US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12386152
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Teranishi; Takaaki et al.

Camera optical lens

Abstract

The present invention discloses a camera optical lens with seven-piece lenses including, from an object side to an image side in sequence, a first lens, a second lens, a third lens, a fourth lens, a fifth lens, a sixth lens and a seventh lens. The camera optical lens satisfies the following conditions: $-1.00 \leq f6/f \leq 10.00$, $1.00 \leq d5/d6 \leq 5.00$, and $1.00 \leq R3/R4 \leq 5.00$. The camera optical lens according to the present invention has excellent optical characteristics, such as large aperture, wide-angle, and ultra-thin.

Inventors: **Teranishi; Takaaki (Osaka, JP), Ji; Yi (Shenzhen, CN)**

Applicant: **AAC Optics (Changzhou) Co., Ltd.** (Changzhou, CN)

Family ID: **1000008749896**

Assignee: **AAC Optics (Changzhou) Co., Ltd. (Changzhou, CN)**

Appl. No.: **17/562037**

Filed: **December 27, 2021**

Prior Publication Data

Document Identifier	Publication Date
US 20220206270 A1	Jun. 30, 2022

Foreign Application Priority Data

CN	202011608012.4	Dec. 29, 2020

Publication Classification

Int. Cl.: **G02B13/00** (20060101); **G02B9/64** (20060101)

U.S. Cl.:

CPC **G02B13/0045** (20130101); **G02B9/64** (20130101);

Field of Classification Search

CPC: G02B (13/0045); G02B (9/64)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2016/0299319	12/2015	Tang	N/A	G02B 13/0045
2021/0048643	12/2020	Lin	N/A	G02B 13/18
2021/0215907	12/2020	Hu	N/A	G02B 9/64
2021/0396973	12/2020	Liu	N/A	G02B 13/0045
2022/0137350	12/2021	Shi	359/708	G02B 9/64
2022/0365317	12/2021	Chen	N/A	G02B 13/0045
2024/0045177	12/2023	Sin	N/A	G02B 9/64

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
110596858	12/2020	CN	G02B 13/0045

Primary Examiner: Mebrahtu; Ephrem Z

Attorney, Agent or Firm: Wiersch Law Group

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 lens 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 aberration.

SUMMARY

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

(4) According to one aspect of the present invention, a camera optical lens comprises, from an object side to an image side in sequence, a first lens, a second lens, a third lens, a fourth lens, a fifth lens, a sixth lens and a seventh lens. The camera optical lens satisfies the following conditions: $-1.00 \leq f6/f \leq 10.00$, $1.00 \leq d5/d6 \leq 5.00$, and $1.00 \leq R3/R4 \leq 5.00$. f denotes a focal length of the camera optical lens, f6 denotes a focal length of the sixth lens, d5 denotes an on-axis thickness of the third lens, d6 denotes an on-axis distance from an image side surface of the third lens to an object side surface of the fourth lens, R3 denotes a central curvature radius of an object side surface of the second lens, and R4 denotes a central curvature radius of an image side surface of the second lens.

(5) As an improvement, the first lens has a positive refractive power and has an object side surface being convex in a paraxial region, the camera optical lens further satisfies the following conditions: $0.37 \leq f1/f6 \leq 1.21$, $-3.22 \leq (R1+R2)/(R1-R2) \leq -0.61$, and $0.04 \leq d1/TTL \leq 0.15$. f1 denotes a focal length of the first lens, R1 denotes a central curvature radius of the object side surface of the first lens, R2 denotes a central curvature radius of an image side surface of the first lens, d1 denotes an on-axis thickness 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 the following conditions: $0.60 \leq f1/f \leq 0.97$, $-2.01 \leq (R1+R2)/(R1-R2) \leq -0.77$, and $0.07 \leq d1/TTL \leq 0.12$.

(7) As an improvement, the second lens has a positive refractive power, the object side surface of the second lens is concave in a paraxial region and the image side surface of the second lens is convex in the paraxial region. The camera optical lens further satisfies the following conditions: $1.66 \leq f2/f \leq 44.41$, $0.75 \leq (R3+R4)/(R3-R4) \leq 61.50$, and $0.02 \leq d3/TTL \leq 0.08$. f2 denotes a focal length 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 the following conditions: $2.66 \leq f2/f \leq 35.53$, $1.21 \leq (R3+R4)/(R3-R4) \leq 49.20$, and $0.04 \leq d3/TTL \leq 0.07$.

(9) As an improvement, the third lens has a negative refractive power, the camera optical lens further satisfies the following conditions: $-3.41 \leq f3/f \leq -0.62$, $-3.79 \leq (R5+R6)/(R5-R6) \leq 2.08$, and $0.02 \leq d5/TTL \leq 0.06$. f3 denotes a focal length of the third lens, R5 denotes a central curvature radius of an object side surface of the third lens, R6 denotes a central curvature radius of the image side surface 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 the following conditions: $-2.13 \leq f3/f \leq -0.78$, $-2.37 \leq (R5+R6)/(R5-R6) \leq 1.66$, and $0.03 \leq d5/TTL \leq 0.05$.

(11) As an improvement, the fourth lens has a positive refractive power, the object side surface of the fourth lens is convex in a paraxial region and the fourth lens further has an image side surface being concave in the paraxial region. The camera optical lens further satisfies the following conditions: $0.97 \leq f4/f \leq 10.79$, $-5.90 \leq (R7+R8)/(R7-R8) \leq -1.34$, and $0.02 \leq d7/TTL \leq 0.09$. f4 denotes a focal length of the fourth lens, R7 denotes a central curvature radius of the object side surface of the fourth lens, R8 denotes a central curvature radius of the image side surface of the fourth lens, d7 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 the following conditions: $1.56 \leq f4/f \leq 8.63$, $-3.69 \leq (R7+R8)/(R7-R8) \leq -1.67$, and $0.04 \leq d7/TTL \leq 0.07$.

(13) As an improvement, the fifth lens has a positive refractive power, the fifth lens further has an object side surface being concave in a paraxial region and an image side surface being convex in the paraxial region. The camera optical lens further satisfies the following conditions: $1.11 \leq f5/f \leq 5.98$, $1.35 \leq (R9+R10)/(R9-R10) \leq 12.33$, and $0.04 \leq d9/TTL \leq 0.14$. f5 denotes a focal length of the fifth lens, R9 denotes a central curvature radius of the object side surface of the fifth lens, R10 denotes a central curvature radius of

the image side surface of the fifth lens, d9 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 the following conditions: $1.78 \leq f5/f \leq 4.78$, $2.17 \leq (R9+R10)/(R9-R10) \leq 9.86$, and $0.07 \leq d9/TTL \leq 0.11$.
(15) As an improvement, the sixth lens has an object side surface being convex in a paraxial region. The camera optical lens further satisfies the following conditions: $-5.75 \leq (R11+R12)/(R11-R12) \leq 1.67$, and $0.05 \leq d11/TTL \leq 0.25$. R11 denotes a central curvature radius of the object side surface of the sixth lens, R12 denotes a central curvature radius of an image side surface of the sixth lens, d11 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: $-3.59 \leq (R11+R12)/(R11-R12) \leq 1.34$, and $0.08 \leq d11/TTL \leq 0.20$.
(17) As an improvement, the seventh lens has an image side surface being concave in a paraxial region and the seventh lens has a negative refractive power, the camera optical lens further satisfies the following conditions: $-9.50 \leq f7/f \leq -0.50$, $0.11 \leq (R13+R14)/(R13-R14) \leq 9.03$, and $0.04 \leq d13/TTL \leq 0.16$. f7 denotes a focal length of the seventh lens, R13 denotes a central curvature radius of an object side surface of the seventh lens, R14 denotes a central curvature radius of the image side surface of the seventh lens, d13 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: $-5.94 \leq f7/f \leq -0.63$, $0.17 \leq (R13+R14)/(R13-R14) \leq 7.22$, and 0.066 $d13/TTL \leq 0.13$.
(19) As an improvement, the camera optical lens further satisfies the following conditions: $0.34 \leq f12/f \leq 1.13$. f12 denotes a combined focal length of the first lens and the second lens.
(20) As an improvement, an FNO of the camera optical lens is less than or equal to 2.34. FNO denotes a ratio of an effective focal length of the camera optical lens to an entrance pupil diameter.
(21) As an improvement, an FOV of the camera optical lens is greater than or equal to 81.34°. 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: $TTL/IH \leq 1.34$. 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.
(23) Beneficial effects of the present invention are that: the camera optical lens according to the present invention has excellent optical characteristics, such as large aperture, wide-angle, and ultra-thin, and is especially suitable for a mobile camera lens component and a WEB camera lens composed of high pixel CCD, CMOS.

Description

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 **10** comprises seven lenses. Specifically, from an object side to an image side, the camera optical lens **10** comprises in sequence: an aperture S**1**, a first lens L**1**, a second lens L**2**, a third lens L**3**, a fourth lens L**4**, a fifth lens L**5**, a sixth lens L**6** and a seventh lens L**7**. Optical elements like optical filter GF can be arranged between the seventh lens L**7** and an image surface Si.
(16) The first lens L**1** is made of plastic material, the second lens L**2** is made of plastic material, the third lens L**3** is made of plastic material, the fourth lens L**4** is made of plastic material, the fifth lens L**5** is made of plastic material, the sixth lens L**6** is made of plastic material, and the seventh lens L**7** 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 sixth lens L**6** is defined as f6. The camera optical lens **10** further satisfies the following condition: −1.00≤f6/f≤10.00. 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.
(18) An on-axis thickness of the third lens L**3** is defined as d5, and an on-axis distance from an image side surface of the third lens L**3** to an object side surface of the fourth lens L**4** is defined as d6. The camera optical lens **10** further satisfies the following condition: 1.00≤d5/d6≤5.00, which specifies a ratio of the on-axis thickness of the third lens L**3** to the on-axis distance from the image side surface of the third lens L**3** to the object side surface of the fourth lens L**4**. When the condition is satisfied, it is beneficial for producing the lenses and assembling the camera optical lens **10**.
(19) A central curvature radius of an object side surface of the second lens L**2** is defined as R3, and a central curvature radius of an image side surface of the second lens L**2** is defined as R4. The camera optical lens **10** further satisfies the following condition: 1.00≤R3/R4≤5.00, which specifies a shape of the second lens L**2**. 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.
(20) In the present embodiment, an object side surface of the first lens L**1** is convex in a paraxial region, an image side surface of the first lens L**1** is concave in the paraxial region, and the first lens L**1** has a positive refractive power. In other optional embodiments, the first lens L**1** may also have a negative refractive power. The object side surface and the image side surface of the first lens L**1** 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) A focal length of the camera optical lens **10** is defined as f, and a focal length of the first lens L**1** is defined as f1. The camera optical lens **10** further satisfies the following condition: 0.37≤f1/f≤1.21. By controlling the positive refractive power of the first lens L**1** being within reasonable range, it is beneficial for developing towards ultra-thin and wide-angle and reducing an aberration of the camera optical lens **10**. Preferably, the following condition shall be satisfied, 0.60≤f1/f≤0.97.
(22) The central curvature radius of the object side surface of the first lens L**1** is defined as R1, and a central curvature radius of the image side surface of the first lens L**1** is defined as R2. The camera optical lens **10** further satisfies the following condition: −3.22≤(R1+R2)/(R1−R2)≤−0.61. This condition reasonably controls a shape of the first lens L**1**, so that the first lens L**1** can effectively correct a spherical aberration of the camera optical lens **10**. Preferably, the following condition shall be satisfied, −2.01≤(R1+R2)/(R1−R2)≤−0.77.
(23) An on-axis thickness of the first lens L**1** is defined as d1. A total optical length from the object side surface of the first lens L**1** 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≤d1/TTL≤0.15. When the condition is satisfied, it benefits for realizing an ultra-thin effect. Preferably, the following condition shall be satisfied, 0.076≤d1/TTL≤0.12.
(24) In the present embodiment, the object side surface of the second lens L**2** is concave in the paraxial region, the image side surface of the second lens L**2** is convex in the paraxial region, and the second lens L**2** has a positive refractive power. In other optional embodiments, the second lens L**2** may also have a negative refractive power. The object side surface and the image side surface of the second lens L**2** can also be arranged as other concave side surface or convex side surface, such as, convex object side surface and concave image side surface and so on.
(25) The focal length of the camera optical lens **10** is defined as f, and a focal length of the second lens L**2** is defined as f2. The camera optical lens **10** further satisfies the following condition: 1.66≤f2/f≤44.41. It is beneficial for correcting the aberration of the camera optical lens **10** by controlling the positive refractive power of the second lens L**2** being within reasonable range. Preferably, the following condition shall be satisfied, 2.66≤(f2/f≤35.53.
(26) The central curvature radius of the object side surface of the second lens L**2** is defined as R3, and the central curvature radius of the image side surface of the second lens L**2** is defined as R4. The camera optical lens **10** further satisfies the following condition: 0.75≤(R3+R4)/(R3−R4)≤(61.50, which specifies a shape of the second lens L**2**. When the condition is satisfied, as the camera optical lens **10** develops towards ultra-thin and wide-angle, it is beneficial for correcting the on-axis chromatic aberration. Preferably, the following condition shall be satisfied, 1.21≤(R3+R4)/(R3−R4)≤(49.20.
(27) An on-axis thickness of the second lens L**2** is defined as d3. The total optical length from the object side surface of the first lens L**1** 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≤d3/TTL≤0.08. When the condition is satisfied, it is beneficial for producing ultra-thin lenses. Preferably, the following condition shall be satisfied, 0.046≤d3/TTL≤0.07.
(28) In the present embodiment, an object side surface of the third lens L**3** is concave in the paraxial region, the image side surface of the third lens L**3** is convex in the paraxial region, and the third lens L**3** has a negative refractive power. In other optional embodiments, the third lens L**3** may also have a positive refractive power. The object side surface and the image side surface of the third lens L**3** can also be arranged as other concave side surface or convex side surface, such as, convex object side surface and concave image side surface and so on.
(29) The focal length of the camera optical lens **10** is defined as f, and a focal length of the third lens L**3** is defined as f3. The camera optical lens **10** further satisfies the following condition: −3.41≤f3/f≤−0.62. 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, −2.13≤f3/f≤−0.78.
(30) A central curvature radius of the object side surface of the third lens L**3** is defined as R5, and a central curvature radius of the image side surface of the third lens L**3** is defined as R6. The camera optical lens **10** further satisfies the following condition: −3.79≤(R5+R6)/(R5−R6)≤(2.08, which specifies a shape of the third lens L**3**. It is beneficial for molding the third lens L**3**. 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, −2.376≤(R5+R6)/(R5−R6)≤1.66.
(31) An on-axis thickness of the third lens L**3** is defined as d5. The total optical length from the object side surface of the first lens L**1** 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≤d5/TTL≤0.06, which benefits for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, 0.036≤d5/TTL≤0.05.
(32) In the present embodiment, the object side surface of the fourth lens L**4** is convex in the paraxial region, an image side surface of

the fourth lens L**4** is concave in the paraxial region, and the fourth lens L**4** has a positive refractive power. In other optional embodiments, the fourth lens L**4** may also have a negative refractive power. The object side surface and the image side surface of the fourth lens L**4** 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.

(33) The focal length of the camera optical lens **10** is defined as f, and a focal length of the fourth lens L**4** is defined as f4. The camera optical lens **10** further satisfies the following condition: $0.97 \leq f4/f \leq 10.79$. 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, $1.56 \leq f4/f \leq 48.63$.

(34) A curvature radius of the object side surface of the fourth lens L**4** is defined as R7, and a central curvature radius of the image side surface of the fourth lens L**4** is defined as R8. The camera optical lens further satisfies the following condition: $-5.90 \leq (R7+R8)/(R7-R8) \leq -1.34$, which specifies a shape of the fourth lens L**4**. 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, $-3.69 \leq (R7+R8)/(R7-R8) \leq -1.67$.

(35) An on-axis thickness of the fourth lens L**4** is defined as d7. The total optical length from the object side surface of the first lens L**1** 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: $0.02 \leq d7/TTL \leq 0.09$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.046 \leq d7/TTL \leq 0.07$.

(36) In the present embodiment, an object side surface of the fifth lens L**5** is concave in the paraxial region, an image side surface of the fifth lens L**5** is convex in the paraxial region, and the fifth lens L**5** has a positive refractive power. In other optional embodiments, the fifth lens L**5** may also have a negative refractive power. The object side surface and the image side surface of the fifth lens L**5** 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.

(37) The focal length of the camera optical lens **10** is defined as f, and a focal length of the fifth lens L**5** is defined as f5. The camera optical lens **10** further satisfies the following condition: $1.11 \leq f5/f \leq 5.98$. When the condition is satisfied, a light angle of the camera optical lens **10** can be smoothed effectively and a sensitivity of the tolerance can be reduced. Preferably, the following condition shall be satisfied, $1.78 \leq f5/f \leq 4.78$.

(38) A central curvature radius of the object side surface of the fifth lens L**5** is defined as R9, and a central curvature radius of the image side surface of the fifth lens L**5** is defined as R10. The camera optical lens further satisfies the following condition: $1.35 \leq (R9+R10)/(R9-R10) \leq 12.33$, which specifies a shape of the fifth lens L**5**. 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, $2.17 \leq (R9+R10)/(R9-R10) \leq 9.86$.

(39) An on-axis thickness of the fifth lens L**5** is defined as d9. The total optical length from the object side surface of the first lens L**1** 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: $0.04 \leq d9/TTL \leq 0.14$. When the condition is satisfied, it is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.076 \leq d9/TTL \leq 0.11$.

(40) In the present embodiment, an object side surface of the sixth lens L**6** is convex in the paraxial region, an image side surface of the sixth lens L**6** is concave in the paraxial region, and the sixth lens L**6** has a negative refractive power. In other optional embodiments, the sixth lens L**6** may also have a positive refractive power. The object side surface and the image side surface of the sixth lens L**6** 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.

(41) A central curvature radius of the object side surface of the sixth lens L**6** is defined as R11, and a central curvature radius of the image side surface of the sixth lens L**6** is defined as R12. The camera optical lens further satisfies the following condition: $-5.75 \leq (R11+R12)/(R11-R12) \leq 1.67$, which specifies a shape of the sixth lens L**6**. 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, $-3.59 \leq (R11+R12)/(R11-R12) \leq 1.34$.

(42) An on-axis thickness of the sixth lens L**6** is defined as d11. The total optical length from the object side surface of the first lens L**1** to the image surface Si of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens further satisfies the following condition: $0.05 \leq d11/TTL \leq 0.25$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.08 \leq d11/TTL \leq 0.20$.

(43) In the present embodiment, an object side surface of the seventh lens L**7** is convex in the paraxial region, an image side surface of the seventh lens L**7** is concave in the paraxial region, and the seventh lens L**7** has a negative refractive power. In other optional embodiments, the seventh lens L**7** may also have a positive refractive power. The object side surface and the image side surface of the seventh lens L**7** 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 L**7** is defined as f7. The camera optical lens **10** further satisfies the following condition: $-9.50 \leq f7/f \leq -0.50$. 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, $-5.94 \leq f7/f \leq -0.63$.

(45) A central curvature radius of the object side surface of the seventh lens L**7** is defined as R13, and a central curvature radius of the image side surface of the seventh lens L**7** is defined as R14. The camera optical lens **10** further satisfies the following condition: $0.11 \leq (R13+R14)/(R13-R14) \leq 9.03$, which specifies a shape of the seventh lens L**7**. 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, $0.17 \leq (R13+R14)/(R13-R14) \leq 7.22$.

(46) An on-axis thickness of the seventh lens L**7** is defined as d13. The total optical length from the object side surface of the first lens L**1** to the image surface Si of the camera optical lens **10** along the optical axis is defined as TTL. The camera optical lens further satisfies the following condition: $0.04 \leq d13/TTL \leq 0.16$, which is beneficial for realizing the ultra-thin effect. Preferably, the following condition shall be satisfied, $0.066 \leq d13/TTL \leq 0.13$.

(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 L**1** and the second lens L**2** is defined as f12. The camera optical lens **10** further satisfies the following condition: 0.34≤f12/f≤1.13. 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, 0.546≤f12/f≤0.91.
(48) In the present embodiment, an F number (FNO) of the camera optical lens **10** is smaller than or equal to 2.34, thereby achieving a large aperture and good imaging performance. Preferably, the FNO of the camera optical lens **10** is smaller than or equal to 2.29.
(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 81.34°, thereby achieving the wide-angle performance. Preferably, the FOV is greater than or equal to 82.17°.
(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 L**1** 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≤1.34, thereby achieving the ultra-thin performance. Preferably, the following condition shall be satisfied, TTL/IH≤1.30.
(51) When the above conditions are satisfied, which makes it is possible that 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 L**1** 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): refers to 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= −0.587 R1 2.389 d1= 0.757 nd1 1.5346 v1 55.69 R2 10.230 d2= 0.266 R3 −31.352 d3= 0.438 nd2 1.5346 v2 55.69 R4 −8.958 d4= 0.050 R5 −5.489 d5= 0.330 nd3 1.6700 v3 19.39 R6 −17.733 d6= 0.319 R7 22.697 d7= 0.452 nd4 1.6700 v4 19.39 R8 67.957 d8= 0.365 R9 −3.159 d9= 0.673 nd5 1.5444 v5 55.82 R10 −2.474 d10= 1.156 R11 68.088 d11= 0.753 nd6 1.5661 v6 37.71 R12 3.657 d12= 0.450 R13 5.959 d13= 0.833 nd7 1.5438 v7 56.03 R14 4.261 d14= 0.500 R15 ∞ d15= 0.210 ndg 1.5168 vg 64.20 R16 ∞ d16= 0.348 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 L**1**; R2: central curvature radius of the image side surface of the first lens L**1**; R3: central curvature radius of the object side surface of the second lens L**2**; R4: central curvature radius of the image side surface of the second lens L**2**; R5: central curvature radius of the object side surface of the third lens L**3**; R6: central curvature radius of the image side surface of the third lens L**3**; R7: central curvature radius of the object side surface of the fourth lens L**4**; R8: central curvature radius of the image side surface of the fourth lens L**4**; R9: central curvature radius of the object side surface of the fifth lens L**5**; R10: central curvature radius of the image side surface of the fifth lens L**5**; R11: central curvature radius of the object side surface of the sixth lens L**6**; R12: central curvature radius of the image side surface of the sixth lens L**6**; R13: central curvature radius of the object side surface of the seventh lens L**7**; R14: central curvature radius of the image side surface of the seventh lens L**7**; 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 Si to the object side surface of the first lens L**1**; d1: on-axis thickness of the first lens L**1**; d2: on-axis distance from the image side surface of the first lens L**1** to the object side surface of the second lens L**2**; d3: on-axis thickness of the second lens L**2**; d4: on-axis distance from the image side surface of the second lens L**2** to the object side surface of the third lens L**3**; d5: on-axis thickness of the third lens L**3**; d6: on-axis distance from the image side surface of the third lens L**3** to the object side surface of the fourth lens L**4**; d7: on-axis thickness of the fourth lens L**4**; d8: on-axis distance from the image side surface of the fourth lens L**4** to the object side surface of the fifth lens L**5**; d9: on-axis thickness of the fifth lens L**5**; d10: on-axis distance from the image side surface of the fifth lens L**5** to the object side surface of the sixth lens L**6**; d11: on-axis thickness of the sixth lens L**6**; d12: on-axis distance from the image side surface of the sixth lens L**5** to the object side surface of the seventh lens L**7**; d13: on-axis thickness of the seventh lens L**7**; d14: on-axis distance from the image side surface of the seventh lens L**7** 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 L**1**; nd2: refractive index of d line of the second lens L**2**; nd3: refractive index of d line of the third lens L**3**; nd4: refractive index of d line of the fourth lens L**4**; nd5: refractive index of d line of the fifth lens L**5**; nd6: refractive index of d line of the sixth lens L**6**; nd7: refractive index of d line of the seventh lens L**7**; ndg: refractive index of d line of the optical filter GF; vd: abbe number; v1: abbe number of the first lens L**1**; v2: abbe number of the second lens L**2**; v3: abbe number of the third lens L**3**; v4: abbe number of the fourth lens L**4**; v5: abbe number of the fifth lens L**5**; v6: abbe number of the sixth lens L**6**; v7: abbe number of the seventh lens L**7**; 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 0.0000E+00 −9.8157E−04 9.9795E−03 −2.5415E−02 4.0551E−02 −3.9698E−02 R2 0.0000E+00 1.3657E−03 −1.1790E−02 3.7698E−02 −6.8710E−02 7.8140E−02 R3 0.0000E+00 −1.0985E−02 −9.8822E−04 1.3266E−03 −4.9481E−03 8.4500E−03 R4 0.0000E+00 −2.7993E−02 1.8620E−03 2.1436E−02 −4.0745E−02 3.9179E−02 R5 0.0000E+00 1.4823E−02 1.2887E−02 −6.3258E−03 −1.1139E−02 2.2250E−02 R6 0.0000E+00 2.2199E−02 1.3606E−02 −2.1431E−02 2.2940E−02 −2.0589E−02 R7 0.0000E+00 −4.9855E−02 −6.5283E−03 1.3453E−02 −3.2251E−02 3.7585E−02 R8 0.0000E+00 −4.2673E−02 6.3752E−03

−1.3762E−02 1.2432E−02 −6.8905E−03 R9 0.0000E+00 −1.3488E−02 9.6140E−03 −1.2768E−02 2.3084E−02 −2.2374E−02 R10 0.0000E+00 −6.0928E−03 6.0089E−03 3.1183E−03 −4.1078E−03 3.1175E−03 R11 0.0000E+00 −8.0713E−02 3.3458E−02 −1.5607E−02 5.6182E−03 −1.3895E−03 R12 0.0000E+00 −1.1244E−01 4.1809E−02 −1.5478E−02 4.2839E−03 −7.9483E−04 R13 0.0000E+00 −7.1950E−02 1.3398E−02 −1.5463E−03 1.2712E−04 −7.5327E−06 R14 −1.0000E+00 −4.4436E−02 9.8922E−03 −1.4358E−03 1.3139E−04 −7.5633E−06 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1 0.0000E+00 2.4161E−02 −8.8811E−03 1.8026E−03 −1.5429E−04 R2 0.0000E+00 −5.5973E−02 2.4636E−02 −6.0807E−03 6.4783E−04 R3 0.0000E+00 −8.1807E−03 4.7083E−03 −1.4740E−03 1.9392E−04 R4 0.0000E+00 −2.1259E−02 6.3157E−03 −9.0274E−04 4.1227E−05 R5 0.0000E+00 −1.7448E−02 7.2534E−03 −1.5845E−03 1.4642E−04 R6 0.0000E+00 1.4022E−02 −6.1796E−03 1.5257E−03 −1.6153E−04 R7 0.0000E+00 −2.7995E−02 1.2921E−02 −3.2782E−03 3.4411E−04 R8 0.0000E+00 1.7212E−03 3.4702E−04 −2.8249E−04 4.4203E−05 R9 0.0000E+00 1.2820E−02 −4.2545E−03 7.4783E−04 −5.3515E−05 R10 0.0000E+00 −1.2952E−03 2.9204E−04 −3.4268E−05 1.6840E−06 R11 0.0000E+00 2.1752E−04 −2.1645E−05 1.4147E−06 −4.9231E−08 R12 0.0000E+00 9.4114E−05 −6.7734E−06 2.6934E−07 −4.5389E−09 R13 0.0000E+00 3.1128E−07 −8.4415E−09 1.3419E−10 −9.4331E−13 R14 −1.0000E+00 2.6618E−07 −5.3138E−09 5.0066E−11 −1.1458E−13

(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).

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

(61) 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).

(62) 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 L**1**, P2R1 and P2R2 represent the object side surface and the image side surface of the second lens L**2**, P3R1 and P3R2 represent the object side surface and the image side surface of the third lens L**3**, P4R1 and P4R2 represent the object side surface and the image side surface of the fourth lens L**4**, P5R1 and P5R2 represent the object side surface and the image side surface of the fifth lens L**5**, P6R1 and P6R2 represent the object side surface and the image side surface of the sixth lens L**6**, and P7R1 and P7R2 represent the object side surface and the image side surface of the seventh lens L**7**. 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**.

(63) TABLE-US-00003 TABLE 3 Number of Inflexion point Inflexion point Inflexion point inflexion points position 1 position 2 position 3 P1R1 0 / / / P1R2 0 / / / P2R1 1 1.365 / / P2R2 0 / / / P3R1 1 0.845 / / P3R2 1 0.435 / / P4R1 1 0.275 / / P4R2 2 0.175 1.485 / P5R1 1 1.295 / / P5R2 1 1.405 / / P6R1 2 0.125 2.315 / P6R2 3 0.515 2.725 3.365 P7R1 2 0.475 2.385 / P7R2 2 0.795 4.355 /

(64) TABLE-US-00004 TABLE 4 Number of Arrest point Arrest point arrest points position 1 position 2 P1R1 0 / / P1R2 0 / / P2R1 1 1.515 / P2R2 0 / / P3R1 1 1.385 / P3R2 1 0.735 / P4R1 1 0.465 / P4R2 2 0.295 1.655 P5R1 0 / / P5R2 0 / / P6R1 1 0.215 / P6R2 1 0.985 / P7R1 2 0.845 4.045 P7R2 1 1.925 /

(65) FIG. **2** and FIG. **3** respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 650 nm, 555 nm and 470 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 555 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.

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

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

(68) In the present embodiment, the entrance pupil diameter (ENPD) of the camera optical lens **10** is 3.129 mm. The image height of 1.0H is 6.247 mm. The FOV is 83.19°. Thus, the camera optical lens **10** 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 2

(69) 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.

(70) An object side surface of the third lens L**3** is convex in a paraxial region, and an image side surface of the third lens L**3** is concave in the paraxial region. An image side surface of the sixth lens L**6** is convex in the paraxial region. An object side surface of the seventh lens L**7** is concave in the paraxial region. A sixth lens L**6** has a positive refractive power.

(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= −0.543 R1 2.605 d1= 0.798 nd1 1.5346 v1 55.69 R2 25.538 d2= 0.084 R3 −423.490 d3= 0.370 nd2 1.5346 v2 55.69 R4 −85.616 d4= 0.050 R5 40.913 d5= 0.330 nd3 1.6700 v3 19.39 R6 4.487 d6= 0.110 R7 5.808 d7= 0.392 nd4 1.6700 v4 19.39 R8 11.759 d8= 0.391 R9 −18.067 d9= 0.701 nd5 1.5444 v5 55.82 R10 −8.321 d10= 0.876 R11 312.514 d11= 1.077 nd6 1.5661 v6 37.71 R12 −13.850 d12= 1.161 R13 −7.392 d13= 0.610 nd7 1.5438 v7 56.03 R14 4.770 d14= 0.500 R15 ∞ d15= 0.210 ndg 1.5168 vg 64.20 R16 ∞ d16= 0.201

(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 1.4057E−01 −2.1100E−03 −2.8000E−03 3.7671E−03 −3.4540E−03 1.6870E−03 R2 0.0000E+00 3.2496E−03 −4.4808E−03 8.1033E−03 −9.0263E−03 4.9803E−03 R3 0.0000E+00 1.2355E−02 −7.4991E−03 6.2471E−03 −7.8641E−03 4.7902E−03 R4 0.0000E+00 −9.7880E−03 2.1445E−02 −3.0485E−02 1.9039E−02 −5.8149E−03 R5 0.0000E+00 −2.7960E−02 4.3881E−02 −3.2849E−02 3.0209E−03 1.8786E−02 R6 0.0000E+00 −2.0972E−02 2.5035E−02 9.4912E−03 −5.9273E−02 8.6006E−02 R7 0.0000E+00

−8.4255E−03 1.3621E−03 4.4963E−03 −7.8098E−03 5.1512E−03 R8 0.0000E+00 7.6872E−04 −1.6916E−03 −3.0416E−03 1.2731E−02 −1.9277E−02 R9 0.0000E+00 −2.0586E−02 −1.5161E−02 3.0624E−02 −3.8858E−02 2.6063E−02 R10 0.0000E+00 −2.5333E−02 −2.6510E−03 3.4500E−03 −4.0736E−03 2.1095E−03 R11 0.0000E+00 −1.9920E−02 4.4647E−03 −1.2576E−02 1.1486E−02 −6.2532E−03 R12 0.0000E+00 −2.6799E−03 −2.2834E−03 −2.6059E−04 3.9773E−04 −1.3572E−04 R13 0.0000E+00 −3.5674E−02 5.5083E−03 −3.8383E−04 2.4187E−05 −2.0299E−06 R14 −1.0000E+00 −3.5016E−02 5.8045E−03 −7.3608E−04 6.6098E−05 −3.9562E−06 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1 1.4057E−01 −4.4471E−04 4.7032E−05 0.0000E+00 0.0000E+00 R2 0.0000E+00 −1.3762E−03 1.5947E−04 0.0000E+00 0.0000E+00 R3 0.0000E+00 −1.3400E−03 1.4811E−04 0.0000E+00 0.0000E+00 R4 0.0000E+00 7.2240E−04 −8.9926E−06 0.0000E+00 0.0000E+00 R5 0.0000E+00 −1.8029E−02 7.9780E−03 −1.8126E−03 1.7258E−04 R6 0.0000E+00 −6.8607E−02 3.2289E−02 −8.4129E−03 9.4102E−04 R7 0.0000E+00 −1.3290E−03 1.2560E−04 0.0000E+00 0.0000E+00 R8 0.0000E+00 1.6182E−02 −7.8110E−03 2.1086E−03 −2.4470E−04 R9 0.0000E+00 −9.3207E−03 1.3955E−03 0.0000E+00 0.0000E+00 R10 0.0000E+00 −5.7077E−04 6.2789E−05 0.0000E+00 0.0000E+00 R11 0.0000E+00 2.0691E−03 −4.1358E−04 4.5743E−05 −2.1215E−06 R12 0.0000E+00 2.3967E−05 −2.3026E−06 1.1383E−07 −2.2711E−09 R13 0.0000E+00 1.3814E−07 −5.5668E−09 1.1772E−10 −1.0144E−12 R14 −1.0000E+00 1.4612E−07 −2.9602E−09 2.4928E−11 0.0000E+00

(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 0 / / / P1R2 0 / / / P2R1 3 0.135 0.955 1.375 P2R2 0 / / / P3R1 2 0.355 0.575 / P3R2 0 / / / P4R1 0 / / / P4R2 0 / / / P5R1 1 1.435 / / P5R2 0 / / / P6R1 2 0.125 2.125 / P6R2 1 2.545 / / P7R1 2 2.275 4.435 / P7R2 3 0.815 4.265 4.755

(77) TABLE-US-00008 TABLE 8 Number of Arrest point Arrest point Arrest point arrest points position 1 position 2 position 3 P1R1 0 / / / P1R2 0 / / / P2R1 3 0.225 1.335 1.405 P2R2 0 / / / P3R1 0 / / / P3R2 0 / / / P4R1 0 / / / P4R2 0 / / / P5R1 0 / / / P5R2 0 / / / P6R1 1 0.205 / / P6R2 0 / / / P7R1 1 4.105 / / P7R2 1 1.635 / /

(78) FIG. **6** and FIG. **7** respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 650 nm, 555 nm and 470 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 555 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 3.291 mm. An image height of 1.0I is 6.247 mm. An FOV is 83.00°. 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) An image side surface of the first lens L**1** is convex in a paraxial region. An object side surface of the third lens L**3** is convex in the paraxial region, and an image side surface of the third lens L**3** is concave in the paraxial region. An object side surface of the seventh lens L**7** is concave in the paraxial region. A sixth lens L**6** has a positive refractive power.

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

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

(85) TABLE-US-00009 TABLE 9 R d nd vd S1 ∞ d0= −0.368 R1 2.799 d1= 0.671 nd1 1.5346 v1 55.69 R2 −67.314 d2= 0.112 R3 −7.383 d3= 0.379 nd2 1.5346 v2 55.69 R4 −7.032 d4= 0.050 R5 22.139 d5= 0.342 nd3 1.6700 v3 19.39 R6 3.566 d6= 0.069 R7 5.206 d7= 0.406 nd4 1.6700 v4 19.39 R8 12.183 d8= 0.444 R9 −12.987 d9= 0.746 nd5 1.5444 v5 55.82 R10 −6.388 d10= 0.963 R11 20.185 d11= 1.330 nd6 1.5661 v6 37.71 R12 41.743 d12= 0.833 R13 −62.182 d13= 0.628 nd7 1.5438 v7 56.03 R14 3.626 d14= 0.503 R15 ∞ d15= 0.211 ndg 1.5168 vg 64.20 R16 ∞ d16= 0.263

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

(87) TABLE-US-00010 TABLE 10 Conic coefficient Aspheric surface coefficients k A4 A6 A8 A10 A12 R1 −7.5329E−02 −4.2033E−03 1.9749E−03 −5.2749E−03 4.2718E−03 −2.0145E−03 R2 0.0000E+00 7.5594E−03 −7.4650E−03 7.0345E−03 −7.6229E−03 5.9177E−03 R3 0.0000E+00 4.3999E−02 −3.9857E−02 4.8937E−02 −6.6995E−02 6.8677E−02 R4 0.0000E+00 3.7860E−02 −3.5165E−02 1.4720E−03 3.8146E−02 −5.4824E−02 R5 0.0000E+00 −3.3808E−02 1.7952E−02 −2.5394E−03 4.3636E−03 −1.0065E−02 R6 0.0000E+00 −3.2388E−02 1.0755E−02 8.2881E−03 −2.2091E−02 3.1027E−02 R7 0.0000E+00 3.0121E−02 −3.4746E−02 2.4066E−02 −1.4510E−02 8.7740E−03 R8 0.0000E+00 2.4011E−02 −1.5427E−02 1.7352E−02 −2.0211E−02 1.5008E−02 R9 0.0000E+00 −1.3754E−02 −1.8431E−02 3.1929E−02 −3.9025E−02 2.5845E−02 R10 0.0000E+00 −2.1624E−02 −5.8826E−03 8.0220E−03 −7.4684E−03 3.5587E−03 R11 0.0000E+00 −1.9763E−02 5.1921E−03 −9.5181E−03 7.2898E−03 −3.4103E−03 R12 0.0000E+00 −1.7499E−03 −2.3066E−03 9.6196E−05 1.1553E−04 −3.7060E−05 R13 0.0000E+00 −3.9835E−02 4.9937E−03 −4.1625E−04 5.2547E−05 −5.7905E−06 R14 −1.0000E+00 −3.9954E−02 6.5722E−03 −9.0776E−04 8.9761E−05 −5.6775E−06 Conic coefficient Aspheric surface coefficients k A14 A16 A18 A20 R1 −7.5329E−02 4.2653E−04 −2.4649E−05 0.0000E+00 0.0000E+00 R2 0.0000E+00 −2.5091E−03 4.6506E−04 0.0000E+00 0.0000E+00 R3 0.0000E+00 −4.5756E−02 1.8646E−02 −4.2155E−03 4.1028E−04 R4 0.0000E+00 3.9456E−02 −1.6127E−02 3.5712E−03 −3.3410E−04 R5 0.0000E+00 8.6490E−03 −3.7918E−03 8.8524E−04 −8.7607E−05 R6 0.0000E+00 −2.6693E−02 1.3430E−02 −3.7079E−03 4.4802E−04 R7 0.0000E+00 −3.5709E−03 6.2205E−04 0.0000E+00 0.0000E+00 R8 0.0000E+00 −5.7240E−03 8.0876E−04 1.2569E−04 −3.8304E−05 R9 0.0000E+00 −9.2469E−03 1.4040E−03 0.0000E+00 0.0000E+00 R10 0.0000E+00 −9.0415E−04 9.6147E−05 0.0000E+00 0.0000E+00 R11 0.0000E+00 9.8152E−04 −1.7161E−04 1.6653E−05 −6.7925E−07 R12 0.0000E+00 5.4534E−06 −4.2272E−07 1.6640E−08 −2.6266E−10 R13 0.0000E+00 3.7895E−07 −1.4019E−08 2.7440E−10 −2.2177E−12 R14 −1.0000E+00 2.1355E−07 −4.3160E−09 3.5949E−11 0.0000E+00

(88) 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.

(89) TABLE-US-00011 TABLE 11 Number of Inflexion point Inflexion point Inflexion point inflexion points position 1 position 2

position 3 P1R1 0 / / / P1R2 1 1.055 / / P2R1 1 1.145 / / P2R2 0 / / / P3R1 2 0.375 0.995 / P3R2 0 / / / P4R1 0 / / / P4R2 0 / / / P5R1 1 1.415 / / P5R2 1 1.745 / / P6R1 2 0.475 2.265 / P6R2 2 0.685 2.875 / P7R1 3 2.395 4.495 4.755 P7R2 3 0.885 4.275 4.835
(90) TABLE-US-00012 TABLE 12 Number of Arrest point Arrest point arrest points position 1 position 2 P1R1 0 / / P1R2 1 1.225 / P2R1 1 1.405 / P2R2 0 / / P3R1 2 0.755 1.175 P3R2 0 / / P4R1 0 / / P4R2 0 / / P5R1 0 / / P5R2 0 / / P6R1 1 0.805 / P6R2 1 1.075 / P7R1 1 3.965 / P7R2 1 1.815 /
(91) FIG. **10** and FIG. **11** respectively illustrate a longitudinal aberration and a lateral color of light with wavelengths of 650 nm, 555 nm and 470 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 555 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.
(92) Table 13 in the following lists values corresponding to the respective conditions. In the present Embodiment 3 in order to satisfy the above conditions.
(93) In the present embodiment, an entrance pupil diameter (ENPD) of the camera optical lens **30** is 2.976 mm. An image height of 1.0H is 6.247 mm. An FOV is 83.99°. 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.
(94) TABLE-US-00013 TABLE 13 Parameters and conditions Embodiment 1 Embodiment 2 Embodiment 3 f6/f −0.98 3.38 9.95 d5/d6 1.03 3.00 4.95 R3/R4 3.50 4.95 1.05 f 6.979 6.910 6.755 f1 5.620 5.343 5.028 f2 23.223 200.000 199.999 f3 −11.886 −7.480 −6.332 f4 50.197 16.533 13.136 f5 15.505 27.543 22.136 f6 −6.822 23.344 67.208 f7 −33.148 −5.222 −6.259 f12 4.736 5.228 5.009 FNO 2.23 2.10 2.27 TTL 7.901 7.860 7.951 IH 6.247 6.247 6.247 FOV 83.19° 83.00° 83.99°
(95) 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 comprising, from an object side to an image side in sequence, a first lens, a second lens, a third lens, a fourth lens, a fifth lens, a sixth lens and a seventh lens; the second lens has a positive refractive power, the object side surface of the second lens is concave in a paraxial region and the image side surface of the second lens is convex in the paraxial region; the sixth lens has an object side surface being convex in a paraxial region; wherein the camera optical lens satisfies the following conditions:
$3.38 \leq f6/f \leq 10.00$;
$-3.59 \leq (R11+R12)/(R11-R12) \leq 1.34$;
$0.08 \leq d11/TTL \leq 0.20$;
$1.00 \leq d5/d6 \leq 5.00$;
$1.00 \leq R3/R4 \leq 5.00$;
$2.66 \leq f2/f \leq 35.53$;
$1.21 \leq (R3+R4)/(R3-R4) \leq 49.20$; and
$0.04 \leq d3/TTL \leq 0.07$; where, f: a focal length of the camera optical lens; 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 an image side surface of the sixth lens; d11: an on-axis thickness of the sixth lens d5: an on-axis thickness of the third lens; d6: an on-axis distance from an image side surface of the third lens to an object side surface of the fourth lens; R3: a central curvature radius of an object side surface of the second lens; R4: a central curvature radius of an image side surface of the second lens; f2: a focal length of the second lens; d3: an on-axis thickness of the second lens; and 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.
2. The camera optical lens according to claim 1, wherein, the first lens has a positive refractive power and has an object side surface being convex in a paraxial region; the camera optical lens further satisfies the following conditions:
$0.37 \leq f1/f \leq 1.21$;
$-3.22 \leq (R1+R2)/(R1-R2) \leq -0.61$; and
$0.04 \leq d1/TTL \leq 0.15$; where, f1: a focal length of the first lens; R1: a central curvature radius of the object side surface of the first lens; R2: a central curvature radius of an image side surface of the first lens; d1: an on-axis thickness of the first lens.
3. The camera optical lens according to claim 2 further satisfying the following conditions:
$0.60 \leq f1/f \leq 0.97$;
$-2.01 \leq (R1+R2)/(R1-R2) \leq -0.77$; and
$0.07 \leq d1/TTL \leq 0.12$.
4. The camera optical lens according to claim 1, wherein, the third lens has a negative refractive power; the camera optical lens further satisfies the following conditions:
$-3.41 \leq f3/f \leq -0.62$;
$-3.79 \leq (R5+R6)/(R5-R6) \leq 2.08$; and
$0.02 \leq d5/TTL \leq 0.06$; where, f3: a focal length of the third lens; R5: a central curvature radius of an object side surface of the third lens; R6: a central curvature radius of the image side surface of the third lens.
5. The camera optical lens according to claim 4 further satisfying the following conditions:
$-2.13 \leq f3/f \leq -0.78$;
$-2.37 \leq (R5+R6)/(R5-R6) \leq 1.66$; and
$0.03 \leq d5/TTL \leq 0.05$.
6. The camera optical lens according to claim 1, wherein, the fourth lens has a positive refractive power, the object side surface of the fourth lens is convex in a paraxial region and the fourth lens further has an image side surface being concave in the paraxial region; the camera optical lens further satisfies the following conditions:

$0.97 \le f4/f \le 10.79$;
$-5.90 \le (R7+R8)/(R7-R8) \le -1.34$; and
$0.02 \le d7/TTL \le 0.09$; where, 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.
7. The camera optical lens according to claim 6 further satisfying the following conditions:
$1.56 \le f4/f \le 8.63$;
$-3.69 \le (R7+R8)/(R7-R8) \le -1.67$; and
$0.04 \le d7/TTL \le 0.07$.
8. The camera optical lens according to claim 1, wherein, the fifth lens has a positive refractive power, the fifth lens further has an object side surface being concave in a paraxial region and an image side surface being convex in the paraxial region; the camera optical lens further satisfies the following conditions:
$1.11 \le f5/f \le 5.98$;
$1.35 \le (R9+R10)/(R9-R10) \le 12.33$; and
$0.04 \le d9/TTL \le 0.14$; 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; d9: an on-axis thickness of the fifth lens.
9. The camera optical lens according to claim 8 further satisfying the following conditions:
$1.78 \le f5/f \le 4.78$;
$2.17 \le (R9+R10)/(R9-R10) \le 9.86$; and
$0.07 \le d9/TTL \le 0.11$.
10. The camera optical lens according to claim 1, wherein, the seventh lens has an image side surface being concave in a paraxial region and the seventh lens has a negative refractive power; the camera optical lens further satisfies the following conditions:
$-9.50 \le f7/f \le -0.50$;
$0.11 \le (R13+R14)/(R13-R14) \le 9.03$; and
$0.04 \le d13/TTL \le 0.16$; where, f7: a focal length of the seventh lens; R13: a central curvature radius of an object side surface of the seventh lens; R14: a central curvature radius of the image side surface of the seventh lens d13: an on-axis thickness of the seventh lens.
11. The camera optical lens according to claim 10 further satisfying the following conditions:
$-5.94 \le f7/f \le -0.63$;
$0.17 \le (R13+R14)/(R13-R14) \le 7.22$; and
$0.06 \le d13/TTL \le 0.13$.
12. The camera optical lens according to claim 1 further satisfying the following condition: 0.34≤f12/f≤1.13; where, f12: a combined focal length of the first lens and the second lens.
13. The camera optical lens according to claim 1, wherein an FNO of the camera optical lens is less than or equal to 2.34, where, FNO: a ratio of an effective focal length of the camera optical lens to an entrance pupil diameter.
14. The camera optical lens according to claim 1, wherein an FOV of the camera optical lens is greater than or equal to 81.34°, where, FOV: a field of view of the camera optical lens in a diagonal direction.
15. The camera optical lens according to claim 1 further satisfying the following conditions: TTL/IH≤1.34; where, IH: an image height of the camera optical lens.