**, and the imaging optical system **101** according to the first embodiment. Specifically, the image capture device **100** may be implemented as a digital camera, for example.

[0269] The housing **104** includes a lens barrel **302**. The lens barrel **302** holds the respective lens groups and the aperture stop A that form the imaging optical system **101**.

[0270] The image sensor **102** is disposed at the image plane S of the imaging optical system according to the first embodiment.

[0271] In the imaging optical system **101**, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** are attached to, or engaged with, a lens frame included in the lens barrel **302** so as to move while the imaging optical system **101** is zooming.

[0272] This provides an image capture device with the ability to compensate for various types of aberrations sufficiently.

[0273] In the example described above, the imaging optical system according to the first embodiment is applied to a digital camera. However, this is only an example and should not be construed as limiting. Alternatively, the imaging optical system is also applicable to a surveillance camera, a smartphone, or any of various other types of image capture devices.

Schematic Configuration for Camera System to which First Embodiment is Applied

[0274] FIG. **7** illustrates a schematic configuration for a camera system, to which the imaging optical system of the first embodiment is applied. Alternatively, the imaging optical system according to the second, third, fourth, or fifth embodiment is also applicable to the camera system.

[0275] The camera system **200** includes a camera body **201** and an interchangeable lens unit **300** to be connected removably to the camera body **201**.

[0276] The camera body **201** includes an image sensor **202**, a monitor **203**, a memory, a camera

mount **204**, and a viewfinder **205**. The image sensor **202** receives an optical image formed by the imaging optical system **301** of the interchangeable lens unit **300** and transforms the optical image into an electrical image signal. The monitor **203** displays the image signal transformed by the image sensor **202**. The memory stores the image signal.
[0277] The imaging optical system **301** of the interchangeable lens unit **300** is the imaging optical system according to the first embodiment.
[0278] The interchangeable lens unit **300** includes not only the imaging optical system **301** but also a lens barrel **302** and a lens mount **304** as well. The lens barrel **302** holds the respective lens groups and aperture stop A that form the imaging optical system **301**. The lens mount **304** is to be connected to the camera mount **204** of the camera body **201**.
[0279] The camera mount **204** and the lens mount **304** are physically connected together. In addition, the camera mount **204** and the lens mount **304** also electrically connect together a controller in the camera body **201** and a controller in the interchangeable lens unit **300**. That is to say, the camera mount **204** and the lens mount **304** serve as interfaces that allow themselves to exchange signals with each other.
[0280] In the imaging optical system **301**, the first lens group G**1**, the second lens group G**2**, the third lens group G**3**, the fourth lens group G**4**, the fifth lens group G**5**, and the sixth lens group G**6** are attached to, or engaged with, a lens frame included in the lens barrel **302** so as to be movable while the imaging optical system **301** is zooming.
[0281] In the camera system **200** including the respective lens groups held by the lens barrel **302** and the camera body **201**, an actuator, a lens frame, and other members to be controlled by the controller in the interchangeable lens unit **300** are provided such that the fifth lens group G**5** may move while the imaging optical system **301** is focusing.
Examples of Numerical Values
[0282] Next, exemplary sets of specific numerical values that were actually adopted in the imaging optical systems with the configurations according to the first, second, third, fourth, and fifth embodiments will be described. Note that in the tables showing these exemplary sets of numerical values, the length is expressed in millimeters (mm), the angle of view is expressed in degrees (°), r indicates the radius of curvature, d indicates the surface interval, nd indicates a refractive index in response to a d-line, vd (also denoted as "vd") indicates an abbe number in response to a d-line, and a surface with an asterisk (*) is an aspheric surface. The aspheric shape is defined by the following equation.
[00050]$Z = \frac{h^2 / r}{1 + \sqrt{1 - (1 + \quad)(h / r)^2}} + $ .Math. $A_n h^n$
where Z is the distance from a point on an aspheric surface, located at a height h measured from the optical axis, to a tangent plane defined with respect to the vertex of the aspheric surface, h is the height as measured from the optical axis, r is the radius of curvature of the vertex, K is a conic constant, and An is an n.sup.th order aspheric surface coefficient.
[0283] FIGS. **1**B, **2**B, **3**B, **4**B, and **5**B are longitudinal aberration diagrams showing what state the imaging optical systems according to the first, second, third, fourth, and fifth embodiments assume.
[0284] In each longitudinal aberration diagram, portion (a) shows the longitudinal aberrations at the wide-angle end, portion (b) shows the longitudinal aberrations at the middle position, and portion (c) shows the longitudinal aberrations at the telephoto end. Each of portions (a), (b) and (c) of these longitudinal aberration diagrams shows spherical aberration (SA (mm)), astigmatism (AST (mm)), and distortion (DIS (%)) in this order from left to right. In each spherical aberration diagram, the ordinate indicates the F number (designated by "F" on the drawings), the solid curve indicates a characteristic in response to a d-line, the shorter dashed curve indicates a characteristic in response to an F-line, and the longer dashed curve indicates a characteristic in response to a C-line. In each astigmatism diagram, the ordinate indicates the image height (designated by "H" on the drawings), the solid curve indicates a characteristic with respect to a sagittal plane (designated by "s" on the

drawings), and the dotted curve indicates a characteristic with respect to a meridional plane (designated by "m" on the drawings). Furthermore, in each distortion diagram, the ordinate indicates the image height (designated by "H" on the drawings).

[0285] FIGS. **1**C, **2**C, **3**C, **4**C, and **5**C are lateral aberration diagrams showing what state the imaging optical systems according to the first, second, third, fourth, and fifth embodiments assume at the telephoto end.

[0286] In each lateral aberration diagram, the upper three aberration diagrams represent a basic state where no image blur compensation is performed at the telephoto end. On the other hand, the lower three aberration diagrams represent an image blur compensated state where the group of image stabilizer lenses is moved to a predetermined degree perpendicularly to the optical axis at the telephoto end. In the three lateral aberration diagrams representing the basic state, the upper graph shows lateral aberration at an image point corresponding to 70% of the maximum image height. The middle graph shows the lateral aberration at an axial image point. The lower graph shows lateral aberration at an image point corresponding to −70% of the maximum image height. In the three lateral aberration diagrams representing the image blur compensated state, the upper graph shows lateral aberration at an image point corresponding to 70% of the maximum image height. The middle graph shows lateral aberration at an axial image point. The lower graph shows lateral aberration at an image point corresponding to −70% of the maximum image height. Also, in each lateral aberration diagram, the abscissa indicates the distance from a principal ray on the pupil plane. The solid curve indicates a characteristic in response to a d-line. The shorter dashed curve indicates a characteristic in response to an F-line. The longer dashed curve indicates a characteristic in response to a C-line.

[0287] Note that in the imaging optical systems according to the respective examples of numerical values, the magnitudes of movement of the group of image stabilizer lenses in a direction perpendicular to the optical axis at the telephoto end are as follows: [0288] First example of numerical values: 0.340 mm [0289] Second example of numerical values: 0.350 mm [0290] Third example of numerical values: 0.348 mm [0291] Fourth example of numerical values: 0.351 mm [0292] Fifth example of numerical values: 0.349 mm

[0293] At the telephoto end at which the shooting distance is infinite (∞), the magnitude of image eccentricity in a situation where the imaging optical system is tilted to 0.3 degrees is equal to the magnitude of image eccentricity in a situation where the group of image stabilizer lenses makes parallel displacement by a distance represented by any of these numerical values in a direction perpendicular to the optical axis.

[0294] As can be seen from these lateral aberration diagrams, the lateral aberration at the axial image point has a sufficient degree of symmetry. It can also be seen that comparing the lateral aberration at an image point corresponding to +70% of the maximum image height with the lateral aberration at an image point corresponding to −70% of the maximum image height in the basic state, their degrees of curvature are both small and their aberration curves have an approximately equal tilt, and therefore, their eccentricity coma aberration and eccentricity astigmatism are both insignificant. This means that even in the image blur compensated state, sufficiently good imaging performance is achieved. In addition, supposing the imaging optical systems have the same image blur compensation angle, as the focal length of the entire imaging optical system shortens, the magnitude of parallel displacement required for image blur compensation decreases. This allows the image blur compensation to be done to a sufficient degree at any zoom position with respect to an image blur compensation angle of about 0.3 degrees without causing a decline in imaging performance.

First Example of Numerical Values

[0295] Following is a first exemplary set of numerical values for the imaging optical system corresponding to the first embodiment shown in FIG. **1**A. Specifically, as the first example of numerical values for the imaging optical system, surface data is shown in Table 1A, aspheric surface data is shown in Table 1B, and various types of data in the infinity in-focus state are shown in Tables 1C-1F.

TABLE-US-00001 TABLE 1A (Surface data) Effective Surface No. r d nd vd diameter Object surface ∞ 1 90.10290 1.20000 1.84666 23.8 24.773 2 59.23570 6.93240 1.49700 81.6 23.749 3 −280.94820 0.20000 23.386 4 44.38180 4.64010 1.49700 81.6 20.573 5 141.93270 Variable 20.258 6 96.78490 1.00000 1.95347 32.6 13.231 7 18.86630 5.70110 10.904 8 −38.17850 0.65900 1.59462 66.8 10.436 9 23.41150 3.68120 1.86672 19.8 9.594 10 −69.86610 1.74760 9.358 11 −29.23560 0.60000 1.88300 40.8 8.624 12 542.90170 Variable 8.369 13 (Aperture) ∞ 1.40000 7.176 14 18.33090 3.15260 1.52711 57.2 8.087 15 −378.74380 2.24620 8.070 16 18.17170 0.60000 1.95698 32.3 8.050 17 12.06780 4.65620 1.52092 60.8 7.669 18 −49.83060 1.96370 7.515 19 −22.70500 0.60000 1.99236 29.7 7.160 20 −843.60570 Variable 7.254 21 17.31530 2.29190 1.49700 81.6 7.832 22 47.62670 2.13040 7.735 23* 71.12630 3.30940 1.58699 59.5 7.622 24* −28.91280 Variable 7.707 25 216.95880 2.02110 1.94372 18.0 8.379 26 −40.67040 0.60000 1.80334 32.2 8.401 27 27.07710 Variable 8.420 28 −19.87370 1.00000 1.82868 43.1 11.234 29 −58.94070 0.50000 12.663 30 109.76350 2.96010 1.76918 34.3 14.777 31 −144.98430 Variable 32 ∞ 2.10000 1.51680 64.2 33 ∞ 1.00000 34 ∞ BF Image plane ∞

TABLE-US-00002 TABLE 1B (Aspheric surface data) 23.sup.rd surface K = 2.63837E+00, A4 = −3.75089E−05, A6 = 7.29717E−07, A8 = 8.23449E−10 A10 = 9.78133E−11, A12 = −5.65229E−13 24.sup.th surface K = −4.87684E−01, A4 = 4.48028E−05, A6 = 7.78441E−07, A8 = 3.87499E−10 A10 = 1.12740E−10, A12 = −3.25867E−13

(Various Types of Data in Infinity in-Focus State)

TABLE-US-00003 TABLE 1C (Various types of data) (Zoom ratio: 6.65091) Wide-angle Middle Telephoto Focal length 28.9887 74.7234 192.8010 F number 4.16046 5.80386 7.38074 Angle of view 37.1877 15.4912 6.1980 Image height 21.1600 21.6300 21.6300 Total lens length 112.8021 138.1617 158.9887 BF 0.00000 0.00000 0.00000 d5 0.9677 19.9101 35.5300 d12 17.9193 9.4440 1.7944 d20 4.4987 2.4455 0.8000 d24 1.7038 2.8663 3.5734 d27 15.9632 16.1916 19.4165 d31 12.8500 28.4927 38.9884 Entrance pupil position 28.2608 72.2588 143.0679 Exit pupil position −45.4074 −59.6027 −70.4186 Anterior principal point 38.7453 53.1738 −192.0587 Posterior principal point 83.8134 63.4383 −33.8123

TABLE-US-00004 TABLE 1D (Data about single lenses) Lens Start surface Focal length 1 1 −207.9336 2 2 99.1038 3 4 127.9079 4 6 −24.7328 5 8 −24.3089 6 9 20.6097 7 11 −31.4021 8 14 33.2620 9 16 −39.4375 10 17 19.1431 11 19 −23.5211 12 21 53.4015 13 23 35.4544 14 25 36.4314 15 26 −20.1547 16 28 −36.6072 17 30 81.6285

TABLE-US-00005 TABLE 1E (Data about zoom lens groups) Lens Anterior Posterior Start Focal configuration principal principal Group surface length length point point 1 1 77.21746 12.97250 2.91283 7.28168 2 6 −13.77232 13.38890 3.73110 7.73141 3 13 37.13341 14.61870 −7.62613 −0.25443 4 21 22.84467 7.73170 2.99875 4.56417 5 25 −46.14273 2.62110 1.71174 2.94933 6 28 −69.55417 4.46010 −2.03613 −0.40964

TABLE-US-00006 TABLE 1F (Zoom powers of zoom lens groups) Group Start surface Wide-angle Middle Telephoto 1 1 0.00000 0.00000 0.00000 2 6 −0.25958 −0.40373 −0.74472 3 13 9.68185 3.59628 2.79645 4 21 −0.07097 −0.24333 −0.36531 5 25 1.63280 1.81060 1.97146 6 28 1.28914 1.51277 1.66474

Second Example of Numerical Values

[0296] Following is a second exemplary set of numerical values for the imaging optical system corresponding to the second embodiment shown in FIG. **2**A. Specifically, as the second example of numerical values for the imaging optical system, surface data is shown in Table 2A, aspheric surface data is shown in Table 2B, and various types of data in the infinity in-focus state are shown in Tables 2C-2F.

TABLE-US-00007 TABLE 2A (Surface data) Effective Surface No. r d nd vd diameter Object surface ∞ 1 93.38500 1.20000 1.84666 23.8 24.106 2 60.44080 6.47880 1.49700 81.6 22.821 3

−254.35560 0.20000 22.413 4 43.18570 4.24470 1.49700 81.6 18.739 5 157.09070 Variable 18.462 6 139.63390 1.00000 1.92003 35.9 13.202 7 18.94060 5.54740 10.831 8 −39.96360 0.65900 1.59341 67.0 10.393 9 23.14480 3.69620 1.86317 20.3 9.586 10 −70.87870 2.32030 9.354 11 −26.99070 0.60000 1.88296 40.8 8.267 12 1528.98670 Variable 8.043 13 (Aperture) ∞ 1.40000 7.176 14 19.79540 3.25900 1.52986 55.8 8.146 15 −105.27840 2.23430 8.149 16 18.76860 0.60000 1.96234 31.8 8.061 17 12.45390 4.44460 1.53351 54.0 7.698 18 −58.18580 1.72980 7.545 19 −24.36650 0.60000 1.97700 30.8 7.270 20 135.37870 Variable 7.358 21 19.29630 3.21910 1.49700 81.6 8.131 22 −144.37450 3.25250 8.068 23* 450.22950 1.99400 1.58699 59.5 7.682 24* −28.52620 Variable 7.719 25 −354.64850 2.09280 1.94798 19.5 8.352 26 −30.10550 0.60000 1.80449 31.4 8.400 27 32.88070 Variable 8.487 28 −22.02600 1.00000 1.79990 44.5 11.542 29 −64.36980 0.67320 12.806 30 252.42800 2.49780 1.84568 22.3 14.371 31 −113.60360 Variable 32 ∞ 2.10000 1.51680 64.2 33 ∞ 1.00000 34 ∞ BF Image plane ∞

TABLE-US-00008 TABLE 2B (Aspheric surface data) 23.sup.rd surface K = −5.00000E+00, A4 = −6.80359E−05, A6 = 9.24863E−07, A8 = −5.33973E−09 A10 = 3.23148E−10, A12 = −1.78860E−12 24.sup.th surface K = 1.81265E+00, A4 = 1.89226E−05, A6 = 1.01029E−06, A8 = −5.28472E−09 A10 = 3.04395E−10, A12 = −1.23164E−12

(Various Types of Data in Infinity in-Focus State)

TABLE-US-00009 TABLE 2C (Various types of data) (Zoom ratio: 6.65357) Wide-angle Middle Telephoto Focal length 28.9794 74.7361 192.8162 F number 4.16053 5.95443 7.38165 Angle of view 36.7545 15.4926 6.1304 Image height 20.4600 21.6300 21.6300 Total lens length 112.7930 137.6008 158.9777 BF 0.00000 0.00000 0.00000 d5 1.1516 17.8465 34.4419 d12 16.8378 8.3951 1.7654 d20 4.2308 2.2115 0.8000 d24 2.2799 4.6044 4.3321 d27 16.7837 14.4138 20.4596 d31 12.8500 31.5471 38.5534 Entrance pupil position 27.4907 64.5952 141.2994 Exit pupil position −47.5629 −63.4954 −72.2329 Anterior principal point 38.8192 51.2798 −180.7116 Posterior principal point 83.8136 62.8646 −33.8385

TABLE-US-00010 TABLE 2D (Data about single lenses) Lens Start surface Focal length 1 1 −205.7934 2 2 98.9385 3 4 118.3732 4 6 −23.9126 5 8 −24.6030 6 9 20.5882 7 11 −30.0329 8 14 31.7333 9 16 −40.3441 10 17 19.6582 11 19 −21.0969 12 21 34.4734 13 23 45.7726 14 25 34.5949 15 26 −19.4527 16 28 −42.3033 17 30 92.9322

TABLE-US-00011 TABLE 2E (Data about zoom lens groups) Lens Anterior Posterior Start Focal configuration principal principal Group surface length length point point 1 1 73.83046 12.12350 3.02330 7.09929 2 6 −13.14402 13.82290 3.89670 8.10468 3 13 41.22271 14.26770 −9.88613 −1.73997 4 21 21.35212 8.46560 3.21513 4.46051 5 25 −44.61667 2.69280 1.30544 2.59593 6 28 −81.62064 4.17100 −2.45525 −1.00244

TABLE-US-00012 TABLE 2F (Zoom powers of zoom lens groups) Group Start surface Wide-angle Middle Telephoto 1 1 0.00000 0.00000 0.00000 2 6 −0.25969 −0.38751 −0.75873 3 13 3.43654 2.19760 2.01004 4 21 −0.20823 −0.43179 −0.52973 5 25 1.68946 1.86214 2.06594 6 28 1.25023 1.47836 1.56472

Third Example of Numerical Values

[0297] Following is a third exemplary set of numerical values for the imaging optical system corresponding to the third embodiment shown in FIG. **3**A. Specifically, as the third example of numerical values for the imaging optical system, surface data is shown in Table 3A, aspheric surface data is shown in Table 3B, and various types of data in the infinity in-focus state are shown in Tables 3C-3F.

TABLE-US-00013 TABLE 3A (Surface data) Effective Surface No. r d nd vd diameter Object surface ∞ 1 89.39310 1.20000 1.84666 23.8 24.744 2 59.08770 7.01900 1.49700 81.6 23.412 3 −261.65280 0.20000 22.887 4 43.01610 4.49310 1.49700 81.6 20.080 5 119.92310 Variable 19.741 6 83.79430 1.00000 1.95302 32.7 13.669 7 18.79360 6.51330 11.226 8 −36.45670 0.65900 1.59342 67.0 10.442 9 23.05660 3.70870 1.86837 20.4 9.583 10 −70.68230 1.78390 9.346 11 −28.97300 0.60000 1.88294 40.8 8.597 12 767.52780 Variable 8.347 13 (Aperture) ∞

1.40000 7.175 14 18.98150 3.15730 1.52706 57.3 8.027 15 −164.90740 1.99820 8.025 16 18.42970 0.60000 1.95402 32.6 8.006 17 12.18010 4.55670 1.52181 60.3 7.631 18 −51.19390 1.70990 7.474 19 −23.77660 0.60000 1.99578 29.5 7.152 20 −689.93870 Variable 7.228 21 20.06570 2.48940 1.49700 81.6 7.869 22 146.51020 2.99990 7.789 23* 292.70690 2.07450 1.58699 59.5 7.540 24* −27.59030 Variable 7.600 25 290.10420 2.11100 1.95145 18.7 8.370 26 −36.00030 0.60000 1.80342 32.2 8.401 27 28.04480 Variable 8.439 28 −18.84090 1.00000 1.84252 42.4 10.951 29 −57.14670 0.58670 12.440 30 122.40400 3.20170 1.74466 38.7 14.625 31 −99.94240 Variable 32 ∞ 2.10000 1.51680 64.2 33 ∞ 1.00000 34 ∞ BF Image plane ∞

TABLE-US-00014 TABLE 3B (Aspheric surface data) 23.sup.rd surface K = 5.00000E+00, A4 = −5.96112E−05, A6 = 8.16552E−07, A8 = 8.09756E−10 A10 = 1.98774E−10, A12 = −8.27231E−13 24.sup.th surface K = 1.88093E+00, A4 = 2.67197E−05, A6 = 8.11536E−07, A8 = 2.85280E−09 A10 = 1.42987E−10, A12 = −8.71894E−15

(Various Types of Data in Infinity in-Focus State)

TABLE-US-00015 TABLE 3C (Various types of data) (Zoom ratio: 6.65330) Wide-angle Middle Telephoto Focal length 28.9799 74.7535 192.8118 F number 4.15987 5.71599 7.38089 Angle of view 36.7522 15.4855 6.2115 Image height 20.8800 21.6300 21.6300 Total lens length 112.0885 135.2097 158.9524 BF 0.00000 0.00000 0.00000 d5 0.6000 19.4360 35.6171 d12 17.7695 8.4958 1.7816 d20 4.7515 2.2708 0.8500 d24 1.7084 3.6014 2.8630 d27 15.0738 15.4479 18.2846 d31 12.8500 26.6238 40.2372 Entrance pupil position 28.2888 71.1897 146.8197 Exit pupil position −44.9962 −57.2933 −71.0917 Anterior principal point 38.5930 48.3602 −183.6243 Posterior principal point 83.1086 60.4561 −33.8594

TABLE-US-00016 TABLE 3D (Data about single lenses) Lens Start surface Focal length 1 1 −209.6654 2 2 97.6971 3 4 132.3948 4 6 −25.6140 5 8 −23.7034 6 9 20.3957 7 11 −31.6093 8 14 32.4892 9 16 −39.5012 10 17 19.3326 11 19 −24.7408 12 21 46.4771 13 23 43.0576 14 25 33.7670 15 26 −19.5398 16 28 −33.7648 17 30 74.3420

TABLE-US-00017 TABLE 3E (Data about zoom lens groups) Start Lens configuration Anterior Posterior Group surface Focal length length principal point principal point 1 1 77.61111 12.91210 2.78850 7.14845 2 6 −13.87490 14.26490 4.06986 8.26886 3 13 35.90345 14.02210 −6.13051 0.40724 4 21 23.98849 7.56380 3.14279 4.29647 5 25 −47.39546 2.71100 1.70770 2.99547 6 28 −65.78898 4.78840 −2.41412 −0.76204

TABLE-US-00018 TABLE 3F (Zoom powers of zoom lens groups) Group Start surface Wide-angle Middle Telephoto 1 1 0.00000 0.00000 0.00000 2 6 −0.26030 −0.40256 −0.75879 3 13 45.92215 4.44253 3.64379 4 21 −0.01490 −0.20220 −0.27093 5 25 1.59403 1.74678 1.91530 6 28 1.31552 1.52487 1.73156

Fourth Example of Numerical Values

[0298] Following is a fourth exemplary set of numerical values for the imaging optical system corresponding to the fourth embodiment shown in FIG. **4**A. Specifically, as the fourth example of numerical values for the imaging optical system, surface data is shown in Table 4A, aspheric surface data is shown in Table 4B, and various types of data in the infinity in-focus state are shown in Tables 4C-4F.

TABLE-US-00019 TABLE 4A (Surface data) Effective Surface No. r d nd vd diameter Object surface ∞ 1 91.07200 1.20000 1.84666 23.8 23.451 2 58.45620 6.32950 1.49700 81.6 22.172 3 −230.31680 0.20000 21.667 4 41.41310 4.23200 1.49700 81.6 18.804 5 119.66320 Variable 18.488 6 93.92320 1.00000 1.95152 32.8 13.251 7 18.22590 6.01180 10.904 8 −40.06930 0.65900 1.59353 67.0 10.357 9 21.45130 3.92760 1.86886 20.9 9.577 10 −65.44920 2.14870 9.350 11 −26.64300 0.60000 1.88300 40.8 8.365 12 2000.00000 Variable 8.142 13 (Aperture) ∞ 1.40000 7.175 14 19.66100 3.09460 1.53232 54.6 8.020 15 −150.34770 2.21410 8.027 16 18.41180 0.60000 1.99890 28.9 8.022 17 12.34910 4.45180 1.53512 53.3 7.654 18 −56.62900 1.74820 7.504 19 −24.57010 0.60000 1.97345 30.6 7.211 20 121.62620 Variable 7.294 21 19.22620 2.92120 1.49700 81.6 7.868 22 −335.45030 2.68680 7.817 23* 132.83390 2.88940

1.58699 59.5 7.578 24* −29.23300 Variable 7.659 25 1125.71610 2.21030 1.94899 18.4 8.364 26 −30.82570 0.60000 1.79893 30.9 8.400 27 30.24630 Variable 8.446 28 −19.92460 1.00000 1.80520 44.2 10.719 29 −56.08430 0.50000 11.942 30 141.20860 3.34570 1.80918 33.9 13.536 31 −65.96530 Variable 13.858 32 −77.85290 0.90000 1.99402 29.6 15.706 33 −271.88690 Variable 16.116 34 ∞ 2.10000 1.51680 64.2 35 ∞ 1.00000 36 ∞ BF Image plane ∞

TABLE-US-00020 TABLE 4B (Aspheric surface data) 23rd surface K = 0.00000E+00, A4 = −3.45181E−05, A6 = 7.54614E−07, A8 = 1.49928E−09 A10 = 9.30690E−11, A12 = −5.69505E−13 24th surface K = 0.00000E+00, A4 = 4.14702E−05, A6 = 8.08831E−07, A8 = 1.34409E−09 A10 = 1.01596E−10, A12 = −3.07347E−13

(Various Types of Data in Infinity in-Focus State)

TABLE-US-00021 TABLE 4C (Various types of data) (Zoom ratio: 6.66602) Wide-angle Middle Telephoto Focal length 28.9279 74.7073 192.8342 F number 4.16045 5.74141 7.38120 Angle of view 36.7900 15.4990 6.1612 Image height 20.6900 21.6300 21.6300 Total lens length 112.8085 136.0732 158.9817 BF 0.00000 0.00000 0.00000 d5 0.6000 18.2707 34.7853 d12 17.1989 7.7230 1.7618 d20 4.0249 1.9070 0.8500 d24 2.2953 3.9935 2.6926 d27 14.4230 13.1757 17.7055 d31 0.8329 16.5345 12.9388 d33 12.8500 13.8927 27.6909 Entrance pupil position 26.9806 65.8742 143.5504 Exit pupil position −44.7949 −51.8512 −64.6710 Anterior principal point 37.2326 32.9545 −238.7267 Posterior principal point 83.8806 61.3660 −33.8525

TABLE-US-00022 TABLE 4D (Data about single lenses) Lens Start surface Focal length 1 1 −196.0942 2 2 94.4969 3 4 125.1788 4 6 −23.9205 5 8 −23.4464 6 9 18.9937 7 11 −29.7725 8 14 32.8710 9 16 −39.4978 10 17 19.3818 11 19 −20.9560 12 21 36.6880 13 23 41.0898 14 25 31.6463 15 26 −19.0259 16 28 −38.8589 17 30 55.9689 18 32 −110.0009

TABLE-US-00023 TABLE 4E (Data about zoom lens groups) Start Lens configuration Anterior Posterior Group surface Focal length length principal point principal point 1 1 74.91797 11.96150 2.67440 6.72042 2 6 −13.60299 14.34710 3.93403 8.33209 3 13 43.68476 14.10870 −10.77441 −2.46916 4 21 21.01395 8.49740 3.19484 4.70746 5 25 −48.46814 2.81030 1.60895 2.94889 6 28 −150.29826 4.84570 −7.39730 −5.95670 7 32 −110.00093 0.90000 −0.18152 0.26609

TABLE-US-00024 TABLE 4F (Zoom powers of zoom lens groups) Group Start surface Wide-angle Middle Telephoto 1 1 0.00000 0.00000 0.00000 2 6 −0.26393 −0.40163 −0.78383 3 13 3.10879 2.01733 1.94873 4 21 −0.22142 −0.46586 −0.51186 5 25 1.58936 1.79134 1.95519 6 28 1.16854 1.27823 1.31643 7 32 1.14437 1.15379 1.27905

Fifth Example of Numerical Values

[0299] Following is a fifth exemplary set of numerical values for the imaging optical system corresponding to the fifth embodiment shown in FIG. **5**A. Specifically, as the fifth example of numerical values for the imaging optical system, surface data is shown in Table 5A, aspheric surface data is shown in Table 5B, and various types of data in the infinity in-focus state are shown in Tables 5C-5F.

TABLE-US-00025 TABLE 5A (Surface data) Effective Surface No. r d nd vd diameter Object surface ∞ 1 90.03880 1.20000 1.84666 23.8 24.419 2 59.49890 6.88130 1.49700 81.6 23.425 3 −238.02650 0.20000 23.075 4 43.24200 4.46730 1.49700 81.6 20.164 5 120.72190 Variable 19.833 6 100.31340 1.00000 1.95339 32.6 13.120 7 18.70010 5.60350 10.817 8 −38.17100 0.65900 1.59300 67.1 10.401 9 22.99430 3.76860 1.86737 20.3 9.581 10 −64.91860 1.67570 9.349 11 −28.55750 0.60000 1.88300 40.8 8.653 12 841.96650 Variable 8.403 13 (Aperture) ∞ 1.40000 7.175 14 18.86310 3.15490 1.53310 54.2 8.042 15 −186.74870 2.34810 8.037 16 18.16240 0.60000 1.96749 31.4 7.995 17 12.16800 4.48690 1.52660 57.5 7.620 18 −56.78280 2.02070 7.457 19 −23.01020 0.60000 1.99774 29.3 7.087 20 257.24460 Variable 7.179 21 17.91410 2.39390 1.49700 81.6 7.845 22 60.47700 1.50600 7.772 23 −151.02030 0.95170 1.61512 62.7 7.742 24 −67.22120 0.20200 7.740 25* 129.48610 2.68730 1.60699 56.2 7.666 26* −28.96240 Variable 7.723 27 313.39890 2.16870 1.94590 18.0 8.367 28 −34.02540 0.60000 1.81627 29.3 8.392 29 28.61340 Variable 8.418 30 −19.75750 1.00000 1.81708 43.6 11.261 31

−57.66910 0.57080 12.677 32 110.58120 2.89310 1.77513 28.6 14.789 33 −155.85260 Variable 34 ∞ 2.10000 1.51680 64.2 35 ∞ 1.00000 36 ∞ BF Image plane ∞
TABLE-US-00026 TABLE 5B (Aspheric surface data) 25th surface K = −5.38904E+01, A4 = −3.89899E−05, A6 = 6.61044E−07, A8 = 2.96723E−09 A10 = 1.15167E−10, A12 = −6.86274E−13 26th surface K = 1.41076E+00, A4 = 4.20336E−05, A6 = 7.19136E−07, A8 = 3.35160E−09 A10 = 1.06972E−10, A12 = −2.50402E−13
(Various Types of Data in Infinity in-Focus State)
TABLE-US-00027 TABLE 5C (Various types of data) (Zoom ratio: 6.65181) Wide-angle Middle Telephoto Focal length 28.9871 74.7438 192.8169 F number 4.15985 5.80061 7.38267 Angle of view 36.7360 15.4905 6.1953 Image height 20.6500 21.6300 21.6300 Total lens length 112.7959 138.0649 158.9983 BF 0.00000 0.00000 0.00000 d5 0.6945 19.6632 35.3906 d12 17.9169 9.3631 1.7786 d20 4.1749 2.3141 0.8000 d26 1.9042 3.1688 3.6242 d29 16.5159 16.5350 20.0114 d33 12.8500 28.3448 38.6515 Entrance pupil position 27.5063 71.0651 142.0332 Exit pupil position −45.9294 −59.8930 −70.5711 Anterior principal point 38.1990 52.4328 −191.9524 Posterior principal point 83.8087 63.3211 −33.8186
TABLE-US-00028 TABLE 5D (Data about single lenses) Lens Start surface Focal length 1 1 −210.9867 2 2 96.5170 3 4 133.0191 4 6 −24.2535 5 8 −24.1021 6 9 19.9742 7 11 −31.2704 8 14 32.3098 9 16 −40.0794 10 17 19.4660 11 19 −21.1463 12 21 50.2766 13 23 196.0953 14 25 39.2449 15 27 32.5473 16 28 −18.9597 17 30 −37.2237 18 32 83.8487
TABLE-US-00029 TABLE 5E (Data about zoom lens groups) Start Lens configuration Anterior Posterior Group surface Focal length length principal point principal point 1 1 76.84915 12.74860 2.76980 7.07585 2 6 −13.92215 13.30680 3.58400 7.58494 3 13 40.29684 14.61060 −10.29737 −1.79000 4 21 21.33848 7.74090 3.05457 4.81994 5 27 46.39917 2.76870 1.71360 3.02924 6 30 −70.09527 4.46390 −2.04382 −0.44404
TABLE-US-00030 TABLE 5F (Zoom powers of zoom lens groups) Group Start surface Wide-angle Middle Telephoto 1 1 0.00000 0.00000 0.00000 2 6 −0.26280 −0.40939 −0.76162 3 13 4.29855 2.53639 2.17021 4 21 −0.15781 −0.34228 −0.46315 5 27 1.64350 1.81528 1.97978 6 30 1.28736 1.50750 1.65549
(Values Corresponding to Inequalities)
[0300] Values, corresponding to the inequalities (1) to (15), of the respective examples of numerical values are shown in the following Table 6:
TABLE-US-00031 TABLE 6 1.sup.st 2.sup.nd 3.sup.rd 4.sup.th 5.sup.th example example example example example of of of of of numerical numerical numerical numerical numerical Inequality values values values values values (1) Th_IS_Obj/Th_G3 0.170 0.174 0.158 0.174 0.178 (2) Th_G4_Air/Th_G4 0.276 0.384 0.397 0.316 0.195 (3) Th_IS_Img/Th_G3 0.149 0.134 0.135 0.138 0.153 (4) (R2_LG3F1 + R1_LG3F2)/ 0.908 0.697 0.799 0.782 0.823 (R2_LG3F1 − R1_LG3F2) (5) (R2_LG4F1 + R1_LG4F2)/ −5.053 −0.514 −3.004 0.433 −0.428 (R2_LG4F1 − R1_LG4F2) (6) nd_LG4Fp1 1.497 1.497 1.497 1.497 1.497 (7) ThwG5_G6/fw 0.551 0.579 0.520 0.499 0.570 (8) fG1/fT 0.401 0.383 0.403 0.389 0.399 (9) fG5/fw −1.592 −1.540 −1.635 −1.675 −1.601 (10) Th_G2_G3/Yw 0.913 0.891 0.918 0.899 0.935 (11) BFw/Yw 0.754 0.780 0.764 0.771 0.772 (12) TTLw/Yw 5.331 5.512 5.370 5.452 5.462 (13) (TTLt − TTLw)/TTLt 0.291 0.291 0.295 0.291 0.291 (14) Th_IS_Obj/Yw 0.106 0.109 0.096 0.107 0.114 (15) Th_IS_Img/Yw 0.093 0.085 0.082 0.084 0.098
[0301] While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that they may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all modifications and variations that fall within the true scope of the present teachings.
INDUSTRIAL APPLICABILITY

[0302] The imaging optical system according to the present disclosure is applicable to various types of cameras including digital still cameras, digital cameras, of which the lens is interchangeable, digital camcorders, cameras for cellphones and smartphones, and cameras for personal digital assistants (PDAs), surveillance cameras for surveillance systems, Web cameras, and onboard cameras. Among other things, the present disclosure is particularly suitably applicable to imaging optical systems that are required to provide high image quality such as digital still camera systems and digital camcorder systems.

Claims

1. An imaging optical system comprising: a first lens group having positive power; a second lens group having negative power; a third lens group having positive power; a fourth lens group having positive power; a fifth lens group having negative power; and a sixth lens group having power, the first, second, third, fourth, fifth, and sixth lens groups being arranged in this order such that the first lens group is located closer to an object than any of the second, third, fourth, fifth or sixth lens group is, and that the sixth lens group is located closer to an image plane than any of the first, second, third, fourth, or fifth lens group is, an interval between each pair of lens groups that are adjacent to each other changing as at least the first, second, third, fourth, fifth, and sixth lens groups move in an optical axis direction aligned with an optical axis of the imaging optical system while the imaging optical system is zooming.
2. The imaging optical system of claim 1, wherein the third lens group includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; and a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization, and the imaging optical system satisfies the following inequality (1): $0.06 < Th\_IS\_Obj / Th\_G3 < 0.50$ (1) where Th_IS_Obj is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Obj, and Th_G**3** is a thickness of the third lens group on the optical axis.
3. The imaging optical system of claim 1, wherein the fourth lens group includes at least two lenses, the imaging optical system satisfies the following inequality (2): $0.05 < Th\_G4\_Air / Th\_G4 < 0.80$ (2) where Th_G**4** Air is a maximum value of an air gap on the optical axis between adjacent lenses included in at least two lenses that form the fourth lens group; and Th_G**4** is a thickness of the fourth lens group on the optical axis.
4. The imaging optical system of claim 1, wherein the third lens group includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; a group of fixed lenses G**3**Obj located closer to the object than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization; and a group of fixed lenses G**3**Img located closer to the image plane than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization.
5. The imaging optical system of claim 1, wherein an object-side surface of lens LG**3**R**1** located closer to the image plane than any of other negative lenses that form part of the third lens group has a convex surface facing the image plane.
6. The imaging optical system of claim 1, wherein the third lens group includes: a group of image stabilizer lenses consisting of a plurality of lenses configured to move perpendicularly to the optical axis during an image stabilization; and a group of fixed lenses G**3**Img located closer to the image plane than the group of image stabilizer lenses is, consisting of one or more lenses, and configured not to move perpendicularly to the optical axis during the image stabilization; the imaging optical

system satisfies the following inequality (3): $0.05 < Th\_IS\_Img / Th\_G3 < 0.80$ (3) where Th_IS_Img is an air gap on the optical axis between the group of image stabilizer lenses and the group of fixed lenses G**3**Img, and Th_G**3** is a thickness of the third lens group on the optical axis.
7. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (4): $0. < (R2\_LG3F1 + R1\_LG3F2) / (R2\_LG3F1 - R1\_LG3F2) < 1.$ (4) where R**2**_LG**3**F**1** is a radius of curvature of an image-side surface of a lens LG**3**F**1** located closer to the object than any other lens belonging to the third lens group, and R**1**_LG**3**F**2** is a radius of curvature of an object-side surface of a lens LG**3**F**2** located adjacent to the lens LG**3**F**1** and closer to the image plane than the lens LG**3**F**1** is.
8. The imaging optical system of claim 1, wherein an image-side surface of a positive lens LG**4**Fp**1** located closer to the object than any other lens belonging to the fourth lens group has a convex surface facing the object.
9. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (5):
$-10.0 < (R2\_LG4F1 + R1\_LG4F2) / (R2\_LG4F1 - R1\_LG4F2) < 1.$ (5) where R**2**_LG**4**F**1** is a radius of curvature of an image-side surface of a lens LG**4**F**1** located closer to the object than any other lens belonging to the fourth lens group, and R**1**_LG**4**F**2** is a radius of curvature of an object-side surface of a lens LG**4**F**2** located adjacent to the lens LG**4**F**1** and closer to the image plane than the lens LG**4**F**1** is.
10. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (6): $nd\_LG4Fp1 < 1.6$ (6) where nd_LG**4**Fp**1** is a refractive index of a positive lens LG**4**Fp**1** located closer to the object than any other lens belonging to the fourth lens group is.
11. The imaging optical system of claim 1, wherein the fifth lens group is configured to move toward the image plane while the imaging optical system is focusing from an infinity in-focus object toward a close-object in-focus state.
12. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (7): $0.1 < ThwG5\_G6 / fw < 0.8$ (7) where ThwG**5**_G**6** is an interval measured on the optical axis between the fifth lens group and the sixth lens group in the imaging optical system at a wide-angle end; and fw is a focal length of the imaging optical system at the wide-angle end.
13. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (8): $0.2 < fG1 / fT < 1.$ (8) where fG**1** is a focal length of the first lens group, and fT is a focal length of the imaging optical system at a telephoto end.
14. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (9): $-2.5 < fG5 / fw < -1.$ (9) where fG**5** is a focal length of the fifth lens group, and fw is a focal length of the imaging optical system at a wide-angle end.
15. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (10): $0.5 < Th\_G2\_G3 / Yw < 3.$ (10) where Th_G**2**_G**3** is an air gap measured on the optical axis between the second lens group and the third lens group in the imaging optical system at a wide-angle end, and Yw is a maximum image height of the imaging optical system at the wide-angle end.
16. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (11): $0.3 < BFw / Yw < 3.$ (11) where BFw is a back focus of the imaging optical system at a wide-angle end; and Yw is a maximum image height of the imaging optical system at the wide-angle end.
17. The imaging optical system of claim 1, wherein the imaging optical system satisfies the

following inequality (12): $2. < TTLw / Yw < 10.0$ (12) where TTLw is a total optical length of the imaging optical system at a wide-angle end; and Yw is a maximum image height of the imaging optical system at the wide-angle end.

18. The imaging optical system of claim 1, wherein the imaging optical system satisfies the following inequality (13): $0.1 < (TTLt - TTLw) / TTLt < 0.5$ (13) where TTLt is a total optical length of the imaging optical system at a telephoto end; and TTLw is a total optical length of the imaging optical system at a wide-angle end.

19. A camera system comprising: an interchangeable lens unit including the imaging optical system of claim 1; and a camera body including: an image sensor configured to receive an optical image of an object formed by the imaging optical system and transform the optical image into an electrical image signal; and a camera mount, the camera body being configured to be connected removably to the interchangeable lens unit via the camera mount, the interchangeable lens unit being configured to form the optical image of the object on the image sensor.

20. An image capture device configured to transform an optical image of an object into an electrical image signal and display and/or store the electrical image signal thus transformed, the image capture device comprising: the imaging optical system of claim 1 configured to form the optical image of the object; and an image sensor configured to transform the optical image formed by the imaging optical system into the electrical image signal.