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OPTICAL IMAGING SYSTEM

Abstract

An optical imaging system includes lenses sequentially disposed from an object side toward an imaging plane. A third lens, a fourth lens, and a fifth lens of the lenses each have a negative refractive power. An F number of the optical imaging system is 1.7 or less.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of application Ser. No. 17/715,150 filed on Apr. 7, 2022, which is a continuation of application Ser. No. 17/025,490 filed on Sep. 18, 2020, now U.S. Pat. No. 11,333,863 issued on May 17, 2022, which is a continuation of U.S. patent application Ser. No. 15/431,112 filed on Feb. 13, 2017, now U.S. Pat. No. 10,816,763 issued on Oct. 27, 2020, which claims the benefit under 35 USC 119 (a) of Korean Patent Application No. 10-2016-0131910 filed on Oct. 12, 2016, in the Korean Intellectual Property Office, the entire disclosures of which are incorporated herein by reference for all purposes.

BACKGROUND

1. Field

[0002] The following description relates to an optical imaging system including six lenses.

2. Description of Related Art

[0003] A small camera module can be mounted on a portable terminal. For example, a small camera module may be mounted on a device having a thin width, such as a mobile phone. A small camera module may include an optical imaging system that is likewise improved by a reduced width, which includes a small number of lenses. For example, a small camera module may have an optical imaging system including four to six lenses.

[0004] However, there may be limitations for an optical imaging system having a small number of lenses used to implement a high-resolution camera module. Likewise, the ability to reduce the width of an optical imaging system including a large number of lenses is limited. Therefore, the development of an optical imaging system capable of simultaneously implementing high resolution with a thin-width camera module is sought.

SUMMARY

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0006] In one general aspect, an optical imaging system includes lenses that are sequentially disposed from an object side toward an imaging plane. A third lens, a fourth lens, and a fifth lens of the lenses have each have a negative refractive power. An F number of the optical imaging system is 1.7 or less.

[0007] An object-side surface of the third lens may be convex along an optical axis of the optical imaging system and an image-side surface of the third lens may be concave along the optical axis. Both surfaces of the fourth lens can be concave along an optical axis of the optical imaging system. An object-side surface of the fifth lens may be convex along an optical axis of the optical imaging system and an image-side surface fifth lens may be concave along the optical axis. A sixth lens can be disposed between the fifth lens and the imaging plane.

[0008] In another general aspect, an optical imaging system includes: a first lens having a positive refractive power; a second lens having a positive refractive power; a third lens having a negative refractive power; a fourth lens having a negative refractive power; a fifth lens having a negative refractive power; and a sixth lens having a negative refractive power. The first lens to the sixth lens are respectively disposed from an object side toward an imaging plane.

[0009] An object-side surface of the first lens can be convex along an optical axis of the optical imaging system and an image-side surface of the first lens can be concave along the optical axis. Both surfaces of the second lens may be convex along an optical axis of the optical imaging system. An object-side surface of the third lens can be convex along an optical axis of the optical imaging system and an image-side surface of the third lens can be concave along the optical axis.

[0010] Both surfaces of the fourth lens can be concave along an optical axis of the optical imaging system. An object-side surface of the fifth lens may be convex along an optical axis of the optical imaging system and an image-side surface of the fifth lens may be concave along the optical axis. An object-side surface of the sixth lens can be convex along an optical axis of the optical imaging system and an image-side surface of the sixth lens can be concave.

[0011] The fifth lens may have an inflection point formed on an object-side surface or an image-side surface. The sixth lens can have an inflection point formed on an object-side surface or an image-side surface.

[0012] The optical imaging system can have an F number of 1.7 or less. The optical imaging system can satisfy one or any combination of the conditional expressions: $1.0 < f_1/f < 2.0$, $0.5 < f_2/f < 2.0$, or $-2.0 < f_3/f < -1.0$, where f represents an overall focal length of the optical imaging system, f_1 represents a focal length of the first lens, f_2 represents a focal length of the second lens, and f_3 represents a focal length of the third lens.

[0013] In another general aspect, an optical imaging system includes a first lens having a convex object-side surface, a second lens having a convex object-side surface, a third lens having a convex object-side surface, a fourth lens having a concave object-side surface and a concave image-side surface, a fifth lens having a convex object-side surface, and a sixth lens having a convex object-side surface.

[0014] The optical imaging system can satisfy the conditional expression $0.9 < f_1/f_2 < 2.0$, where f_1 represents a focal length of the first lens and f_2 represents a focal length of the second lens. The optical imaging system may satisfy the conditional expression $-1.2 < f_2/f_3 < -0.3$, where f_2 represents a focal length of the second lens and f_3 represents a focal length of the third lens. The optical imaging system may also satisfy one or any combination of the conditional expressions $0.3 < R_1/f$, $0.7 < R_5/f$, or $10 < R_8/f$, where R_1 represents a radius of curvature of an object-side surface of the first lens, R_5 represents a radius of curvature of an object-side surface of the third lens, R_8 represents a radius of curvature of an image-side surface of the fourth lens. Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0015] FIG. 1 is a view of an optical imaging system, according to a first example.

[0016] FIG. 2 is a set of graphs illustrating aberration curves of the optical imaging system illustrated in FIG. 1.

[0017] FIG. 3 is a table listing aspherical characteristics of the optical imaging system illustrated in FIG. 1.

[0018] FIG. 4 is a view of an optical imaging system, according to a second example.

[0019] FIG. 5 is a set of graphs illustrating aberration curves of the optical imaging system illustrated in FIG. 4.

[0020] FIG. 6 is a table listing aspherical characteristics of the optical imaging system illustrated in FIG. 4.

[0021] FIG. 7 is a view of an optical imaging system, according to a third example.

[0022] FIG. 8 is a set of graphs illustrating aberration curves of the optical imaging system illustrated in FIG. 7.

[0023] FIG. 9 is a table listing aspherical characteristics of the optical imaging system illustrated in FIG. 7.

[0024] Throughout the drawings and the detailed description, the same reference numerals refer to the same elements where applicable. The drawings may not be to scale, and the relative size, proportions, and depiction of elements in the drawings may be exaggerated for clarity, illustration, and convenience.

DETAILED DESCRIPTION

[0025] The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. However, various changes, modifications, and equivalents of the methods, apparatuses, and/or systems described herein will be apparent after an understanding of the disclosure of this application. For example, the sequences of operations described herein are merely examples, and are not limited to those set forth herein, but may be changed as will be apparent after an understanding of the disclosure of this application, with the exception of operations necessarily occurring in a certain order. Also, descriptions of functions and constructions that are well known may be omitted for increased clarity and conciseness.

[0026] The features described herein may be embodied in different forms, and are not to be construed as being limited to the examples described herein. Rather, the examples described herein have been provided merely to illustrate some of the many possible ways of implementing the methods, apparatuses, and/or systems described herein that will be apparent after an understanding of the disclosure of this application.

[0027] Although terms such as “first,” “second,” and “third” may be used herein to describe various components, regions, or sections, these components, regions, or sections are not to be limited by these terms. Rather, these terms are only used to distinguish one component, region, or section from another component, region, or section. Thus, a first component, region, or section referred to in examples described herein may also be referred to as a second component, region, or section without departing from the teachings of the examples.

[0028] The terminology used herein is for describing various examples only, and is not to be used to limit the disclosure. The articles “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “includes,” and “has” specify the presence of stated features, numbers, operations, members, elements, and/or combinations thereof, but do not preclude the presence or addition of one or more other features, numbers, operations, members, elements, and/or combinations thereof.

[0029] Due to manufacturing techniques and/or tolerances, variations of the shapes shown in the drawings may occur. Thus, the examples described herein are not limited to the specific shapes shown in the drawings, but include changes in shape that occur during manufacturing.

[0030] The features of the examples described herein may be combined in various ways as will be apparent after an understanding of the disclosure of this application. Further, although the examples described herein have a variety of configurations, other configurations are possible as will be apparent after an understanding of the disclosure of this application.

[0031] Examples provide an optical imaging system having high resolution. Hereinafter, examples are described in further detail with reference to the accompanying drawings.

[0032] In accordance with an example, a first lens refers to a lens closest to an object or a subject from which an image is captured. A sixth lens is a lens closest to an imaging plane or an image sensor. In an embodiment, all radii of curvature of lenses, thicknesses, distances from an object-side surface of the first lens to an imaging plane (TTL), half diagonal lengths of the imaging plane (IMG HT), and focal lengths of each lens are indicated in millimeters (mm). A person skilled in the relevant art will appreciate that other units of measurement may be used. Further, in embodiments, all radii of curvature, thicknesses, OALs (optical axis distances from the first surface of the first lens to the image sensor), a distance on the optical axis between the stop and the image sensor

(SLs), image heights (IMGHs) (image heights), and back focus lengths (BFLs) of the lenses, an overall focal length of an optical system, and a focal length of each lens are indicated in millimeters (mm). Further, thicknesses of lenses, gaps between the lenses, OALs, TLs, SLs are distances measured based on an optical axis of the lenses.

[0033] A surface of a lens being convex means that an optical axis portion of a corresponding surface is convex, and a surface of a lens being concave means that an optical axis portion of a corresponding surface is concave. Therefore, in a configuration in which one surface of a lens is described as being convex, an edge portion of the lens may be concave. Likewise, in a configuration in which one surface of a lens is described as being concave, an edge portion of the lens may be convex. In other words, a paraxial region of a lens may be convex, while the remaining portion of the lens outside the paraxial region is either convex, concave, or flat. Further, a paraxial region of a lens may be concave, while the remaining portion of the lens outside the paraxial region is either convex, concave, or flat. In addition, in an embodiment, thicknesses and radii of curvatures of lenses are measured in relation to optical axes of the corresponding lenses.

[0034] In accordance with illustrative examples, the embodiments described of the optical system include six lenses with a refractive power. However, the number of lenses in the optical system may vary, for example, between two to six lenses, while achieving the various results and benefits described below. Also, although each lens is described with a particular refractive power, a different refractive power for at least one of the lenses may be used to achieve the intended result.

[0035] An optical imaging system includes six lenses. For example, the optical imaging system may include a first lens, a second lens, a third lens, a fourth lens, a fifth lens, a sixth lens, sequentially disposed from an object side.

[0036] The first lens has a refractive power. In an example, the first lens has a positive refractive power. At least one surface of the first lens is convex. For example, an object-side surface of the first lens is convex.

[0037] The first lens may have an aspherical surface. In an embodiment, both surfaces of the first lens are aspherical. The first lens is formed of a material having a high degree of light transmissivity and excellent workability. For example, the first lens is formed of a plastic material. However, a material of the first lens is not limited to being a plastic material. In another example, the first lens may be formed of a glass material. The first lens may have a low refractive index. For example, the refractive index of the first lens is lower than 1.6.

[0038] The second lens has a refractive power. In an example, the second lens has a positive refractive power. One surface of the second lens is convex. For example, an object-side surface of the second lens is convex.

[0039] The second lens has an aspherical surface. In an embodiment, an object-side surface of the second lens is aspherical. The second lens is formed of a material having a high degree of light transmissivity and excellent workability. For example, the second lens is formed of a plastic material. However, a material of the second lens is not limited to being plastic. In another example, the second lens may be formed of a glass material. The second lens may have a refractive index substantially the same as that of the first lens. For example, the refractive index of the second lens is lower than 1.6.

[0040] The third lens has a refractive power. In an example, the third lens has a negative refractive power. At least one surface of the third lens is convex. As an example, an object-side surface of the third lens is convex.

[0041] The third lens has an aspherical surface. In embodiments, an image-side surface of the third lens is aspherical. The third lens is formed of a material having a high degree of light transmissivity and excellent workability. For example, the third lens is formed of a plastic material. However, a material of the third lens is not limited to being plastic. In another example, the third lens may be formed of a glass material. The third lens has a refractive index higher than that of the first lens. In an embodiment, the refractive index of the third lens is 1.6 or more.

[0042] The fourth lens has a refractive power. As an example, the fourth lens has a negative refractive power. At least one surface of the fourth lens is concave. In an embodiment, both surfaces of the fourth lens are concave.

[0043] The fourth lens has an aspherical surface. In an example, both surfaces of the fourth lens are aspherical. The fourth lens is formed of a material having a high degree of light transmissivity and excellent workability. For example, the fourth lens is formed of a plastic material. However, a material of the fourth lens is not limited to being plastic. In another example, the fourth lens may be formed of a glass material. The fourth lens has a refractive index higher than that of the first lens. In an embodiment, the refractive index of the fourth lens is 1.6 or more.

[0044] The fifth lens has a refractive power. In an example, the fifth lens has a negative refractive power. One surface of the fifth lens is convex. For instance, an object-side surface of the fifth lens is convex. The fifth lens has an inflection point. In an embodiment, an object-side surface or an image-side surface of the fifth lens has one or more inflection points.

[0045] The fifth lens includes an aspherical surface. As an example, both surfaces of the fifth lens are aspherical. The fifth lens is formed of a material having a high degree of light transmissivity and excellent workability. For example, the fifth lens is formed of a plastic material. However, a material of the fifth lens is not limited to being plastic. In another example, the fifth lens may be formed of a glass material. The fifth lens has a refractive index higher than that of the first lens. In an embodiment, the refractive index of the fifth lens is 1.6 or more.

[0046] The sixth lens has a refractive power. In an example, the sixth lens has a negative refractive power. At least one surface of the sixth lens is convex. As an example, an object-side surface of the sixth lens is convex. The sixth lens has an inflection point. In some embodiments, an object-side surface or an image-side surface of the sixth lens has one or more inflection points.

[0047] The sixth lens has an aspherical surface. For example, both surfaces of the sixth lens are aspherical. The sixth lens is formed of a material having a high degree of light transmissivity and excellent workability. As an example, the sixth lens is formed of a plastic material. However, a material of the sixth lens is not limited to being plastic. In another example, the sixth lens may be formed of a glass material. The sixth lens may have a refractive index substantially the same as that of the first lens. In an embodiment, the refractive index of the sixth lens is lower than 1.6.

[0048] Aspherical surfaces of each of the first lens to the sixth lens may be represented by Equation 1.

$$[00001] \quad Z = \frac{cr^2}{1 + \sqrt{1 - (1+k)c^2r^2}} + Ar^4 + Br^6 + Cr^8 + Dr^{10} + Er^{12} + Fr^{14} + Gr^{16} + Hr^{18} + Jr^{20} \quad (1)$$

[0049] In Equation 1, c represents an inverse of a radius of curvature of the lens, k represents a conic constant, r represents a distance from a certain point on an aspherical surface of the lens to an optical axis, A to J represent aspherical constants, and Z (or SAG) represents a distance between the certain point on the aspherical surface of the lens at the distance r and a tangential plane meeting the apex of the aspherical surface of the lens.

[0050] The optical imaging system may further include a filter, an image sensor, and a stop. The filter may be disposed between the sixth lens and the image sensor. The filter may block certain wavelengths of light to obtain a clear image. For example, the filter blocks infrared wavelengths of light. The image sensor may form an imaging plane. In an embodiment, a surface of the image sensor forms an imaging plane. The stop may be disposed to adjust an amount of light incident on a lens. As an example, the stop is disposed in front of the first lens.

[0051] The optical imaging system satisfies any one or any combination any two or more of the following Conditional Expressions:

[00002] $1. < f1 / f < 2.$ (ConditionalExpression1)

$0.5 < f2 / f < 2.$ (ConditionalExpression2) $2. < f3 / f < -1.$ (ConditionalExpression3)

$f4 / f < 0$ (ConditionalExpression4) $f5 / 5 < 0$ (ConditionalExpression5)

$f_6 / f < 0$ (ConditionalExpression6) $V_1 - V_2 < 10$ (ConditionalExpression7)
 $30 < V_1 - V_3 < 40$ (ConditionalExpression8) $30 < V_1 - V_5 < 40$ (ConditionalExpression9)
 $TTL / f < 1.3$ (ConditionalExpression10) $TTL / f_{12} < 1.9$ (ConditionalExpression11)
 $f_{13} / EPD < 1.7$ (ConditionalExpression12) $0.9 < f_1 / f_2 < 2$. (ConditionalExpression13)
 $-1.2 < f_2 / f_3 < -0.3$ (ConditionalExpression14) $0.15 < BFL / f$ (ConditionalExpression15)
 $D_{12} / f < 0.08$ (ConditionalExpression16) $0.3 < R_1 / f$ (ConditionalExpression17)
 $0.7 < R_5 / f$ (ConditionalExpression18) $10 < R_8 / f$ (ConditionalExpression19)
 $75^\circ < FOV$ (ConditionalExpression20) $FNo. \leq 1.7$ (ConditionalExpression21)

[0052] In the Conditional Expressions, f represents an overall focal length of the optical imaging system, f_1 represents a focal length of the first lens, f_2 represents a focal length of the second lens, f_3 represents a focal length of the third lens, f_4 represents a focal length of the fourth lens, f_5 represents a focal length of a fifth lens, and f_6 represents a focal length of a sixth lens. Furthermore, in Conditional Expressions 7 through 9, V_1 represents an Abbe number of the first lens, V_2 represents an Abbe number of the second lens, V_3 represents an Abbe number of the third lens, and V_5 represents an Abbe number of a fifth lens. In Conditional Expressions 10 through 16, TTL represents a distance from an object-side surface of the first lens to an imaging plane, f_{12} represents a composite focal length of the first lens and the second lens, f_{13} represents a composite focal length of the first lens to the third lens, BFL represents a distance from an image-side surface of a sixth lens to an imaging plane, and D_{12} represents a distance from an image-side surface of the first lens to an object-side surface of the second lens. In Conditional Expressions 17 through 20, R_1 represents a radius of curvature of an object-side surface of the first lens, R_5 represents a radius of curvature of an object-side surface of the third lens, R_8 represents a radius of curvature of an image-side surface of the fourth lens, FOV represents an angle of view of the optical imaging system, and EPD represents entrance pupil diameter of the optical imaging system.

[0053] Conditional Expression 1 is an equation to provide parameters of the first lens for optical imaging systems. As an example, in cases outside of the numerical range of Conditional Expression 1, the first lens may have significantly high or low refractive power, and overall optical performance of the optical imaging system may decrease.

[0054] Conditional Expression 2 is an equation to provide parameters of the second lens for optical imaging systems. For example, in a case in which the second lens has significantly high or low refractive power, outside of the numerical range of Conditional Expression 2, it may be difficult to perform aberration correction for the optical imaging system.

[0055] Conditional Expressions 3 to 6 are equations to calibrate the refractive power of the third lens to the sixth lens for optical imaging systems. For example, in cases in which the third lens to the sixth lens are outside of the numerical ranges of Conditional Expressions 3 to 6, the third lens to the sixth lens may be limited to having a negative refractive power.

[0056] Conditional Expressions 7 through 9 are equations to provide parameters for significantly reducing chromatic aberration. Conditional Expressions 10 and 11 are equations to reduce the size of the optical imaging system. For example, in a case in which the optical imaging system is outside of the numerical range of Conditional Expressions 10 or 11, it may be difficult to miniaturize the optical imaging system.

[0057] Conditional Expression 12 is an equation to allow for the imaging of a bright image. As an example, in a case in which the optical imaging system is outside of the numerical range of Conditional Expression 12, the optical imaging system may be limited to having an F number of 1.7 or less.

[0058] Conditional Expression 13 is an equation for a refractive power ratio between the first lens and the second lens that improves aberration characteristics. For example, in a case in which the

first lens and the second lens are outside of the numerical range of Conditional Expression 13, one of the first lens and the second lens may have a significantly high relative refractive power. Thus, aberration characteristics of the optical imaging system may be decreased and optical performance may be decreased.

[0059] Conditional Expression 14 is an equation for a refractive power ratio between the second lens and the third lens that improves aberration characteristics. For example, in a case in which the second lens and the third lens are outside of the numerical range of Conditional Expression 14, one of the second lens and the third lens may have a significantly high relative refractive power. Thus, aberration characteristics of the optical imaging system may be decreased and overall optical performance may also be decreased.

[0060] Conditional Expression 15 is an equation for miniaturization of the optical imaging system. For example, in cases in which optical imaging systems are outside of an upper limit value of Conditional Expression 15, it may be difficult to miniaturize the optical imaging system.

[0061] Conditional Expression 16 is an equation for improving longitudinal chromatic aberration characteristics of an optical imaging system. For instance, in a case in which the optical imaging system is outside of the numerical range of Conditional Expression 16, it may be difficult to improve longitudinal chromatic aberration characteristics.

[0062] Conditional Expressions 17 through 19 are equations for limiting magnitudes of the refractive power of the first lens, the third lens, or the fourth lens, respectively. For example, cases in which the first lens, the third lens, or the fourth lens are outside of the numerical range of Conditional Expression 17 through 19, performance of the optical imaging system may be decreased.

[0063] Next, optical imaging systems, according to several examples, will be described. An optical imaging system, according to a first example, will be described with reference to FIG. 1. An optical imaging system **100**, according to the first example, includes an optical system including a first lens **110**, a second lens **120**, a third lens **130**, a fourth lens **140**, a fifth lens **150**, and a sixth lens **160**.

[0064] The first lens **110** has a positive refractive power. An object-side surface of lens **110** is convex and an image-side surface of lens **110** is concave. The second lens **120** has a positive refractive power. Both surfaces of lens **120** are convex. The third lens **130** has a negative refractive power. An object-side surface of lens **130** is convex, and an image-side surface of lens **130** is concave.

[0065] The fourth lens **140** has a negative refractive power. Both surfaces of lens **140** are concave. The fifth lens **150** has a negative refractive power. An object-side surface of lens **150** is convex and an image-side surface of lens **150** is concave. In addition, fifth lens **150** has an inflection point formed on an object-side surface or an image-side surface. The sixth lens **160** has a negative refractive power. An object-side surface of lens **160** is convex. An image-side surface of lens **160** is concave. In addition, sixth lens **160** has an inflection point formed on an object-side surface or an image-side surface.

[0066] According to the example, optical imaging system **100** may further include a filter **170**, an image sensor **180**, and a stop ST. The filter **170** is disposed between the sixth lens **160** and the image sensor **180**, and the stop ST is disposed in an object-side surface of the first lens **110**.

[0067] In the optical imaging system **100**, f12 is 2.985 mm, and f13 is 4.360 mm. The optical imaging system, configured as described above, represents aberration characteristics as illustrated in the graphs of FIG. 2. FIG. 3 represents aspherical characteristics of the optical imaging system, according to the first example. Characteristics of lenses of the optical imaging system **100**, according to the first example, are listed in Table 1.

TABLE-US-00001

TABLE 1 First Example											
F No. = 1.60 FOV = 78.2° f = 4.230 TTL = 5.168											
Surface Radius of Thickness/ Refractive Abbe Focal No. Element Curvature Distance Index											
Number	Length	S0	Stop	Infinity	-0.2100	S1	First	2.2842	0.6223	1.547	56.10 7.265 S2 Lens

4.8609 0.1742 S3 Second 3.1371 0.5706 1.547 56.10 4.393 S4 Lens -9.5742 0.0200 S5 Third 8.1852 0.2500 1.669 20.40 -6.511 S6 Lens 2.8072 0.4140 S7 Fourth -62.5895 0.3576 1.669 20.40 -58.628 S8 Lens 105.1747 0.3110 S9 Fifth 6.3323 0.7065 1.669 20.40 -50.000 S10 Lens 5.0860 0.1407 S11 Sixth 1.9476 0.6381 1.537 55.70 -17.828 S12 Lens 1.4331 0.1833 S13 Filter Infinity 0.1100 1.519 64.20 S14 Infinity 0.1000 S15 Imaging Infinity 0.5700 Plane

[0068] With reference to FIG. 4, an optical imaging system, according to a second example, will be described. An optical imaging system **200**, according to the second example, includes an optical system including a first lens **210**, a second lens **220**, a third lens **230**, a fourth lens **240**, a fifth lens **250**, and a sixth lens **260**.

[0069] The first lens **210** has a positive refractive power. An object-side surface of lens **210** is convex and an image-side surface of lens **210** is concave. The second lens **220** has a positive refractive power. Both surfaces of lens **220** are convex. The third lens **230** has a negative refractive power. An object-side surface of lens **230** is convex and an image-side surface of lens **230** is concave.

[0070] The fourth lens **240** has a negative refractive power. Both surfaces of lens **240** are be concave. The fifth lens **250** has a negative refractive power. An object-side surface of lens **250** is convex and an image-side surface of lens **250** is concave. In addition, fifth lens **250** has an inflection point formed on an object-side surface or an image-side surface. The sixth lens **260** has a negative refractive power. An object-side surface of lens **260** is convex and an image-side surface of lens **260** is concave. Moreover, sixth lens **260** has an inflection point formed on an object-side surface or an image-side surface.

[0071] The optical imaging system **200** includes a filter **270**, an image sensor **280**, and a stop ST. The filter **270** is disposed between the sixth lens **260** and the image sensor **280**, while the stop ST may be disposed in an object-side surface of first lens **210**.

[0072] In optical imaging system **200**, f12 is 3.005 mm and f13 is 4.380 mm. The optical imaging system, configured as described above, represents aberration characteristics as illustrated in the graphs of FIG. 5. FIG. 6 represents aspherical characteristics of the optical imaging system, according to the second example. Characteristics of lenses of the optical imaging system **200**, according to the second example, are listed in Table 2.

TABLE-US-00002 TABLE 2 Second Example F No. = 1.65 FOV = 76.4° f = 4.350 TTL = 5.229

Surface Number	Radius of Curvature	Thickness	Refractive Index	Abbe Number	Focal Length	Element
S0	Infinity	-0.2100				Stop
S1	2.1945	0.6404	1.547	56.10	6.406	Lens
S2	5.2739	0.1862				Lens
S3	3.6685	0.5365	1.547	56.10	4.819	Lens
S4	-8.8553	0.0200				Lens
S5	7.9540	0.2500	1.669	20.40	-6.544	Lens
S6	2.7874	0.4285				Lens
S7	-5179.8622	0.4181	1.669	20.40	-90.150	Lens
S8	60.9954	0.3429				Lens
S9	9.7098	0.7008	1.669	20.40	-50.000	Lens
S10	7.3070	0.1275				Lens
S11	1.9803	0.6169	1.537	55.70	-12.785	Lens
S12	1.3697	0.1817				Lens
S13	Infinity	0.1100	1.519	64.20		Filter
S14	Infinity	0.1000				Imaging
S15	Infinity	0.5700				Plane

[0073] With reference to FIG. 7, an optical imaging system, according to a third example, will be described. An optical imaging system **300**, according to the third example, includes an optical system including a first lens **310**, a second lens **320**, a third lens **330**, a fourth lens **340**, a fifth lens **350**, and a sixth lens **360**.

[0074] The first lens **310** has a positive refractive power. An object-side surface of lens **310** is convex and an image-side surface of lens **310** is concave. The second lens **320** has a positive refractive power. Both surfaces of lens **320** are convex. The third lens **330** has a negative refractive power. An object-side surface of lens **330** is convex and an image-side surface of lens **330** is concave.

[0075] The fourth lens **340** has a negative refractive power. Both surfaces of lens **340** may be concave. The fifth lens **350** has a negative refractive power. An object-side surface of lens **350** is convex and an image-side surface of lens **350** is concave. In addition, fifth lens **350** has an inflection point formed on an object-side surface or an image-side surface. The sixth lens **360** has a

negative refractive power. An object-side surface of lens **360** is convex and an image-side surface of lens **360** is concave. In addition, sixth lens **360** has an inflection point formed on an object-side surface or an image-side surface.

[0076] The optical imaging system **300** includes a filter **370**, an image sensor **380**, and a stop ST. The filter **370** is disposed between the sixth lens **360** and the image sensor **380**, and the stop ST is disposed in an object-side surface of the first lens **310**.

[0077] In the optical imaging system **300**, f12 is 3.001 mm and f13 is 4.318 mm. The optical imaging system, configured as described above, represents aberration characteristics as illustrated by the graphs of FIG. **8**, while FIG. **9** represents aspherical characteristics of the optical imaging system. Characteristics of lenses of the optical imaging system **300**, according to the third example, are listed in Table 3.

TABLE-US-00003 TABLE 3 Third Example F No. = 1.63 FOV = 77.6° f = 4.290 TTL = 5.222
Surface Radius of Thickness/ Refractive Abbe Focal No. Element Curvature Distance Index
Number Length S0 Stop Infinity -0.2100 S1 First 2.2740 0.6458 1.547 56.10 6.911 S2 Lens 5.1414
0.1790 S3 Second 3.3935 0.5618 1.547 56.10 4.555 S4 Lens -8.7933 0.0200 S5 Third 8.0928
0.2500 1.669 20.40 -6.733 S6 Lens 2.8570 0.3911 S7 Fourth -48.6160 0.4243 1.669 20.40
-66.814 S8 Lens 553.5900 0.3119 S9 Fifth 6.8191 0.7268 1.669 20.40 -50.000 S10 Lens 5.4220
0.1456 S11 Sixth 2.0356 0.6058 1.537 55.70 -13.506 S12 Lens 1.4242 0.1799 S13 Filter Infinity
0.1100 1.519 64.20 S14 Infinity 0.1000 S15 Imaging Infinity 0.5700 Plane

[0078] Table 4 lists values of Conditional Expressions of the optical imaging systems, according to the first example to the third example.

TABLE-US-00004 TABLE 4 Conditional Expression First Example Second Example Third
Example f1/f 1.7175 1.4727 1.6110 f2/f 1.0386 1.1079 1.0617 f3/f -1.5392 -1.5044 -1.5694 f4/f
-13.8601 -20.7241 -15.5743 f5/f -11.8203 -11.4943 -11.6550 f6/f -4.2146 -2.9391 -3.1482 V1-
V2 0 0 0 V1-V3 35.70 35.70 35.70 V1-V5 35.70 35.70 35.70 TTL/f 1.2219 1.2022 1.2172 TTL/f12
1.7314 1.7405 1.7403 f13/EPD 1.6392 1.6590 1.6358 f1/f2 1.6537 1.3293 1.5174 f2/f3 -0.6748
-0.7364 -0.6765 BFL/f 0.2277 0.2211 0.2237 D1/f 0.0412 0.0428 0.0417 R1/f 0.5400 0.5045
0.5301 R5/f 1.9350 1.8285 1.8864 R8/f 24.8640 14.0219 129.0420

[0079] As set forth above, according to examples, an optical imaging system having high resolution may be implemented. While this disclosure includes specific examples, it will be apparent after an understanding of the disclosure of this application that various changes in form and details may be made in these examples without departing from the spirit and scope of the claims and their equivalents. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples.

[0080] Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner, and/or replaced or supplemented by other components or their equivalents. Therefore, the scope of the disclosure is defined not by the detailed description, but by the claims and their equivalents, and all variations within the scope of the claims and their equivalents are to be construed as being included in the disclosure.

Claims

1. An optical imaging system comprising: a first lens comprising a refractive power; a second lens comprising a convex object-side surface in a paraxial region; a third lens comprising a refractive power; a fourth lens comprising a refractive power; a fifth lens comprising a refractive power; and a sixth lens comprising a refractive power, wherein the first to sixth lenses are sequentially disposed from an object side of the optical imaging system, wherein the optical imaging system has a total number of six lenses with refractive power, wherein a distance from the image-side surface

of the third lens to an object-side surface of the fourth lens is greater than a distance from an image-side surface of the fourth lens to an object-side surface of the fifth lens, wherein an absolute value of a radius of curvature of an object-side surface of the fourth lens is greater than an absolute value of a radius of curvature of an image-side surface of the second lens, and wherein an absolute value of a radius of curvature of an image-side surface of the second lens is greater than an absolute value of a radius of curvature of an object-side surface of the fifth lens.

2. The optical imaging system of claim 1, wherein the first lens has a convex object-side surface in a paraxial region.
 3. The optical imaging system of claim 1, wherein the third lens has a convex object-side surface in a paraxial region.
 4. The optical imaging system of claim 1, wherein the fourth lens has a concave object-side surface in a paraxial region.
 5. The optical imaging system of claim 1, wherein the fifth lens has a convex object-side surface in a paraxial region.
 6. The optical imaging system of claim 1, wherein the sixth lens has a convex object-side surface in a paraxial region.
 7. An optical imaging system comprising: a first lens comprising a refractive power; a second lens comprising positive refractive power and a convex object-side surface in a paraxial region; a third lens comprising a refractive power; a fourth lens comprising negative refractive power; a fifth lens comprising a refractive power; and a sixth lens comprising a refractive power, wherein the first to sixth lenses are sequentially disposed from an object side of the optical imaging system, wherein the optical imaging system has a total number of six lenses with refractive power, and wherein an absolute value of a radius of curvature of an object-side surface of the fourth lens is greater than an absolute value of a radius of curvature of an image-side surface of the second lens.
 8. The optical imaging system of claim 7, wherein the first lens has a concave image-side surface in a paraxial region.
 9. The optical imaging system of claim 7, wherein the third lens has a convex object-side surface in a paraxial region.
 10. The optical imaging system of claim 7, wherein the fourth lens has a concave image-side surface in a paraxial region.
 11. The optical imaging system of claim 7, wherein the sixth lens has a convex object-side surface in a paraxial region.
 12. The optical imaging system of claim 7, wherein the sixth lens has a concave image-side surface in a paraxial region.
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