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Camera optical lens

Abstract

The present invention discloses a camera optical lens with seven-piece lens including, from an object side to an image side in sequence, a first lens having a positive refractive power, a second lens having a negative refractive power, a third lens having a positive refractive power, a fourth lens having a negative refractive power, a fifth lens having a positive refractive power, a sixth lens having a positive refractive power and a seventh lens having a negative refractive power. The camera optical lens satisfies the following conditions: $1.30 \leq f_1/f \leq 2.00$, $5.00 \leq d_1/d_2 \leq 8.01$, and $1.00 \leq d_4/d_6 \leq 5.00$. The camera optical lens according to the present invention has excellent optical characteristics, such as large aperture, wide angle, and ultra-thin.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
9958649	12/2017	Lai	N/A	G02B 13/0045
10670837	12/2019	Kuo	N/A	G02B 13/0045
11586011	12/2022	Hsieh	N/A	G02B 9/64
2014/0376105	12/2013	Sekine	359/708	G02B 3/02
2019/0187414	12/2018	Zhang	N/A	G02B 9/62
2021/0041670	12/2020	Yang	N/A	G02B 9/64
2021/0405327	12/2020	Dai	N/A	G02B 9/64
2022/0137369	12/2021	Hsu	359/708	G02B 9/64

OTHER PUBLICATIONS

Gross et al. "Handbook of Optical Systems vol. 3: Aberration Theory and Correction of Optical Systems" Weinheim Germany, Wiley-VCH Verlag GmbH & Co. KGaA, pp. 377-379 (Year: 2007). cited by examiner

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Background/Summary

FIELD OF THE PRESENT INVENTION

(1) The present invention relates to the field of optical lens, and more particularly, to a camera optical lens suitable for handheld terminal devices, such as smart phones and digital cameras, monitors or PC lenses.

DESCRIPTION OF RELATED ART

(2) In recent years, with the rise of various smart devices, the demand for miniaturized camera optics has been increasing, and the pixel size of photosensitive devices has shrunk, coupled with the development trend of electronic products with good functions, thin and portable appearance, Therefore, miniaturized imaging optical lenses with good image quality have become the mainstream in the current market. In order to obtain better imaging quality, a multi-piece lens structure is often used. Moreover, with the development of technology and the increase of diversified needs of users, as the pixel area of the photosensitive device continues to shrink and the system's requirements for image quality continue to increase, the seven-piece lenses structure gradually appears in the lens design. There is an urgent need for a wide-angle imaging lens with excellent optical characteristics, small size, and fully corrected aberrations.

SUMMARY

(3) In the present invention, a camera optical lens has excellent optical characteristics with large aperture stop, ultra-thin characteristic and wide angled.

(4) According to one aspect of the present invention, a camera optical lens comprising, from an object side to an image side in sequence, a first lens having a positive refractive power, a second lens having a negative refractive power, a third lens having a positive refractive power, a fourth lens having a negative refractive power, a fifth lens having a positive refractive power, a sixth lens having a positive refractive power and a seventh lens having a negative refractive power. Herein the camera optical lens satisfies the following conditions: $1.30 \leq f_1/f_6 \leq 2.00$, $5.00 \leq d_1/d_2 \leq 8.01$, and $1.00 \leq d_4/d_6 \leq 5.00$. f denotes a focal length of the optical camera lens, f_1 denotes a focal length of the first lens, d_1 denotes an on-axis thickness of the first lens, d_2 denotes an on-axis distance from an image side surface of the first lens to an object side surface of the second lens, d_4 denotes an on-axis distance from an image side surface of the second lens to an object side surface of the third lens, and d_6 denotes an on-axis distance from an image side surface of the third lens to an object side surface of the fourth lens.

(5) As an improvement, the camera optical lens further satisfies that the first lens has an object side surface being convex in a paraxial region and the image side surface of the first lens is concave in the paraxial region. The camera optical lens further satisfies the following conditions: $-4.08 \leq (R_1+R_2)/(R_1-R_2) \leq -1.07$ and $0.04 \leq d_1/TTL \leq 0.21$. R_1 denotes a central curvature radius of the object side surface of the first lens, R_2 denotes a central curvature radius of the image side surface of the first lens, and TTL denotes a total optical length from the object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(6) As an improvement, the camera optical lens further satisfies that the following conditions: $-2.55 \leq (R_1+R_2)/(R_1-R_2) \leq -1.33$ and $0.07 \leq d_1/TTL \leq 0.17$.

(7) As an improvement, the camera optical lens further satisfies that the object side surface of the second lens is convex in a paraxial region and the image side surface of the second lens is concave in the paraxial region. The camera optical lens further satisfies the following conditions: $-5.66 \leq f_2/f_3 \leq -1.18$, $1.77 \leq (R_3+R_4)/(R_3-R_4) \leq 6.49$, and $0.02 \leq d_3/TTL \leq 0.17$. f_2 denotes a focal length of the second lens, R_3 denotes a central curvature radius of the object side surface of the second

lens, R4 denotes a central curvature radius of the image side surface of the second lens, d3 denotes an on-axis thickness of the second lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(8) As an improvement, the camera optical lens further satisfies that the following conditions: $-3.53 \leq f_2/f \leq -1.47$, $2.83 \leq (R_3+R_4)/(R_3-R_4) \leq 5.19$, and $0.03 \leq d_3/TTL \leq 0.14$.

(9) As an improvement, the camera optical lens further satisfies that the object side surface of the third lens is convex in a paraxial region and the image side surface of the third lens is convex in the paraxial region. The camera optical lens further satisfies the following conditions: $0.63 \leq f_3/f \leq 2.48$, $-1.41 \leq (R_5+R_6)/(R_5-R_6) \leq -0.19$, and $0.04 \leq d_5/TTL \leq 0.13$. f_3 denotes a focal length of the third lens, R_5 denotes a central curvature radius of the object side surface of the third lens, R_6 denotes a central curvature radius of an image side surface of the third lens, d_5 denotes an on-axis thickness of the third lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(10) As an improvement, the camera optical lens further satisfies that the following conditions: $1.01 \leq f_3/f \leq 1.99$, $-0.88 \leq (R_5+R_6)/(R_5-R_6) \leq -0.24$, and $0.06 \leq d_5/TTL \leq 0.10$.

(11) As an improvement, the camera optical lens further satisfies that the object side surface of the fourth lens is concave in a paraxial region and the fourth lens further has an image side surface being convex in the paraxial region. The camera optical lens further satisfies the following conditions: $-142.89 \leq f_4/f \leq -4.19$, $-27.29 \leq (R_7+R_8)/(R_7-R_8) \leq -1.42$, and $0.02 \leq d_7/TTL \leq 0.11$. f_4 denotes a focal length of the fourth lens, R_7 denotes a central curvature radius of the object side surface of the fourth lens, R_8 denotes a central curvature radius of the image side surface of the fourth lens, d_7 denotes an on-axis thickness of the fourth lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(12) As an improvement, the camera optical lens further satisfies that the following conditions: $-89.31 \leq f_4/f \leq -5.24$, $-17.05 \leq (R_7+R_8)/(R_7-R_8) \leq -1.77$, and $0.04 \leq d_7/TTL \leq 0.09$.

(13) As an improvement, the camera optical lens further satisfies that the fifth lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region. The camera optical lens further satisfies the following conditions: $37.92 \leq f_5/f \leq 268.10$, $-641.90 \leq (R_9+R_{10})/(R_9-R_{10}) \leq 1012.65$, and $0.03 \leq d_9/TTL \leq 0.10$. f_5 denotes a focal length of the fifth lens, R_9 denotes a central curvature radius of the object side surface of the fifth lens, R_{10} denotes a central curvature radius of the image side surface of the fifth lens, d_9 denotes an on-axis thickness of the fifth lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(14) As an improvement, the camera optical lens further satisfies that the following conditions: $60.68 \leq f_5/f \leq 214.48$, $-401.19 \leq (R_9+R_{10})/(R_9-R_{10}) \leq 810.12$, and $0.046 \leq d_9/TTL \leq 0.08$.

(15) As an improvement, the camera optical lens further satisfies that the sixth lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region, the camera optical lens further satisfies the following conditions: $0.88 \leq f_6/f \leq 5.01$, $-23.98 \leq (R_{11}+R_{12})/(R_{11}-R_{12}) \leq -4.24$, and $0.05 \leq d_{11}/TTL \leq 0.18$. f_6 denotes a focal length of the sixth lens, R_{11} denotes a central curvature radius of the object side surface of the sixth lens, R_{12} denotes a central curvature radius of the image side surface of the sixth lens, d_{11} denotes an on-axis thickness of the sixth lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(16) As an improvement, the camera optical lens further satisfies the following conditions: $1.40 \leq f_6/f \leq 4.01$, $-14.99 \leq (R_{11}+R_{12})/(R_{11}-R_{12}) \leq -5.29$, and $0.07 \leq d_{11}/TTL \leq 0.14$.

(17) As an improvement, the camera optical lens further satisfies that the seventh lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region. The camera optical lens further satisfies the following conditions: $-2.73 \leq f_7/f \leq -0.79$, $0.63 \leq (R_{13}+R_{14})/(R_{13}-R_{14}) \leq 5.49$, and $0.03 \leq d_{13}/TTL \leq 0.09$. f_7 denotes a focal length of the seventh lens, R_{13} denotes a central curvature radius of the object side surface of the seventh lens, R_{14} denotes a central curvature radius of the image side surface of the seventh lens, d_{13} denotes an on-axis thickness of the seventh lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

(18) As an improvement, the camera optical lens further satisfies the following conditions: $-1.71 \leq f_7/f \leq -0.98$, $1.01 \leq (R_{13}+R_{14})/(R_{13}-R_{14}) \leq 4.39$, and $0.04 \leq d_{13}/TTL \leq 0.07$.

(19) As an improvement, the camera optical lens further satisfies the following conditions: $1.66 \leq f_{12}/f \leq 6.56$. f_{12} denotes a combined focal length of the first lens and the second lens.

(20) As an improvement, the camera optical lens further satisfies that an FNO of the camera optical lens is less than or equal to 2.06. FNO denotes a ratio of an effective focal length of the camera optical lens to an entrance pupil diameter.

(21) As an improvement, the camera optical lens further satisfies that an FOV of the camera optical lens is greater than or equal to 68.28° . FOV denotes a field of view of the camera optical lens in a diagonal direction.

(22) As an improvement, the camera optical lens further satisfies the following conditions: $TTL/IH \leq 1.93$. IH denotes an image height of the camera optical lens, and TTL denotes a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis.

BRIEF DESCRIPTION OF THE DRAWINGS

(1) In order to explain the technical solutions in the embodiments of the present invention more clearly, the following will briefly introduce the drawings that need to be used in the description of the embodiments. Obviously, the drawings in the following description are only some embodiments of the present invention. For those of ordinary skill in the art, without creative work, other drawings can be obtained based on these drawings, among which:

(2) FIG. 1 is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 1 of the present invention;

(3) FIG. 2 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 1;

(4) FIG. 3 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 1;

(5) FIG. 4 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 1;

(6) FIG. 5 is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 2 of the present invention;

(7) FIG. 6 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 5;

(8) FIG. 7 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 5;

(9) FIG. 8 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 5;

(10) FIG. 9 is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 3 of the present invention;

(11) FIG. 10 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 9;

(12) FIG. 11 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 9; and

(13) FIG. 12 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 9.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

(14) In order to make the objects, technical solutions, and advantages of the present invention more apparent, the embodiments of the present invention will be described in detail below. However, it will be apparent to the one skilled in the art that, in the various embodiments of the present invention, a number of technical details are presented in order to provide the reader with a better understanding of the invention. However, the technical solutions claimed in the present invention can be implemented without these technical details and various changes and modifications based on the following embodiments.

Embodiment 1

(15) As referring to the accompanying drawings, the present invention provides a camera optical lens **10**. FIG. 1 shows the camera optical lens **10** according to embodiment 1 of the present invention. The camera optical lens comprises seven lenses. Specifically, from an object side to an image side, the camera optical lens **10** comprises in sequence: an aperture S1, a first lens L1, a second lens L2, a third lens L3, a fourth lens L4, a fifth lens L5, a sixth lens L6 and a seventh lens L7. Optical elements like optical filter GF can be arranged between the seventh lens L7 and an image surface S1.

(16) The first lens L1 is made of plastic material, the second lens L2 is made of plastic material, the third lens L3 is made of plastic material, the fourth lens L4 is made of plastic material, the fifth lens L5 is made of plastic material, the sixth lens L6 is made of plastic material, and the seventh lens L7 is made of plastic material. In other optional embodiments, each lens may also be made of other materials.

(17) A focal length of the camera optical lens **10** is defined as f , and a focal length of the first lens L1 is defined as f_1 . The camera optical lens **10** further satisfies the following condition: $1.30 \leq f_1/f \leq 2.00$, which specifies a positive refractive power of the first lens L1. When the value is lower than 1.30, although the lens develop toward ultra-thin, the positive refractive power of the first lens L1 is too high, so that the aberration cannot be corrected and it is bad for producing wide angle lens. When the value is higher than 2.00, the positive refractive power of the first lens L1 is too weaker, the lens cannot develop toward ultra-thin.

(18) An on-axis thickness of the first lens L1 is defined as d_1 , and an on-axis distance from an image side surface of the first lens L1 to an object side surface of the second lens L2 is defined as d_2 . The camera optical lens further satisfies the following condition: $5.00 \leq d_1/d_2 \leq 8.00$, which specifies a ratio of the on-axis thickness of the first lens L1 to the on-axis distance from the image side surface of the first lens L1 to the object side surface of the second lens L2. When the condition is satisfied, it benefits for developing towards a wide-angle lens.

(19) An on-axis distance from an image side surface of the second lens L2 to an object side surface of the third lens L3 is defined as d_4 , and an on-axis distance from an image side surface of the third lens L3 to an object side surface of the fourth lens L4 is defined as d_6 . The camera optical lens **10** further satisfies the following condition: $1.00 \leq d_4/d_6 \leq 5.00$, which specifies a ratio of the on-axis distance from the image side surface of the second lens L2 to the object side surface of the third lens L3 to the on-axis distance from the image side surface of the third lens L3 to the object side surface of the fourth lens L4. When the condition is satisfied, it benefits for achieving the ultra-thin performance.

(20) In the present embodiment, an object side surface of the first lens L1 is convex in a paraxial region, the image side surface of the first lens L1 is concave in the paraxial region, and the first lens L1 has a positive refractive power. In other optional embodiments, the object side surface and the image side surface of the first lens L1 can also be arranged as other concave side surface or convex side surface, such as, concave object side surface and convex image side surface and so on.

(21) The central curvature radius of the object side surface of the first lens L1 is defined as R_1 , and a central curvature radius of the image side surface of the first lens L1 is defined as R_2 . The camera optical lens **10** further satisfies the following condition: $-4.08 \leq (R_1 + R_2)/(R_1 - R_2) \leq -1.07$. This condition reasonably controls a shape of the first lens L1, so

that the first lens L1 can effectively correct a spherical aberration of the camera optical lens **10**. Preferably, the following condition shall be satisfied, $-2.556 \leq (R1+R2)/(R1-R2) \leq -1.33$.

(22) The on-axis thickness of the first lens L1 is defined as d1. A total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along an optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $0.04 \leq d1/TTL \leq 0.21$. When the condition is satisfied, it benefits for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.07 \leq d1/TTL \leq 0.17$.

(23) In the present embodiment, the object side surface of the second lens L2 is convex in the paraxial region, the image side surface of the second lens L2 is concave in the paraxial region, and the second lens L2 has a negative refractive power. In other optional embodiments, the object side surface and the image side surface of the second lens L2 can also be arranged as other concave side surface or convex side surface, such as, concave object side surface and convex image side surface and so on.

(24) The focal length of the camera optical lens **10** is defined as f, and the focal length of the second lens L2 is defined as f2. The camera optical lens **10** further satisfies the following condition: $-5.66 \leq f2/f \leq -1.18$. It is beneficial for correcting an aberration of the camera optical lens **10** by controlling the negative refractive power of the second lens L2 being within reasonable range. Preferably, the following condition shall be satisfied, $-3.53 \leq f2/f \leq -1.47$.

(25) A central curvature radius of the object side surface of the second lens L2 is defined as R3, and a central curvature radius of the image side surface of the second lens L2 is defined as R4. The camera optical lens **10** further satisfies the following condition: $1.77 \leq (R3+R4)/(R3-R4) \leq 6.49$, which specifies a shape of the second lens L2. When the condition is satisfied, as the camera optical lens **10** develops towards ultra-thin and wide-angle, it is beneficial for correcting an on-axis chromatic aberration. Preferably, the following condition shall be satisfied, $2.83 \leq (R3+R4)/(R3-R4) \leq 5.19$.

(26) An on-axis thickness of the second lens L2 is defined as d3. The total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $0.02 \leq d3/TTL \leq 0.17$. When the condition is satisfied, it is beneficial for producing ultra-thin lenses. Preferably, the following condition shall be satisfied, $0.03 \leq d3/TTL \leq 0.14$.

(27) In the present embodiment, the object side surface of the third lens L3 is convex in the paraxial region, the image side surface of the third lens L3 is convex in the paraxial region, and the third lens L3 has a positive refractive power. In other optional embodiments, the object side surface and the image side surface of the third lens L3 can also be arranged as other concave side surface or convex side surface, such as, concave object side surface and concave image side surface and so on.

(28) The focal length of the camera optical lens **10** is defined as f, and the focal length of the third lens L3 is defined as f3. The camera optical lens **10** further satisfies the following condition: $0.63 \leq f3/f \leq 2.48$. By a reasonable distribution of the refractive power, which makes it is possible that the camera optical lens **10** has an excellent imaging quality and a lower sensitivity. Preferably, the following condition shall be satisfied, $1.01 \leq f3/f \leq 1.99$.

(29) A central curvature radius of the object side surface of the third lens L3 is defined as R5, and a central curvature radius of the image side surface of the third lens L3 is defined as R6. The camera optical lens **10** further satisfies the following condition: $-1.41 \leq (R5+R6)/(R5-R6) \leq -0.19$, which specifies a shape of the third lens L3. It is beneficial for molding the third lens L3. When the condition is satisfied, a degree of deflection of light passing through the lens can be alleviated, and the aberration can be reduced effectively. Preferably, the following condition shall be satisfied, $-0.886 \leq (R5+R6)/(R5-R6) \leq -0.24$.

(30) An on-axis thickness of the third lens L3 is defined as d5. The total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $0.04 \leq d5/TTL \leq 0.13$, which benefits for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.06 \leq d5/TTL \leq 0.10$.

(31) In the present embodiment, the object side surface of the fourth lens L4 is concave in the paraxial region, an image side surface of the fourth lens L4 is convex in the paraxial region, and the fourth lens L4 has a negative refractive power. In other optional embodiments, the object side surface and the image side surface of the fourth lens L4 can also be arranged as other convex side surface or concave side surface, such as, convex object side surface and concave image side surface and so on.

(32) The focal length of the camera optical lens **10** is defined as f, and a focal length of the fourth lens L4 is defined as f4. The camera optical lens **10** further satisfies the following condition: $-142.89 \leq f4/f \leq -4.19$. By a reasonable distribution of the refractive power, which makes it is possible that the camera optical lens **10** has the excellent imaging quality and the lower sensitivity. Preferably, the following condition shall be satisfied, $-89.31 \leq f4/f \leq -5.24$.

(33) A curvature radius of the object side surface of the fourth lens L4 is defined as R7, and a central curvature radius of the image side surface of the fourth lens L4 is defined as R8. The camera optical lens further satisfies the following condition: $-27.29 \leq (R7+R8)/(R7-R8) \leq -1.42$, which specifies a shape of the fourth lens L4. When the condition is satisfied, as the development of ultra-thin and wide-angle lens, it is beneficial for solving the problems, such as correcting an off-axis aberration. Preferably, the following condition shall be satisfied, $-17.05 \leq (R7+R8)/(R7-R8) \leq -1.77$.

(34) An on-axis thickness of the fourth lens L4 is defined as d7. The total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $0.02 \leq d7/TTL \leq 0.11$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.04 \leq d7/TTL \leq 0.09$.

(35) In the present embodiment, an object side surface of the fifth lens L5 is convex in the paraxial region, an image side

surface of the fifth lens L5 is concave in the paraxial region, and the fifth lens L5 has a positive refractive power. In other optional embodiments, the object side surface and the image side surface of the fifth lens L5 can also be arranged as other convex side surface or concave side surface, such as, concave object side surface and convex image side surface and so on. (36) The focal length of the camera optical lens **10** is defined as f , and a focal length of the fifth lens L5 is defined as f_5 . The camera optical lens **10** further satisfies the following condition: $37.92 \leq f_5/f \leq 268.10$. When the condition is satisfied, a light angle of the camera optical lens **10** can be smoothed effectively and the sensitivity of the tolerance can be reduced. Preferably, the following condition shall be satisfied, $60.68 \leq f_5/f \leq 214.48$.

(37) A central curvature radius of the object side surface of the fifth lens L5 is defined as R_9 , and a central curvature radius of the image side surface of the fifth lens L5 is defined as R_{10} . The camera optical lens further satisfies the following condition: $-641.90 \leq (R_9 + R_{10})/(R_9 - R_{10}) \leq 1012.65$, which specifies a shape of the fifth lens L5. When the condition is satisfied, as the development of the ultra-thin and wide-angle lenses, it is beneficial for correcting the off-axis aberration. Preferably, the following condition shall be satisfied, $-401.19 \leq (R_9 + R_{10})/(R_9 - R_{10}) \leq 810.12$.

(38) An on-axis thickness of the fifth lens L5 is defined as d_9 . The total optical length from the object side surface of the first lens L1 to the image surface S_i of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $0.03 \leq d_9/\text{TTL} \leq 0.10$. When the condition is satisfied, it is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.04 \leq d_9/\text{TTL} \leq 0.08$.

(39) In the present embodiment, the object side surface of the sixth lens L6 is convex in the paraxial region, the image side surface of the sixth lens L6 is concave in the paraxial region, and the sixth lens L6 has a positive refractive power. In other optional embodiments, the object side surface and the image side surface of the sixth lens L6 can be arranged as other convex side surface or concave side surface, such as, concave object side surface and convex image side surface and so on.

(40) The focal length of the camera optical lens **10** is defined as f , and a focal length of the sixth lens L6 is defined as f_6 . The camera optical lens further satisfies the following condition: $0.88 \leq f_6/f \leq 5.01$. By a reasonable distribution of the refractive power, which makes it is possible the camera optical lens **10** has the excellent imaging quality and the lower sensitivity. Preferably, the following condition shall be satisfied, $1.40 \leq f_6/f \leq 4.01$.

(41) A central curvature radius of the object side surface of the sixth lens L6 is defined as R_{11} , and a central curvature radius of the image side surface of the sixth lens L6 is defined as R_{12} . The camera optical lens further satisfies the following condition: $-23.98 \leq (R_{11} + R_{12})/(R_{11} - R_{12}) \leq -4.24$, which specifies a shape of the sixth lens L6. When the condition is satisfied, as the development of ultra-thin and wide-angle lens, it is beneficial for solving the problems, such as correcting the off-axis aberration. Preferably, the following condition shall be satisfied, $-14.99 \leq (R_{11} + R_{12})/(R_{11} - R_{12}) \leq -5.29$.

(42) An on-axis thickness of the sixth lens L6 is defined as d_{11} . The total optical length from the object side surface of the first lens L1 to the image surface S_i of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens further satisfies the following condition: $0.05 \leq d_{11}/\text{TTL} \leq 0.18$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.07 \leq d_{11}/\text{TTL} \leq 0.14$.

(43) In the present embodiment, an object side surface of the seventh lens L7 is convex in the paraxial region, an image side surface of the seventh lens L7 is concave in the paraxial region, and the seventh lens L7 has a negative refractive power. In other optional embodiments, the object side surface and the image side surface of the seventh lens L7 can be arranged as other convex side surface or concave side surface, such as, concave object side surface and convex image side surface and so on.

(44) The focal length of the camera optical lens **10** is defined as f , and a focal length of the seventh lens L7 is defined as f_7 . The camera optical lens **10** further satisfies the following condition: $-2.73 \leq f_7/f \leq -0.79$. By a reasonable distribution of the refractive power, which makes it is possible the camera optical lens **10** has the excellent imaging quality and the lower sensitivity. Preferably, the following condition shall be satisfied, $-1.71 \leq f_7/f \leq -0.98$.

(45) A central curvature radius of the object side surface of the seventh lens L7 is defined as R_{13} , and a central curvature radius of the image side surface of the seventh lens L7 is defined as R_{14} . The camera optical lens **10** further satisfies the following condition: $0.63 \leq (R_{13} + R_{14})/(R_{13} - R_{14}) \leq 5.49$, which specifies a shape of the seventh lens L7. When the condition is satisfied, as the development of ultra-thin and wide-angle lens, it is beneficial for correcting the off-axis aberration. Preferably, the following condition shall be satisfied, $1.01 \leq (R_{13} + R_{14})/(R_{13} - R_{14}) \leq 4.39$.

(46) An on-axis thickness of the seventh lens L7 is defined as d_{13} . The total optical length from the object side surface of the first lens L1 to the image surface S_i of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens further satisfies the following condition: $0.03 \leq d_{13}/\text{TTL} \leq 0.09$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.04 \leq d_{13}/\text{TTL} \leq 0.07$.

(47) In the present embodiment, the focal length of the camera optical lens **10** is f , and a combined focal length of the first lens L1 and the second lens L2 is defined as f_{12} . The camera optical lens **10** further satisfies the following condition: $1.66 \leq f_{12}/f \leq 6.56$. This condition can eliminate aberration and distortion of the camera optical lens **10**, reduce a back focal length of the camera optical lens **10**, and maintain the miniaturization of the camera lens system group. Preferably, the following condition shall be satisfied, $2.65 \leq f_{12}/f \leq 5.25$.

(48) In the present embodiment, an F number (FNO) of the camera optical lens **10** is smaller than or equal to 2.26, thereby achieving a large aperture and good imaging performance. Preferably, the FNO of the camera optical lens **10** is smaller than or equal to 2.02.

(49) In the present embodiment, a field of view of the camera optical lens **10** in a diagonal direction is defined as FOV. The FOV is greater than or equal to 68.28° , thereby achieving the wide-angle performance. Preferably, the FOV **10** is

greater than or equal to 68.98°.

(50) In the present embodiment, an image height of the camera optical lens **10** is defined as IH. The total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along an optical axis is defined as TTL. The camera optical lens **10** further satisfies the following condition: $TTL/IH \leq 1.93$, thereby achieving the ultra-thin performance. Preferably, the following condition shall be satisfied, $TTL/IH \leq 1.88$.

(51) When the above conditions are satisfied, which makes it is possible the camera optical lens has excellent optical performances, and meanwhile can meet design requirements of ultra-thin, wide-angle and large aperture. According the characteristics of the camera optical lens **10**, it is particularly suitable for a mobile camera lens component and a WEB camera lens composed of high pixel CCD, CMOS.

(52) The following examples will be used to describe the camera optical lens **10** of the present invention. The symbols recorded in each example will be described as follows. The focal length, on-axis distance, central curvature radius, on-axis thickness, inflexion point position, and arrest point position are all in units of mm.

(53) TTL: the total optical length from the object side surface of the first lens L1 to the image surface Si of the camera optical lens **10** along the optical axis, the unit of TTL is mm.

(54) F number (FNO): a ratio of an effective focal length of the camera optical lens **10** to an entrance pupil diameter (ENPD).

(55) Preferably, inflexion points and/or arrest points can also be arranged on the object side surface and/or image side surface of the lens, so that the demand for high quality imaging can be satisfied, the description below can be referred for specific implementable scheme.

(56) The design information of the camera optical lens **10** in Embodiment 1 of the present invention is shown in the tables 1 and 2.

(57) TABLE-US-00001 TABLE 1 R d nd vd S1 ∞ d0 = -0.300 R1 3.739 d1 = 1.210 nd1 1.5444 v1 55.82 R2 16.187 d2 = 0.241 R3 5.741 d3 = 0.325 nd2 1.6700 v2 19.39 R4 3.214 d4 = 0.380 R5 6.880 d5 = 0.733 nd3 1.5444 v3 55.82 R6 -12.290 d6 = 0.371 R7 -14.769 d7 = 0.401 nd4 1.5661 v4 37.71 R8 -41.041 d8 = 0.398 R9 8.320 d9 = 0.545 nd5 1.5661 v5 37.71 R10 8.372 d10 = 0.439 R11 3.018 d11 = 1.020 nd6 1.5444 v6 55.82 R12 3.567 d12 = 0.836 R13 3.386 d13 = 0.425 nd7 1.5661 v7 37.71 R14 1.933 d14 = 0.628 R15 ∞ d15 = 0.210 ndg 1.5168 vg 64.17 R16 ∞ d16 = 0.300 where, the meaning of the various symbols is as follows. S1: aperture; R: curvature radius of an optical surface, a central curvature radius for a lens; R1: central curvature radius of the object side surface of the first lens L1; R2: central curvature radius of the image side surface of the first lens L1; R3: central curvature radius of the object side surface of the second lens L2; R4: central curvature radius of the image side surface of the second lens L2; R5: central curvature radius of the object side surface of the third lens L3; R6: central curvature radius of the image side surface of the third lens L3; R7: central curvature radius of the object side surface of the fourth lens L4; R8: central curvature radius of the image side surface of the fourth lens L4; R9: central curvature radius of the object side surface of the fifth lens L5; R10: central curvature radius of the image side surface of the fifth lens L5; R11: central curvature radius of the object side surface of the sixth lens L6; R12: central curvature radius of the image side surface of the sixth lens L6; R13: central curvature radius of the object side surface of the seventh lens L7; R14: central curvature radius of the image side surface of the seventh lens L7; R15: central curvature radius of an object side surface of the optical filter GF; R16: curvature radius of an image side surface of the optical filter GF; d: on-axis thickness of a lens and an on-axis distance between lenses; d0: on-axis distance from the aperture S1 to the object side surface of the first lens L1; d1: on-axis thickness of the first lens L1; d2: on-axis distance from the image side surface of the first lens L1 to the object side surface of the second lens L2; d3: on-axis thickness of the second lens L2; d4: on-axis distance from the image side surface of the second lens L2 to the object side surface of the third lens L3; d5: on-axis thickness of the third lens L3; d6: on-axis distance from the image side surface of the third lens L3 to the object side surface of the fourth lens L4; d7: on-axis thickness of the fourth lens L4; d8: on-axis distance from the image side surface of the fourth lens L4 to the object side surface of the fifth lens L5; d9: on-axis thickness of the fifth lens L5; d10: on-axis distance from the image side surface of the fifth lens L5 to the object side surface of the sixth lens L6; d11: on-axis thickness of the sixth lens L6; d12: on-axis distance from the image side surface of the sixth lens L5 to the object side surface of the seventh lens L7; d13: on-axis thickness of the seventh lens L7; d14: on-axis distance from the image side surface of the seventh lens L7 to the object side surface of the optical filter GF; d15: on-axis thickness of the optical filter GF; d16: on-axis distance from the image side surface of the optical filter GF to the image surface; nd: refractive index of d line (d-line is green light with a wavelength of 550 nm); nd1: refractive index of d line of the first lens L1; nd2: refractive index of d line of the second lens L2; nd3: refractive index of d line of the third lens L3; nd4: refractive index of d line of the fourth lens L4; nd5: refractive index of d line of the fifth lens L5; nd6: refractive index of d line of the sixth lens L6; nd7: refractive index of d line of the seventh lens L7; ndg: refractive index of d line of the optical filter GF; vd: abbe number; v1: abbe number of the first lens L1; v2: abbe number of the second lens L2; v3: abbe number of the third lens L3; v4: abbe number of the fourth lens L4; v5: abbe number of the fifth lens L5; v6: abbe number of the sixth lens L6; v7: abbe number of the seventh lens L7; vg: abbe number of the optical filter GF;

(58) Table 2 shows the aspherical surface data of the camera optical lens **10** in Embodiment 1 of the present invention.

(59) TABLE-US-00002 TABLE 2 Conic coefficient Aspheric surface coefficients k A4 A6 A8 A10 A12 R1 7.9874E-01 9.1677E-05 4.3339E-03 -7.6576E-03 8.4947E-03 -5.9580E-03 R2 2.9986E+01 -1.9458E-02 1.2852E-02 -2.7663E-03 -3.0382E-03 2.8648E-03 R3 -1.0511E+01 -3.8379E-02 3.1581E-02 -9.1462E-03 -3.7555E-03 5.7034E-03 R4 -1.5527E+00 -1.7891E-02 1.8435E-02 7.4253E-03 -2.7403E-02 3.1874E-02 R5 1.5710E+01 -2.7255E-02 -2.0888E-02 1.4218E-02 8.6725E-03 -3.6884E-02 R6 -5.4165E+00 3.1179E-02 -1.2203E-01

1.4163E-01 -1.0812E-01 5.4706E-02 R7 2.9999E+01 7.4125E-02 -1.6763E-01 1.6340E-01 -9.6470E-02
3.6841E-02 R8 1.0117E+01 5.3533E-02 -1.1172E-01 9.4006E-02 -5.6223E-02 2.4081E-02 R9 1.0488E+01
3.3448E-02 -4.0937E-02 2.6454E-02 -1.2626E-02 3.9310E-03 R10 7.1979E+00 -6.3990E-02 2.2736E-02
-4.5419E-04 -3.5081E-03 1.4540E-03 R11 -1.8018E+00 -7.9506E-03 -6.5874E-03 -1.0379E-04 1.4719E-04
-3.8737E-05 R12 -4.5565E+00 7.1430E-02 -3.5574E-02 7.3111E-03 -8.1185E-04 4.2540E-05 R13 -1.1674E+01
-6.1119E-02 1.7888E-02 -2.3088E-03 1.5246E-04 -3.5860E-06 R14 -5.1117E+00 -4.0606E-02 1.2496E-02
-2.7764E-03 4.2232E-04 -4.3605E-05 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1
7.9874E-01 2.5935E-03 -6.8051E-04 9.5900E-05 -5.6209E-06 R2 2.9986E+01 -1.1371E-03 2.0807E-04
-7.8756E-06 -1.6336E-06 R3 -1.0511E+01 -2.8869E-03 7.9006E-04 -1.0631E-04 5.3409E-06 R4 -1.5527E+00
-2.1749E-02 9.2277E-03 -2.2486E-03 2.4552E-04 R5 1.5710E+01 3.7264E-02 -1.8954E-02 4.9634E-03
-5.2554E-04 R6 -5.4165E+00 -1.8607E-02 4.1348E-03 -5.3301E-04 2.9859E-05 R7 2.9999E+01 -8.9493E-03
1.3188E-03 -1.0589E-04 3.4486E-06 R8 1.0117E+01 -6.8645E-03 1.2138E-03 -1.1899E-04 4.8914E-06 R9
1.0488E+01 -7.6488E-04 8.9981E-05 -5.8760E-06 1.6375E-07 R10 7.1979E+00 -2.7704E-04 2.8383E-05
-1.5176E-06 3.3291E-08 R11 -1.8018E+00 1.5835E-05 -2.7710E-06 2.0350E-07 -5.3983E-09 R12 -4.5565E+00
9.9959E-07 -3.2487E-07 2.0592E-08 -4.6002E-10 R13 -1.1674E+01 -1.7452E-07 1.4934E-08 -3.9332E-10
3.4015E-12 R14 -5.1117E+00 3.0098E-06 -1.3211E-07 3.3111E-09 -3.5886E-11

(60) For convenience, an aspheric surface of each lens surface uses the aspheric surfaces shown in the below condition (1). However, the present invention is not limited to the aspherical polynomials form shown in the condition (1).

(61)

$$z = (cr^2) / \{1 + [1 - (k + 1)(c^2 r^2)]^{1/2}\} + A4r^4 + A6r^6 + A8r^8 + A10r^{10} + A12r^{12} + A14r^{14} + A16r^{16} + A18r^{18} + A20r^{20} \quad (1)$$

(62) Where, K is a conic coefficient, A4, A6, A8, A10, A12, A14, A16, A18, A20 are aspheric surface coefficients. c is the curvature at the center of the optical surface. r is a vertical distance between a point on an aspherical curve and the optic axis, and z is an aspherical depth (a vertical distance between a point on an aspherical surface, having a distance of r from the optic axis, and a surface tangent to a vertex of the aspherical surface on the optic axis).

(63) Table 3 and Table 4 show design data of inflexion points and arrest points of respective lens in the camera optical lens **10** according to Embodiment 1 of the present invention. P1R1 and P1R2 represent the object side surface and the image side surface of the first lens L1, P2R1 and P2R2 represent the object side surface and the image side surface of the second lens L2, P3R1 and P3R2 represent the object side surface and the image side surface of the third lens L3, P4R1 and P4R2 represent the object side surface and the image side surface of the fourth lens L4, P5R1 and P5R2 represent the object side surface and the image side surface of the fifth lens L5, P6R1 and P6R2 represent the object side surface and the image side surface of the sixth lens L6, and P7R1 and P7R2 represent the object side surface and the image side surface of the seventh lens L7. The data in the column named “inflexion point position” refers to vertical distances from inflexion points arranged on each lens surface to the optical axis of the camera optical lens **10**. The data in the column named “arrest point position” refers to vertical distances from arrest points arranged on each lens surface to the optical axis of the camera optical lens **10**.

(64) TABLE-US-00003 TABLE 3 Number of Inflexion point Inflexion point inflexion points position 1 position 2 P1R1 1 1.625 / P1R2 1 0.715 / P2R1 2 0.965 1.405 P2R2 1 1.475 / P3R1 1 0.825 / P3R2 1 1.745 / P4R1 1 1.625 / P4R2 1 2.075 / P5R1 2 1.245 2.205 P5R2 2 0.875 2.155 P6R1 2 0.905 2.335 P6R2 2 1.445 3.605 P7R1 2 0.615 1.855 P7R2 2 0.835 4.115

(65) TABLE-US-00004 TABLE 4 Number of Arrest point Arrest point arrest points Position 1 position 2 P1R1 0 // P1R2 1 1.195 / P2R1 0 // P2R2 0 // P3R1 1 1.255 / P3R2 0 // P4R1 0 // P4R2 0 // P5R1 1 1.755 / P5R2 2 1.625 2.375 P6R1 1 1.555 / P6R2 1 3.075 / P7R1 2 1.315 2.495 P7R2 1 2.245 /

(66) FIG. 2 and FIG. 3 respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 656 nm, 588 nm and 486 nm after passing the camera optical lens **10** according to Embodiment 1. FIG. 4 illustrates a field curvature and a distortion of light with a wavelength of 588 nm after passing the camera optical lens **10** according to Embodiment 1, in which a field curvature S is a field curvature in a sagittal direction and T is a field curvature in a tangential direction.

(67) Table 13 shows various values of Embodiments 1, 2 and 3 and values corresponding to parameters which are specified in the above conditions.

(68) As shown in Table 13, Embodiment 1 satisfies the above conditions.

(69) In the present embodiment, the entrance pupil diameter (ENPD) of the camera optical lens **10** is 3.259 mm. The image height of 1.0H is 4.595 mm. The FOV is 69.68°. Thus, the camera optical lens **10** satisfies design requirements of large apertures, ultra-thin and wide-angle while the on-axis and off-axis aberrations are sufficiently corrected, thereby achieving excellent optical characteristics.

Embodiment 2

(70) Embodiment 2 is basically the same as Embodiment 1, the meaning of its symbols is the same as that of Embodiment 1, in the following, only the differences are listed.

(71) FIG. 5 shows a schematic diagram of a structure of a camera optical lens **20** according to Embodiment 2 of the present invention. Table 5 and table 6 show the design data of a camera optical lens **20** in Embodiment 2 of the present invention.

(72) TABLE-US-00005 TABLE 5 R d nd vd S1 ∞ d0 = -0.212 R1 3.704 d1 = 0.635 nd1 1.5444 v1 55.82 R2 13.238 d2 = 0.098 R3 4.948 d3 = 0.819 nd2 1.6700 v2 19.39 R4 3.028 d4 = 0.317 R5 5.903 d5 = 0.542 nd3 1.5444 v3 55.82 R6

-33.610 d6 = 0.106 R7 -29.921 d7 = 0.512 nd4 1.5444 v4 55.82 R8 -51.819 d8 = 0.425 R9 8.031 d9 = 0.380 nd5 1.5661 v5 37.71 R10 8.008 d10 = 0.469 R11 2.028 d11 = 0.729 nd6 1.5444 v6 55.82 R12 2.785 d12 = 0.945 R13 27.460 d13 = 0.420 nd7 1.5444 v7 55.82 R14 3.164 d14 = 0.444 R15 ∞ d15 = 0.210 ndg 1.5168 vg 64.17 R16 ∞ d16 = 0.300

(73) Table 6 shows aspherical surface data of each lens of the camera optical lens **20** in Embodiment 2 of the present invention.

(74) TABLE-US-00006 TABLE 6 Conic coefficient Aspheric surface coefficients k A4 A6 A8 A10 A12 R1 -5.3259E-01 -7.5453E-03 1.2806E-02 -4.0293E-02 7.0545E-02 -7.6755E-02 R2 -3.0000E+01 -6.7119E-02 5.3335E-02 -1.2201E-02 -3.3424E-02 5.4061E-02 R3 -1.3188E+01 -5.6836E-02 6.0685E-02 -6.0185E-02 7.3006E-02 -7.6333E-02 R4 -1.7773E+00 -1.8018E-02 -2.9140E-03 1.9805E-02 -1.7482E-02 -1.6279E-03 R5 1.4404E+01 -2.2014E-02 6.0201E-03 -3.5316E-02 3.8148E-02 -1.9834E-02 R6 -3.0000E+01 1.2784E-02 -3.6559E-02 1.1571E-02 2.2735E-02 -5.4642E-02 R7 3.0000E+01 3.1696E-02 -1.0585E-01 1.4590E-01 -1.3235E-01 7.1309E-02 R8 -2.9951E+01 2.6071E-02 -1.1238E-01 1.3451E-01 -1.0211E-01 4.9259E-02 R9 1.0932E+01 5.0475E-02 -1.0860E-01 9.8517E-02 -5.4615E-02 1.9131E-02 R10 7.2610E+00 -1.6232E-02 -3.9758E-02 4.4071E-02 -1.9698E-02 3.9961E-03 R11 -3.0694E+00 -4.2443E-02 5.3442E-03 -2.1269E-03 1.0728E-03 -4.1743E-04 R12 -6.6785E+00 -5.2506E-05 -3.0105E-03 1.0556E-03 -2.7206E-04 4.7160E-05 R13 -1.2909E+01 -1.0492E-01 4.6129E-02 -9.9956E-03 1.3233E-03 -1.1408E-04 R14 -1.2253E+01 -4.9812E-02 1.6983E-02 -3.4744E-03 4.5521E-04 -3.8713E-05 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1 -5.3259E-01 5.2394E-02 -2.1839E-02 5.0750E-03 -5.0392E-04 R2 -3.0000E+01 -4.2380E-02 1.9171E-02 -4.7662E-03 5.0452E-04 R3 -1.3188E+01 5.3727E-02 -2.3285E-02 5.6022E-03 -5.7249E-04 R4 -1.7773E+00 1.3252E-02 -1.0104E-02 3.2930E-03 -4.0781E-04 R5 1.4404E+01 -2.9276E-03 8.6458E-03 -4.0956E-03 6.6484E-04 R6 -3.0000E+01 4.9113E-02 -2.2550E-02 5.2793E-03 -4.9604E-04 R7 3.0000E+01 -2.1635E-02 3.5201E-03 -2.6414E-04 5.1363E-06 R8 -2.9951E+01 -1.4907E-02 2.7255E-03 -2.7268E-04 1.1373E-05 R9 1.0932E+01 -4.4864E-03 7.0019E-04 -6.6117E-05 2.8630E-06 R10 7.2610E+00 -2.0193E-04 -5.6823E-05 9.7768E-06 -4.6700E-07 R11 -3.0694E+00 9.4769E-05 -1.1523E-05 7.0533E-07 -1.7196E-08 R12 -6.6785E+00 -5.3725E-06 3.8631E-07 -1.5917E-08 2.8811E-10 R13 -1.2909E+01 6.4639E-06 -2.3291E-07 4.8431E-09 -4.4201E-11 R14 -1.2253E+01 2.1272E-06 -7.2766E-08 1.4019E-09 -1.1527E-11

(75) Table 7 and table 8 show design data of inflexion points and arrest points of respective lens in the camera optical lens **20** according to Embodiment 2 of the present invention.

(76) TABLE-US-00007 TABLE 7 Number of Inflexion point Inflexion point Inflexion point inflexion points position 1 position 2 position 3 P1R1 1 1.375 // P1R2 1 0.345 // P2R1 1 1.235 // P2R2 1 1.145 // P3R1 1 0.785 // P3R2 1 1.465 // P4R1 1 1.325 // P4R2 1 1.745 // P5R1 2 0.945 2.005 / P5R2 2 0.605 1.905 / P6R1 2 0.855 2.285 / P6R2 2 1.305 3.275 / P7R1 3 0.175 1.355 3.405 P7R2 3 0.655 2.665 3.545

(77) TABLE-US-00008 TABLE 8 Number of Arrest point Arrest point arrest points position 1 position 2 P1R1 0 // P1R2 1 0.695 / P2R1 0 // P2R2 0 // P3R1 1 1.145 / P3R2 0 // P4R1 1 1.605 / P4R2 0 // P5R1 1 1.425 / P5R2 2 1.475 2.165 P6R1 1 1.575 / P6R2 1 2.445 / P7R1 2 0.305 2.175 P7R2 1 1.655 /

(78) FIG. 6 and FIG. 7 respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 656 nm, 588 nm and 486 nm after passing the camera optical lens **20** according to Embodiment 2. FIG. 8 illustrates a field curvature and a distortion of light with a wavelength of 588 nm after passing the camera optical lens **10** according to Embodiment 2, in which a field curvature S is a field curvature in a sagittal direction and T is a field curvature in a tangential direction.

(79) As shown in Table 13, Embodiment 2 satisfies the above conditions.

(80) In the present embodiment, an entrance pupil diameter (ENPD) of the camera optical lens **20** is 2.798 mm. An image height of 1.0H is 4.595 mm. An FOV is 77.86°. Thus, the camera optical lens **20** satisfies design requirements of large aperture, ultra-thin and wide-angle while the on-axis and off-axis aberrations are sufficiently corrected, thereby achieving excellent optical characteristics.

Embodiment 3

(81) Embodiment 3 is basically the same as Embodiment 1 and involves symbols having the same meanings as Embodiment 1, and only differences therebetween will be described in the following.

(82) FIG. 9 shows a schematic diagram of a structure of a camera optical lens **30** according to Embodiment 3 of the present invention.

(83) Tables 9 and 10 show design data of a camera optical lens **30** in Embodiment 3 of the present invention.

(84) TABLE-US-00009 TABLE 9 R d nd vd S1 ∞ d0 = -0.201 R1 3.959 d1 = 0.625 nd1 1.5444 v1 55.82 R2 11.567 d2 = 0.078 R3 5.109 d3 = 0.844 nd2 1.6700 v2 19.39 R4 3.190 d4 = 0.319 R5 5.645 d5 = 0.573 nd3 1.5444 v3 55.82 R6 -32.460 d6 = 0.064 R7 -27.683 d7 = 0.526 nd4 1.5444 v4 55.82 R8 -32.062 d8 = 0.369 R9 7.490 d9 = 0.380 nd5 1.5661 v5 37.71 R10 7.454 d10 = 0.471 R11 1.891 d11 = 0.687 nd6 1.5444 v6 55.82 R12 2.592 d12 = 1.032 R13 14.780 d13 = 0.432 nd7 1.5444 v7 55.82 R14 2.931 d14 = 0.465 R15 ∞ d15 = 0.210 ndg 1.5168 vg 64.17 R16 ∞ d16 = 0.300

(85) Table 10 shows aspherical surface data of each lens of the camera optical lens **30** in Embodiment 3 of the present invention.

(86) TABLE-US-00010 TABLE 10 Conic coefficient Aspheric surface coefficients k A4 A6 A8 A10 A12 R1 1.5527E-01 -5.9860E-03 1.3624E-02 -4.8205E-02 1.0262E-01 -1.2965E-01 R2 -3.1022E+00 -8.2636E-02 9.2173E-02

-4.2091E-02 -4.4355E-02 1.0711E-01 R3 -1.6828E+01 -7.0640E-02 9.2355E-02 -1.1339E-01 1.5685E-01
-1.8015E-01 R4 -2.5121E+00 -2.1675E-02 -5.0406E-03 4.9233E-02 -1.0210E-01 1.2643E-01 R5 1.3595E+01
-2.9137E-02 2.1076E-02 -7.1832E-02 1.0789E-01 -1.0879E-01 R6 2.9969E+01 3.7957E-02 -1.2306E-01
1.4732E-01 -9.9814E-02 1.5108E-02 R7 -1.2989E+01 5.9403E-02 -1.9057E-01 2.5659E-01 -2.0749E-01
9.7173E-02 R8 -2.7936E+01 3.9981E-02 -1.3736E-01 1.4683E-01 -9.8207E-02 4.2529E-02 R9 1.0941E+01
4.5756E-02 -7.8196E-02 5.5622E-02 -2.4699E-02 6.5012E-03 R10 7.1409E+00 -4.5749E-02 2.9592E-02
-2.4851E-02 1.8768E-02 -9.0351E-03 R11 -2.9909E+00 -4.8409E-02 2.1450E-02 -1.3523E-02 5.2835E-03
-1.2983E-03 R12 -5.4199E+00 6.8580E-03 -5.3873E-03 9.6261E-04 -6.4452E-05 -3.6805E-06 R13 -3.0000E+01
-8.6138E-02 3.3467E-02 -6.6395E-03 8.2526E-04 -6.8300E-05 R14 -6.9909E+00 -5.3989E-02 1.9177E-02
-4.2792E-03 6.1671E-04 -5.8375E-05 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1
1.5527E-01 1.0013E-01 -4.6453E-02 1.1889E-02 -1.2914E-03 R2 -3.1022E+00 -9.9506E-02 5.0048E-02
-1.3412E-02 1.5070E-03 R3 -1.6828E+01 1.3581E-01 -6.1360E-02 1.4837E-02 -1.4470E-03 R4 -2.5121E+00
-1.0181E-01 5.1081E-02 -1.4521E-02 1.7872E-03 R5 1.3595E+01 6.9055E-02 -2.6855E-02 5.5871E-03
-4.5528E-04 R6 2.9969E+01 2.2476E-02 -1.5550E-02 4.0984E-03 -4.0163E-04 R7 -1.2989E+01 -2.4204E-02
2.4783E-03 7.6474E-05 -2.4740E-05 R8 -2.7936E+01 -1.1780E-02 1.9922E-03 -1.8418E-04 7.0183E-06 R9
1.0941E+01 -9.2859E-04 1.0516E-05 1.7912E-05 -1.8419E-06 R10 7.1409E+00 2.5349E-03 -4.0641E-04
3.4825E-05 -1.2466E-06 R11 -2.9909E+00 1.9962E-04 -1.8258E-05 9.0019E-07 -1.8348E-08 R12 -5.4199E+00
8.8877E-07 -4.9728E-08 4.9247E-10 2.5686E-11 R13 -3.0000E+01 3.7902E-06 -1.3572E-07 2.8251E-09
-2.5822E-11 R14 -6.9909E+00 3.6064E-06 -1.3936E-07 3.0398E-09 -2.8430E-11

(87) Table 11 and table 12 show Embodiment 3 design data of inflexion points and arrest points of respective lens in the camera optical lens **30** according to Embodiment 3 of the present invention.

(88) TABLE-US-00011 TABLE 11 Number of Inflexion Inflexion Inflexion Inflexion point Point point point
points position 1 position 2 position 3 position 4 P1R1 0 / / / / P1R2 3 0.355 0.845 1.065 / P2R1 1 0.975 / / / P2R2 1 1.065
/ / / P3R1 1 0.795 / / / P3R2 1 1.485 / / / P4R1 1 1.305 / / / P4R2 1 1.745 / / / P5R1 2 0.975 1.965 / / P5R2 4 0.705 1.095
1.295 1.895 P6R1 2 0.915 2.345 / / P6R2 2 1.335 3.455 / / P7R1 3 0.265 1.465 3.675 / P7R2 3 0.735 3.095 3.885 /

(89) TABLE-US-00012 TABLE 12 Number of Arrest point Arrest point arrest points position 1 position 2 P1R1 0 / / P1R2
1 1.215 / P2R1 0 / / P2R2 0 / / P3R1 1 1.145 / P3R2 0 / / P4R1 1 1.585 / P4R2 0 / / P5R1 1 1.465 / P5R2 2 1.665 2.045
P6R1 1 1.675 / P6R2 1 2.665 / P7R1 2 0.465 2.355 P7R2 1 1.955 /

(90) FIG. **10** and FIG. **11** respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 656 nm, 588 nm and 486 nm after passing the camera optical lens **30** according to Embodiment 3. FIG. **12** illustrates a field curvature and a distortion of light with a wavelength of 588 nm after passing the camera optical lens **30** according to Embodiment 3, in which a field curvature S is a field curvature in a sagittal direction and T is a field curvature in a tangential direction.

(91) Table 13 in the following lists values corresponding to the respective conditions. In the present Embodiment 3 in order to satisfy the above conditions.

(92) In the present embodiment, an entrance pupil diameter (ENPD) of the camera optical lens **30** is 2.721 mm. An image height of 1.0H is 4.595 mm. An FOV is 79.15°. Thus, the camera optical lens **30** satisfies design requirements of large aperture, ultra-thin and wide-angle while the on-axis and off-axis aberrations are sufficiently corrected, thereby achieving excellent optical characteristics.

(93) TABLE-US-00013 TABLE 13 Parameters and conditions Embodiment 1 Embodiment 2 Embodiment 3 f1/f 1.32 1.65
1.98 d1/d2 5.02 6.48 8.01 d4/d6 1.02 2.99 4.98 f 6.518 5.595 5.441 f1 8.636 9.232 10.747 f2 -11.491 -14.055 -15.386 f3
8.213 9.269 8.880 f4 -40.981 -131.139 -388.755 f5 494.357 1000.000 970.879 f6 21.757 10.226 9.540 f7 -8.892 -6.610
-6.802 f12 21.818 18.525 23.793 FNO 2.00 2.00 2.00 TTL 8.462 7.351 7.375 IH 4.595 4.595 4.595 FOV 69.68° 77.86°
79.15°

(94) It is to be understood, however, that even though numerous characteristics and advantages of the present exemplary embodiments have been set forth in the foregoing description, together with details of the structures and functions of the embodiments, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms where the appended claims are expressed.

Claims

1. A camera optical lens with seven lenses, comprising, from an object side to an image side in sequence: a first lens having a positive refractive power, a second lens having a negative refractive power, a third lens having a positive refractive power, a fourth lens having a negative refractive power, a fifth lens having a positive refractive power, a sixth lens having a positive refractive power and a seventh lens having a negative refractive power; number of lenses with refractive power is 7; wherein the camera optical lens satisfies the following conditions:

$1.3 \leq f1/f \leq 2$; $5 \leq d1/d2 \leq 8.01$; and $1 \leq d4/d6 \leq 5$;

$-142.89 \leq f4/f \leq -4.19$; $-27.29 \leq (R7 + R8)/(R7 - R8) \leq -1.42$; and $0.02 \leq d7/TTL \leq 0.11$; where, f: a focal length of the optical camera lens; f1: a focal length of the first lens; f4: a focal length of the fourth lens; R7: a central curvature radius of the object side surface of the fourth lens; R8: a central curvature radius of the image side surface of the fourth

lens; d7: an on-axis thickness of the fourth lens; TTL: a total optical length from an object side surface of the first lens of the camera optical lens to an image surface of the camera optical lens along an optical axis; d1: an on-axis thickness of the first lens; d2: an on-axis distance from an image side surface of the first lens to an object side surface of the second lens; d4: an on-axis distance from an image side surface of the second lens to an object side surface of the third lens; and d6: an on-axis distance from an image side surface of the third lens to an object side surface of the fourth lens.

2. The camera optical lens according to claim 1, wherein, the first lens has an object side surface being convex in a paraxial region and the image side surface of the first lens is concave in the paraxial region; the camera optical lens further satisfies the following conditions: $-4.08 \leq (R1 + R2) / (R1 - R2) \leq -1.07$; and $0.04 \leq d1 / \text{TTL} \leq 0.17$ where, R1: a central curvature radius of the object side surface of the first lens; and R2: a central curvature radius of the image side surface of the first lens.

3. The camera optical lens according to claim 2 further satisfying the following conditions:
 $-2.55 \leq (R1 + R2) / (R1 - R2) \leq -1.33$; and $0.07 \leq d1 / \text{TTL} \leq 0.17$.

4. The camera optical lens according to claim 1, wherein, the object side surface of the second lens is convex in a paraxial region and the image side surface of the second lens is concave in the paraxial region; the camera optical lens further satisfies the following conditions:

$-5.66 \leq f2 / f \leq -1.18$; $1.77 \leq (R3 + R4) / (R3 - R4) \leq 6.49$; and $0.02 \leq d3 / \text{TTL} \leq 0.17$; where, f2: a focal length of the second lens; R3: a central curvature radius of the object side surface of the second lens; R4: a central curvature radius of the image side surface of the second lens; and d3: an on-axis thickness of the second lens.

5. The camera optical lens according to claim 4 further satisfying the following conditions:
 $-3.53 \leq f2 / f \leq -1.47$; $2.83 \leq (R3 + R4) / (R3 - R4) \leq 5.19$; and $0.03 \leq d3 / \text{TTL} \leq 0.14$.

6. The camera optical lens according to claim 1, wherein, the object side surface of the third lens is convex in a paraxial region and the image side surface of the third lens is concave in the paraxial region; the camera optical lens further satisfies the following conditions: $0.63 \leq f3 / f \leq 2.48$; $-1.41 \leq (R5 + R6) / (R5 - R6) \leq -0.19$; and $0.04 \leq d5 / \text{TTL} \leq 0.13$; where, f3: a focal length of the third lens; R5: a central curvature radius of the object side surface of the third lens; R6: a central curvature radius of the image side surface of the third lens; and d5: an on-axis thickness of the third lens.

7. The camera optical lens according to claim 6 further satisfying the following conditions:
 $1.01 \leq f3 / f \leq 1.99$; $-0.88 \leq (R5 + R6) / (R5 - R6) \leq -0.24$; and $0.06 \leq d5 / \text{TTL} \leq 0.1$.

8. The camera optical lens according to claim 1, wherein, the object side surface of the fourth lens is concave in the paraxial region and the fourth lens further has an image side surface being convex in the paraxial region.

9. The camera optical lens according to claim 8 further satisfying the following conditions:
 $-89.31 \leq f4 / f \leq -5.24$; $-17.05 \leq (R7 + R8) / (R7 - R8) \leq -1.77$; and $0.04 \leq d7 / \text{TTL} \leq 0.09$.

10. The camera optical lens according to claim 1, wherein, the fifth lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region; the camera optical lens further satisfies the following conditions: $37.92 \leq f5 / f \leq 268.1$; $-641.9 \leq (R9 + R10) / (R9 - R10) \leq 1012.65$; and $0.03 \leq d9 / \text{TTL} \leq 0.1$; where, f5: a focal length of the fifth lens; R9: a central curvature radius of the object side surface of the fifth lens; R10: a central curvature radius of the image side surface of the fifth lens; and d9: an on-axis thickness of the fifth lens.

11. The camera optical lens according to claim 10 further satisfying the following conditions:
 $60.68 \leq f5 / f \leq 214.48$; $-401.19 \leq (R9 + R10) / (R9 - R10) \leq 810.12$; and $0.04 \leq d9 / \text{TTL} \leq 0.08$.

12. The camera optical lens according to claim 1, wherein, the sixth lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region; the camera optical lens further satisfies the following conditions: $0.88 \leq f6 / f \leq 5.01$; $-23.98 \leq (R11 + R12) / (R11 - R12) \leq -4.24$; and $0.05 \leq d11 / \text{TTL} \leq 0.18$; where, f6: a focal length of the sixth lens; R11: a central curvature radius of the object side surface of the sixth lens; R12: a central curvature radius of the image side surface of the sixth lens; and d11: an on-axis thickness of the sixth lens.

13. The camera optical lens according to claim 12 further satisfying the following conditions:
 $1.4 \leq f6 / f \leq 4.01$; $-14.99 \leq (R11 + R12) / (R11 - R12) \leq -5.29$; and $0.07 \leq d11 / \text{TTL} \leq 0.14$.

14. The camera optical lens according to claim 1, wherein, the seventh lens has an object side surface being convex in a paraxial region and an image side surface being concave in the paraxial region; the camera optical lens further satisfies the following conditions: $-2.73 \leq f7 / f \leq -0.79$; $0.63 \leq (R13 + R14) / (R13 - R14) \leq 5.49$; and $0.03 \leq d13 / \text{TTL} \leq 0.09$; where, f7: a focal length of the seventh lens; R13: a central curvature radius of the object side surface of the seventh lens; R14: a central curvature radius of the image side surface of the seventh lens; and D13: an on-axis thickness of the seventh lens.

15. The camera optical lens according to claim 14 further satisfying the following conditions:
 $-1.71 \leq f7 / f \leq -0.98$; $1.01 \leq (R13 + R14) / (R13 - R14) \leq 4.39$; and $0.04 \leq d13 / \text{TTL} \leq 0.07$.

16. The camera optical lens according to claim 1 further satisfying the following condition: $1.66 \leq f12 / f \leq 6.56$; where, f12: a combined focal length of the first lens and the second lens.

17. The camera optical lens according to claim 1, wherein an FNO of the camera optical lens is less than or equal to 2.06, where, FNO: a ratio of an effective focal length of the camera optical lens to an entrance pupil diameter.

18. The camera optical lens according to claim 1, wherein an FOV of the camera optical lens is greater than or equal to 68.28° , where, FOV: a field of view of the camera optical lens in a diagonal direction.

19. The camera optical lens according to claim 1 further satisfying the following condition: $\text{TTL} / \text{IH} \leq 1.93$; where, IH: an image height of the camera optical lens.

