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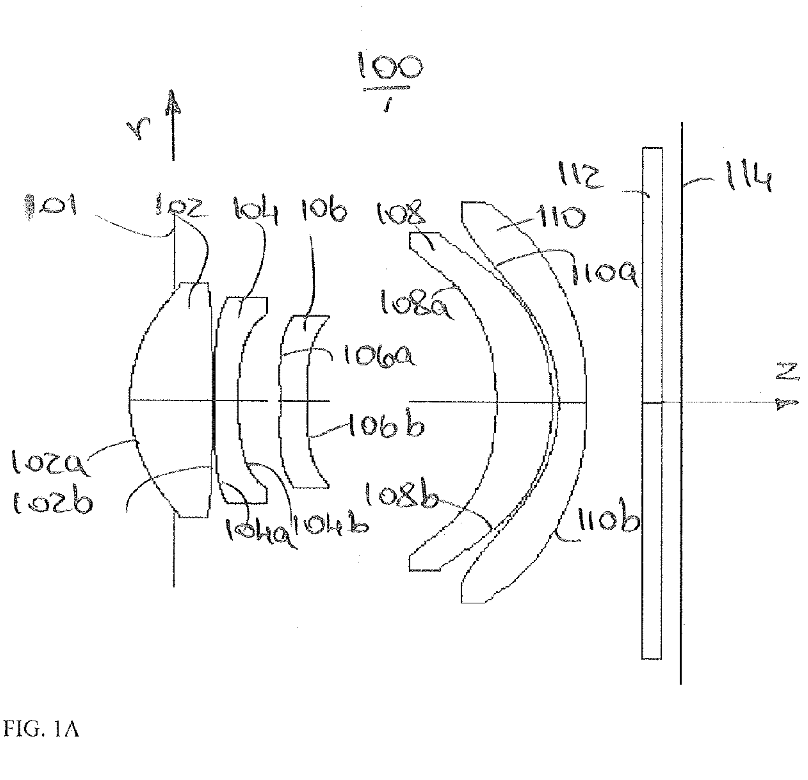

FIG. 1A

(57) Abstract: An optical lens assembly includes five lens elements and provides a TTL/EFL < 1.0. In an embodiment, the focal length of the first lens element fl < TTL/2, an air gap between first and second lens elements is smaller than half the second lens element thickness, an air gap between the third and fourth lens elements is greater than TTL/5 and an air gap between the fourth and fifth lens elements is smaller than about 1.5 times the fifth lens element thickness. All lens elements may be aspheric.

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MINIATURE TELEPHOTO LENS ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims priority from US Provisional Patent Application No. 61/842,987 having the same title and filed July 4, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate to an optical lens system and lens assembly, and more particularly, to a miniature telephoto lens assembly included in such a system and used in a portable electronic product such as a cellphone.

BACKGROUND

Digital camera modules are currently being incorporated into a variety of host devices. Such host devices include cellular telephones, personal data assistants (PDAs), computers, and so forth. Consumer demand for digital camera modules in host devices continues to grow. Cameras in cellphone devices in particular require a compact imaging lens system for good quality imaging and with a small total track length (TTL). Conventional lens assemblies comprising four lens elements are no longer sufficient for good quality imaging in such devices. The latest lens assembly designs, e.g. as in US 8,395,851, use five lens elements. However, the design in US 8,395,851 suffers from at least the fact that the ratio between TTL and an effective focal length (EFL) is too large.

Therefore, a need exists in the art for a five lens element optical lens assembly that can provide a small TTL/EFL ratio and better image quality than existing lens assemblies.

SUMMARY

Embodiments disclosed herein refer to an optical lens assembly comprising, in order from an object side to an image side: a first lens element with positive refractive power having a convex object-side surface, a second lens element with negative refractive power having a thickness d_2 on an optical axis and separated from the first lens element by a first air gap, a third lens element with negative refractive power and separated from the second lens element by a second air gap, a fourth lens element having a positive refractive power and separated from the third lens element by a third air gap, and a fifth lens element having a negative refractive power, separated from the fourth lens element by a fourth air gap, the fifth lens element having a thickness d_5 on the optical axis.

An optical lens system incorporating the lens assembly may further include a stop positioned before the first lens element, a glass window disposed between the image-side surface of the fifth lens element and an image sensor with an image plane on which an image of the object is formed.

TTL is defined as the distance on an optical axis between the object-side surface of the first lens element and the image sensor. "EFL" has its regular meaning. In all embodiments, TTL is smaller than the EFL, i.e. the TTL/EFL ratio is smaller than 1.0. In some embodiments, the TTL/EFL ratio is smaller than 0.9. In an embodiment, the TTL/EFL ratio is about 0.85. In all embodiments, the lens assembly has an F number F# < 3.2. In an embodiment, the focal length of the first lens element f1 is smaller than TTL/2, the first, third and fifth lens elements have each an Abbe number ("Vd") greater than 50, the second and fourth lens elements have each an Abbe number smaller than 30, the first air gap is smaller than $d_2/2$, the third air gap is greater than TTL/5 and the fourth air gap is smaller than $1.5d_5$. In some embodiments, the surfaces of the lens elements may be aspheric.

In an optical lens assembly disclosed herein, the first lens element with positive refractive power allows the TTL of the lens system to be favorably reduced. The combined design of the first, second and third lens elements plus the relative short distances between them enable a long EFL and a short TTL. The same combination, together with the high dispersion (low Vd) for the second lens element and low dispersion (high Vd) for the first and third lens elements, also helps to reduce chromatic aberration. In particular, the ratio TTL/EFL < 1.0 and minimal chromatic aberration are obtained by fulfilling the relationship $1.2\times|f3| > |f2| > 1.5\times f1$, where "f" indicates the lens element effective focal length and the numerals 1, 2, 3, 4, 5 indicate the lens element number.

The relatively large distance between the third and the fourth lens elements plus the combined design of the fourth and fifth lens elements assist in bringing all fields' focal points to the image plane. Also, because the fourth and fifth lens elements have different dispersions and have respectively positive and negative power, they help in minimizing chromatic aberration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows a first embodiment of an optical lens system disclosed herein;

FIG. 1B shows the modulus of the optical transfer function (MTF) vs. focus shift of the entire optical lens assembly for various fields in the first embodiment;

FIG. 1C shows the distortion vs. field angle (+Y direction) in percent in the first embodiment;

FIG. 2A shows a second embodiment of an optical lens system disclosed herein;

FIG. 2B shows the MTF vs. focus shift of the entire optical lens assembly for various fields in the second embodiment;

FIG. 2C shows the distortion +Y in percent in the second embodiment;

FIG. 3A shows a third embodiment of an optical lens system disclosed herein;

FIG. 3B shows the MTF vs. focus shift of the entire optical lens system for various fields in the third embodiment;

FIG. 3C shows the distortion +Y in percent in the third embodiment.

DETAILED DESCRIPTION

In the following description, the shape (convex or concave) of a lens element surface is defined as viewed from the respective side (i.e. from an object side or from an image side). FIG. 1A shows a first embodiment of an optical lens system disclosed herein and marked **100**. FIG. 1B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **100**. FIG. 1C shows the distortion +Y in percent vs. field. Embodiment **100** comprises in order from an object side to an image side: an optional stop **101**; a first plastic lens element **102** with positive refractive power having a convex object-side surface **102a** and a convex or concave image-side surface **102b**; a second plastic lens element **104** with negative refractive power and having a meniscus convex object-side surface **104a**, with an image side surface marked **104b**; a third plastic lens element **106** with negative refractive power having a concave object-side surface **106a** with an inflection point and a concave image-side surface **106b**; a fourth plastic lens element **108** with positive refractive power having a positive meniscus, with a concave object-side surface marked **108a** and an image-side surface marked **108b**; and a fifth plastic lens element **110** with negative refractive power having a negative meniscus, with a concave object-side surface marked **110a** and an image-side surface marked **110b**. The optical lens system further comprises an optional glass window **112** disposed between the image-side surface **110b** of fifth lens element **110** and an image plane **114** for image formation of an object. Moreover, an image sensor (not shown) is disposed at image plane **114** for the image formation.

In embodiment **100**, all lens element surfaces are aspheric. Detailed optical data is given in Table 1, and the aspheric surface data is given in Table 2, wherein the units of the radius of curvature (R), lens element thickness and/or distances between elements along the optical axis and diameter are expressed in mm. "Nd" is the refraction index. The equation of the aspheric surface profiles is expressed by:

$$z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + \alpha_1 r^2 + \alpha_2 r^4 + \alpha_3 r^6 + \alpha_4 r^8 + \alpha_5 r^{10} + \alpha_6 r^{12} + \alpha_7 r^{14}$$

where r is distance from (and perpendicular to) the optical axis, k is the conic coefficient, c = 1/R where R is the radius of curvature, and α are coefficients given in Table 2. In the equation above as applied to embodiments of a lens assembly disclosed herein, coefficients α_1 and α_7 are zero. Note that the maximum value of r "max r" = Diameter/2. Also note that Table 1 (and in Tables 3 and 5 below), the distances between various elements (and/or surfaces) are marked "Lmn" (where *m* refers to the lens element number, *n* =1 refers to the element thickness and *n* = 2 refers to the air gap to the next element) and are measured on the optical axis z, wherein the stop is at z = 0. Each number is measured from the previous surface. Thus, the first distance -0.466 mm is measured from the stop to surface **102a**, the distance L11 from surface **102a** to surface **102b** (i.e. the thickness of first lens element **102**) is 0.894 mm, the gap L12 between surfaces **102b** and **104a** is 0.020 mm, the distance L21 between surfaces **104a** and **104b** (i.e. thickness d2 of second lens element **104**) is 0.246 mm, etc. Also, L21 = d_2 and L51 = d_5.

#	Comment	Radius R [mm]	Distances [mm]	Nd/Vd	Diameter [mm]
1	Stop	Infinite	-0.466		2.4
2	L11	1.5800	0.894	1.5345/57.095	2.5
3	L12	-11.2003	0.020		2.4
4	L21	33.8670	0.246	1.63549/23.91	2.2
5	L22	3.2281	0.449		1.9
6	L31	-12.2843	0.290	1.5345/57.095	1.9
7	L32	7.7138	2.020		1.8
8	L41	-2.3755	0.597	1.63549/23.91	3.3
9	L42	-1.8801	0.068		3.6
10	L51	-1.8100	0.293	1.5345/57.095	3.9
11	L52	-5.2768	0.617		4.3
12	Window	Infinite	0.210	1.5168/64.17	3.0
13		Infinite	0.200		3.0

Table 1

#	Conic coefficient k	α_2	α_3	α_4	α_5	α_6
2	-0.4668	7.9218E-03	2.3146E-02	-3.3436E-02	2.3650E-02	-9.2437E-03
3	-9.8525	2.0102E-02	2.0647E-04	7.4394E-03	-1.7529E-02	4.5206E-03
4	10.7569	-1.9248E-03	8.6003E-02	1.1676E-02	-4.0607E-02	1.3545E-02
5	1.4395	5.1029E-03	2.4578E-01	-1.7734E-01	2.9848E-01	-1.3320E-01
6	0.0000	2.1629E-01	4.0134E-02	1.3615E-02	2.5914E-03	-1.2292E-02
7	-9.8953	2.3297E-01	8.2917E-02	-1.2725E-01	1.5691E-01	-5.9624E-02
8	0.9938	-1.3522E-02	-7.0395E-03	1.4569E-02	-1.5336E-02	4.3707E-03
9	-6.8097	-1.0654E-01	1.2933E-02	2.9548E-04	-1.8317E-03	5.0111E-04
10	-7.3161	-1.8636E-01	8.3105E-02	-1.8632E-02	2.4012E-03	-1.2816E-04
11	0.0000	-1.1927E-01	7.0245E-02	-2.0735E-02	2.6418E-03	-1.1576E-04

Table 2

Embodiment **100** provides a field of view (FOV) of 44 degrees, with EFL = 6.90 mm, F# = 2.80 and TTL of 5.904 mm. Thus and advantageously, the ratio TTL/EFL = 0.855. Advantageously, the Abbe number of the first, third and fifth lens element is 57.095. Advantageously, the first air gap between lens elements **102** and **104** (the gap between surfaces **102b** and **104a**) has a thickness (0.020 mm) which is less than a tenth of thickness d_2 (0.246 mm). Advantageously, the Abbe number of the second and fourth lens elements is 23.91. Advantageously, the third air gap between lens elements **106** and **108** has a thickness (2.020 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **108** and **110** has a thickness (0.068 mm) which is smaller than $1.5d_5$ (0.4395 mm).

The focal length (in mm) of each lens element in embodiment **100** is as follows: f1 = 2.645, f2 = -5.578, f3 = -8.784, f4 = 9.550 and f5 = -5.290. The condition $1.2\mathrm{x}|f3| > |f2| < 1.5\mathrm{x}f1$ is clearly satisfied, as 1.2x8.787 > 5.578 > 1.5x2.645. f1 also fulfills the condition f1< TTL/2, as 2.645 < 2.952.

FIG. 2A shows a second embodiment of an optical lens system disclosed herein and marked **200**. FIG. 2B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **200**. FIG. 2C shows the distortion +Y in percent vs. field. Embodiment **200** comprises in order from an object side to an image side: an optional stop **201**; a first plastic lens element **202** with positive refractive power having a convex object-side surface **202a** and a convex or concave image-side surface **202b**; a second glass lens element **204** with negative refractive power, having a meniscus convex object-side surface **204a**, with an image side surface marked **204b**; a third plastic lens element **206** with negative refractive power having a concave object-side surface **206a** with an inflection point and a concave image-side surface **206b**; a fourth plastic lens element **208** with positive refractive power having a positive meniscus, with a concave object-side surface marked **208a** and an image-side surface marked **208b**; and a fifth plastic lens element **210** with negative refractive power having a negative meniscus, with a concave object-side surface marked **110a** and an image-side surface marked **210b**. The optical lens system further comprises an optional glass window **212** disposed between the image-side surface **210b** of fifth lens element **210** and an image plane **214** for image formation of an object.

In embodiment **200**, all lens element surfaces are aspheric. Detailed optical data is given in Table 3, and the aspheric surface data is given in Table 4, wherein the markings and units are the same as in, respectively, Tables 1 and 2. The equation of the aspheric surface profiles is the same as for embodiment **100**.

#	Comment	Radius R [mm]	Distances [mm]	Nd/Vd	Diameter [mm]
1	Stop	Infinite	-0.592		2.5
2	L11	1.5457	0.898	1.53463/56.18	2.6
3	L12	-127.7249	0.129		2.6
4	L21	6.6065	0.251	1.91266/20.65	2.1
5	L22	2.8090	0.443		1.8
6	L31	9.6183	0.293	1.53463/56.18	1.8
7	L32	3.4694	1.766		1.7
8	L41	-2.6432	0.696	1.632445/23.35	3.2
9	L42	-1.8663	0.106		3.6
10	L51	-1.4933	0.330	1.53463/56.18	3.9
11	L52	-4.1588	0.649		4.3
12	Window	Infinite	0.210	1.5168/64.17	5.4
13		Infinite	0.130		5.5

Table 3

#	Conic coefficient k	α_2	α_3	α_4	α_5	α_6
2	0.0000	-2.7367E-03	2.8779E-04	-4.3661E-03	3.0069E-03	-1.2282E-03
3	-10.0119	4.0790E-02	-1.8379E-02	2.2562E-02	-1.7706E-02	4.9640E-03
4	10.0220	4.6151E-02	5.8320E-02	-2.0919E-02	-1.2846E-02	8.8283E-03
5	7.2902	3.6028E-02	1.1436E-01	-1.9022E-02	4.7992E-03	-3.4079E-03
6	0.0000	1.6639E-01	5.6754E-02	-1.2238E-02	-1.8648E-02	1.9292E-02
7	8.1261	1.5353E-01	8.1427E-02	-1.5773E-01	1.5303E-01	-4.6064E-02
8	0.0000	-3.2628E-02	1.9535E-02	-1.6716E-02	-2.0132E-03	2.0112E-03
9	0.0000	1.5173E-02	-1.2252E-02	3.3611E-03	-2.5303E-03	8.4038E-04
10	-4.7688	-1.4736E-01	7.6335E-02	-2.5539E-02	5.5897E-03	-5.0290E-04
11	0.00E+00	-8.3741E-02	4.2660E-02	-8.4866E-03	1.2183E-04	7.2785E-05

Table 4

Embodiment **200** provides a FOV of 43.48 degrees, with EFL = 7 mm, F# = 2.86 and TTL = 5.90mm. Thus and advantageously, the ratio TTL/EFL = 0.843. Advantageously, the Abbe number of the first, third and fifth lens elements is 56.18. The first air gap between lens elements **202** and **204** has a thickness (0.129 mm) which is about half the thickness d_2 (0.251 mm). Advantageously, the Abbe number of the second lens element is 20.65 and of the fourth lens element is 23.35. Advantageously, the third air gap between lens elements **206** and **208** has a thickness (1.766 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **208** and **210** has a thickness (0.106 mm) which is less than $1.5xd_5$ (0.495 mm).

The focal length (in mm) of each lens element in embodiment **200** is as follows: f1 = 2.851, f2 = -5.468, f3 = -10.279, f4 = 7.368 and f5 = -4.536. The condition 1.2x|f3| > |f2| < 1.5xf1 is clearly satisfied, as 1.2x10.279 > 5.468 > 1.5x 2.851. f1 also fulfills the condition f1< TTL/2, as 2.851 < 2.950.

FIG. 3A shows a third embodiment of an optical lens system disclosed herein and marked **300**. FIG. 3B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **300**. FIG. 3C shows the distortion +Y in percent vs. field. Embodiment **300** comprises in order from an object side to an image side: an optional stop **301**; a first glass lens element **302** with positive refractive power having a convex object-side surface **302a** and a convex or concave image-side surface **302b**; a second plastic lens element **204** with negative refractive power, having a meniscus convex object-side surface **304a**, with an image side surface marked **304b**; a third plastic lens element **306** with negative refractive power having a concave object-side surface **306a** with an inflection point and a concave image-side surface **306b**; a fourth plastic lens element **308** with positive refractive power having a positive meniscus, with a concave object-side surface marked **308a** and an image-side surface marked **308b**; and a fifth plastic lens element **310** with negative refractive power having a negative meniscus, with a concave object-side surface marked **310a** and an image-side surface marked **310b**. The optical lens system further comprises an optional glass window **312** disposed between the image-side surface **310b** of fifth lens element **310** and an image plane **314** for image formation of an object.

In embodiment **300**, all lens element surfaces are aspheric. Detailed optical data is given in Table 5, and the aspheric surface data is given in Table 6, wherein the markings and units are the same as in, respectively, Tables 1 and 2. The equation of the aspheric surface profiles is the same as for embodiments **100** and **200**.

#	Comment	Radius R [mm]	Distances [mm]	Nd/Vd	Diameter [mm]
1	Stop	Infinite	-0.38		2.4
2	L11	1.5127	0.919	1.5148/63.1	2.5
3	L12	-13.3831	0.029		2.3
4	L21	8.4411	0.254	1.63549/23.91	2.1
5	L22	2.6181	0.426		1.8
6	L31	-17.9618	0.265	1.5345/57.09	1.8
7	L32	4.5841	1.998		1.7
8	L41	-2.8827	0.514	1.63549/23.91	3.4
9	L42	-1.9771	0.121		3.7
10	L51	-1.8665	0.431	1.5345/57.09	4.0
11	L52	-6.3670	0.538		4.4
12	Window	Infinite	0.210	1.5168/64.17	3.0
13		Infinite	0.200		3.0

Table 5

#	Conic coefficient k	α_2	α_3	α_4	α_5	α_6
2	-0.534	1.3253E-02	2.3699E-02	-2.8501E-02	1.7853E-02	-4.0314E-03
3	-13.473	3.0077E-02	4.7972E-03	1.4475E-02	-1.8490E-02	4.3565E-03
4	-10.132	7.0372E-04	1.1328E-01	1.2346E-03	-4.2655E-02	8.8625E-03
5	5.180	-1.9210E-03	2.3799E-01	-8.8055E-02	2.1447E-01	-1.2702E-01
6	0.000	2.6780E-01	1.8129E-02	-1.7323E-02	3.7372E-02	-2.1356E-02
7	10.037	2.7660E-01	-1.0291E-02	-6.0955E-02	7.5235E-02	-1.6521E-02
8	1.703	2.6462E-02	-1.2633E-02	-4.7724E-04	-3.2762E-03	1.6551E-03
9	-1.456	5.7704E-03	-1.8826E-02	5.1593E-03	-2.9999E-03	8.0685E-04
10	-6.511	-2.1699E-01	1.3692E-01	-4.2629E-02	6.8371E-03	-4.1415E-04
11	0.000	-1.5120E-01	8.6614E-02	-2.3324E-02	2.7361E-03	-1.1236E-04

Table 6

Embodiment **300** provides a FOV of 44 degrees, EFL = 6.84 mm, F# = 2.80 and TTL = 5.904 mm. Thus and advantageously, the ratio TTL/EFL = 0.863. Advantageously, the Abbe number of the first lens element is 63.1, and of the third and fifth lens elements is 57.09. The first air gap between lens elements **302** and **304** has a thickness (0.029 mm) which is about $1/10^{th}$ the thickness d_2 (0.254 mm). Advantageously, the Abbe number of the second and fourth lens elements is 23.91. Advantageously, the third air gap between lens elements **306** and **308** has a thickness (1.998 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **208** and **210** has a thickness (0.121 mm) which is less than $1.5d_5$ (0.6465 mm).

The focal length (in mm) of each lens element in embodiment **300** is as follows: f1 = 2.687, f2 = -6.016, f3 = -6.777, f4 = 8.026 and f5 = -5.090. The condition $1.2x|f3| > |f2| < 1.5xf1$ is clearly satisfied, as 1.2x6.777> 6.016 > 1.5x 2.687. f1 also fulfills the condition f1< TTL/2, as 2.687 < 2.952.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

WHAT IS CLAIMED IS

1. An optical lens assembly comprising, in order from an object side to an image side:

a) a first lens element with positive refractive power having a convex object-side surface;

b) a second lens element with negative refractive power having a thickness d_2 on an optical axis and separated from the first lens element by a first air gap;

c) a third lens element with negative refractive power and separated from the second lens element by a second air gap;

d) a fourth lens element having a positive refractive power and separated from the third lens element by a third air gap; and

e) a fifth lens element having a negative refractive power, separated from the fourth lens element by a fourth air gap and having a thickness d_5 on the optical axis;

wherein a ratio between an effective focal length (EFL) and a total track length (TTL) of an optical lens system including the lens assembly is smaller than 1.0, wherein a focal length f1 of the first lens element is smaller than TTL/2 and wherein the third air gap is greater than TTL/5.

2. The optical lens assembly of claim 1, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

3. The optical lens assembly of claim 1, wherein the first, third and fifth lens elements have each an Abbe number greater than 50, and wherein the second and fourth lens elements have each an Abbe number smaller than 30.

4. The optical lens assembly of claim 3, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth

lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

5. The optical lens assembly of claim 3, wherein the first air gap is smaller than $d_2/2$.

6. The optical lens assembly of claim 5, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

7. The optical lens assembly of claim 1, wherein all lens elements are made of plastic.

8. The optical lens assembly of claim 1, wherein the first lens element is made of glass and wherein all other lens elements are made of plastic.

9. The optical lens assembly of claim 1, wherein the second lens element is made of glass and all other lens elements are made of plastic.

10. The optical lens assembly of claim 1, wherein the lens assembly has an F number smaller than 3.2.

11. The optical lens assembly of claim 3, wherein the lens assembly has an F number smaller than 3.2.

12. The optical lens assembly of claim 5, wherein the lens assembly has an F number smaller than 3.2.

13. The optical lens assembly of claim 1, wherein all lens element surfaces are aspheric.

14. The optical lens assembly of claim 3, wherein all lens element surfaces are aspheric.

15. The optical lens assembly of claim 5, wherein all lens element surfaces are aspheric.

16. The optical lens assembly of claim 1, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition $1.2x|f3| > |f2| > 1.5xf1$.

17. The optical lens assembly of claim 2, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition $1.2x|f3| > |f2| > 1.5xf1$.

18. The optical lens assembly of claim 3, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition $1.2x|f3| > |f2| > 1.5xf1$.

19. The optical lens assembly of claim 5, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition $1.2x|f3| > |f2| >1.5xf1$.

20. The optical lens assembly of claim 1, wherein EFL = 6.84 mm, F# = 2.80 and TTL = 5.90 mm.

AMENDED CLAIMS
received by the International Bureau on 22.12.2014

WHAT IS CLAIMED IS:

1. An optical lens assembly comprising, in order from an object side to an image side:

a) a first lens element with positive refractive power having a convex object-side surface;

b) a second lens element with negative refractive power having a thickness d_2 on an optical axis and separated from the first lens element by a first air gap;

c) a third lens element with negative refractive power and separated from the second lens element by a second air gap;

d) a fourth lens element having a positive refractive power and separated from the third lens element by a third air gap; and

e) a fifth lens element having a negative refractive power, separated from the fourth lens element by a fourth air gap and having a thickness d_5 on the optical axis;

wherein a ratio between a total track length (TTL) and an effective focal length (EFL) ~~and a total track length (TTL)~~ of an optical lens system including the lens assembly is smaller than 1.0, wherein a focal length f1 of the first lens element is smaller than TTL/2 and wherein the third air gap is greater than TTL/5.

2. The optical lens assembly of claim 1, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

3. The optical lens assembly of claim 1, wherein the first, third and fifth lens elements have each an Abbe number greater than 50, and wherein the second and fourth lens elements have each an Abbe number smaller than 30.

4. The optical lens assembly of claim 3, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

5. The optical lens assembly of claim 3, wherein the first air gap is smaller than $d_2/2$.

6. The optical lens assembly of claim 5, wherein the first lens element has a convex object-side surface and a convex or concave image-side surface, wherein the second lens element has a meniscus convex object-side surface, wherein the fourth lens element has a positive meniscus and a concave object-side surface, wherein the fifth lens element has a negative meniscus and a concave object-side surface and wherein the fourth air gap is smaller than $1.5d_5$.

7. The optical lens assembly of claim 1, wherein all lens elements are made of plastic.

8. The optical lens assembly of claim 1, wherein the first lens element is made of glass and wherein all other lens elements are made of plastic.

9. The optical lens assembly of claim 1, wherein the second lens element is made of glass and all other lens elements are made of plastic.

10. The optical lens assembly of claim 1, wherein the lens assembly has an F number smaller than 3.2.

11. The optical lens assembly of claim 3, wherein the lens assembly has an F number smaller than 3.2.

12. The optical lens assembly of claim 5, wherein the lens assembly has an F number smaller than 3.2.

13. The optical lens assembly of claim 1, wherein all lens element surfaces are aspheric.

14. The optical lens assembly of claim 3, wherein all lens element surfaces are aspheric.

15. The optical lens assembly of claim 5, wherein all lens element surfaces are aspheric.

16. The optical lens assembly of claim 1, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition
$1.2x|f3| > |f2| > 1.5xf1$.

17. The optical lens assembly of claim 2, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition
$1.2x|f3| > |f2| > 1.5xf1$.

18. The optical lens assembly of claim 3, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition
$1.2x|f3| > |f2| > 1.5xf1$.

19. The optical lens assembly of claim 5, wherein f1, a focal length f2 of the second lens element and a focal length f3 of the third lens element fulfill the condition
$1.2x|f3| > |f2| >1.5xf1$.

20. The optical lens assembly of claim 1, wherein EFL = 6.84 mm, F# = 2.80 and TTL = 5.90 mm.

21. A lens unit having an optical axis, a total track length (TTL) and an effective focal length (EFL), the lens unit being comprised of five lens elements which are spaced apart

along the optical axis, the lens elements being made of different plastic materials and being configured such that a ratio between the TTL and EFL of the lens unit is smaller than 1.

22. The lens unit according to Claim 21, wherein said different plastic materials include plastic with Abbe number greater than 50 and plastic with Abbe number smaller than 30.

23. The lens unit according to Claim 21 or 22, wherein the first, second and third lens elements, in order from an object side to an image side along said optical axis, are configured and operable to provide a telephoto optical effect; the fourth lens element is spaced from the third lens element along the optical axis a distance larger than 1/5 of the TTL; and the fourth and fifth lens elements are configured to compensate for chromatic aberrations dispersed during light passage through said distance between the third and fourth lens elements.

24. The lens unit according to any one of Claims 21 to 23, wherein the first, third and fifth lens elements are made of plastic having Abbe number greater than 50.

25. The lens unit according to any one of Claims 21 to 24, wherein the second and fourth lens elements are made of plastic having Abbe number smaller than 30.

26. The lens unit according to any one of Claims 21 to 25, wherein said TTL is about 5.9mm.

27. The lens unit according to any one of Claims 21 to 26, wherein the ratio TTL/EFL is about 0.85.

28. A cellular telephone comprising the lens unit according to any one of claims 21 to 27.

29. A lens unit comprising:

five lens elements defining together a total track length (TTL) of the lens unit smaller than an effective focal lens (EFL) thereof, the five lenses being made of plastic materials having different Abbe numbers including Abbe numbers greater than 50 and smaller than 30, the five lens elements being accommodated in a spaced-apart relationship along an optical axis and defining, in order from an object side to an image side along the optical axis:

first, second and third lens elements configured and operable to provide a telephoto optical effect, and

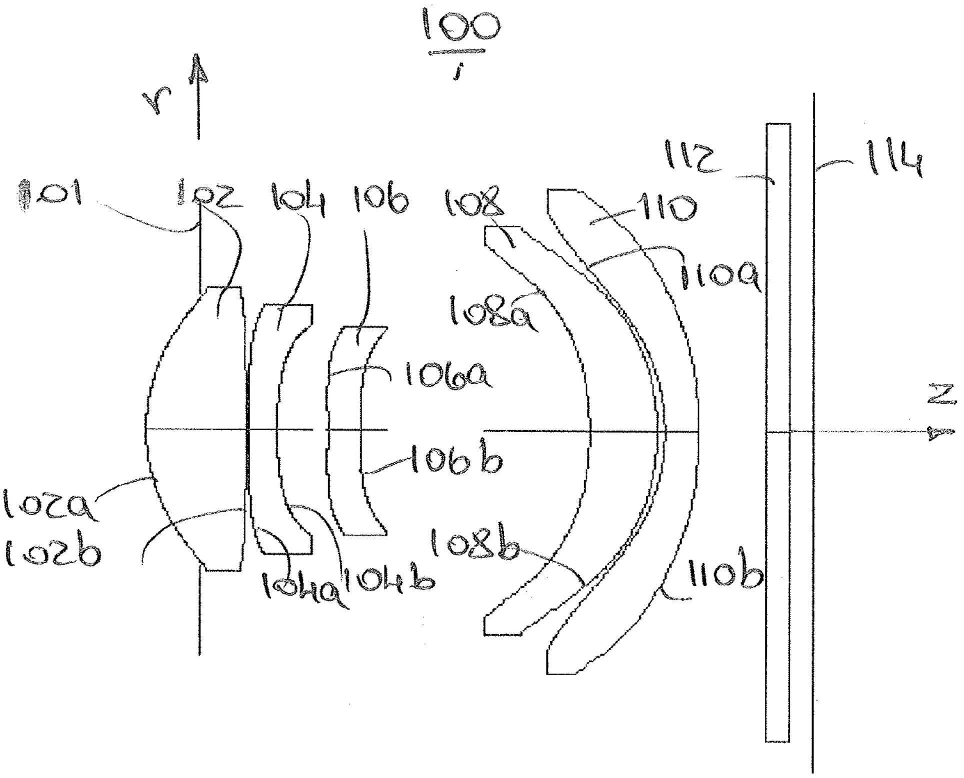
fourth and fifth lens elements configured to add compensation for chromatic aberrations and assist in bringing all fields focal points to an image plane, the fourth lens element being spaced from the third lens element along the optical axis a distance larger than 1/5 of the TTL.

30. A cellular telephone comprising a lens unit, the lens unit comprising:

five lens elements defining together a total track lens (TTL) of the lens unit smaller than an effective focal lens (EFL) thereof, said five lenses being made of plastic materials having different Abbe numbers including Abbe numbers greater than 50 and smaller than 30, said five lens elements being accommodated in a spaced-apart relationship along an optical axis and defining:

first, second and third lens elements configured and operable to provide a telephoto optical effect, and

fourth and fifth lens elements configured to add compensation for chromatic aberrations and assist in bringing all fields focal points to an image plane, the fourth lens element being spaced from the third lens element along the optical axis a distance larger than 1/5 of the TTL.


100
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101
102
104
106
108
110
112
114
108a
110a
106a
106b
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102a
102b
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108b
110b

FIG. 1A

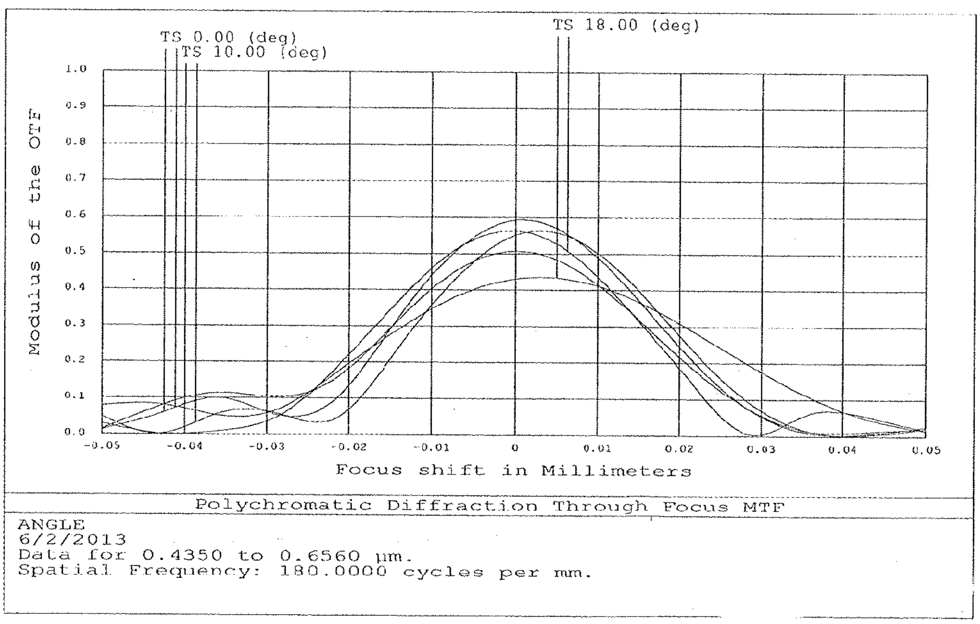

TS 0.00 (deg)
TS 10.00 (deg)
TS 18.00 (deg)
Modulus of the OTF
Focus shift in Millimeters
Polychromatic Diffraction Through Focus MTF
ANGLE
6/2/2013
Data for 0.4350 to 0.6560 µm.
Spatial Frequency: 180.0000 cycles per mm.

FIG. 1B

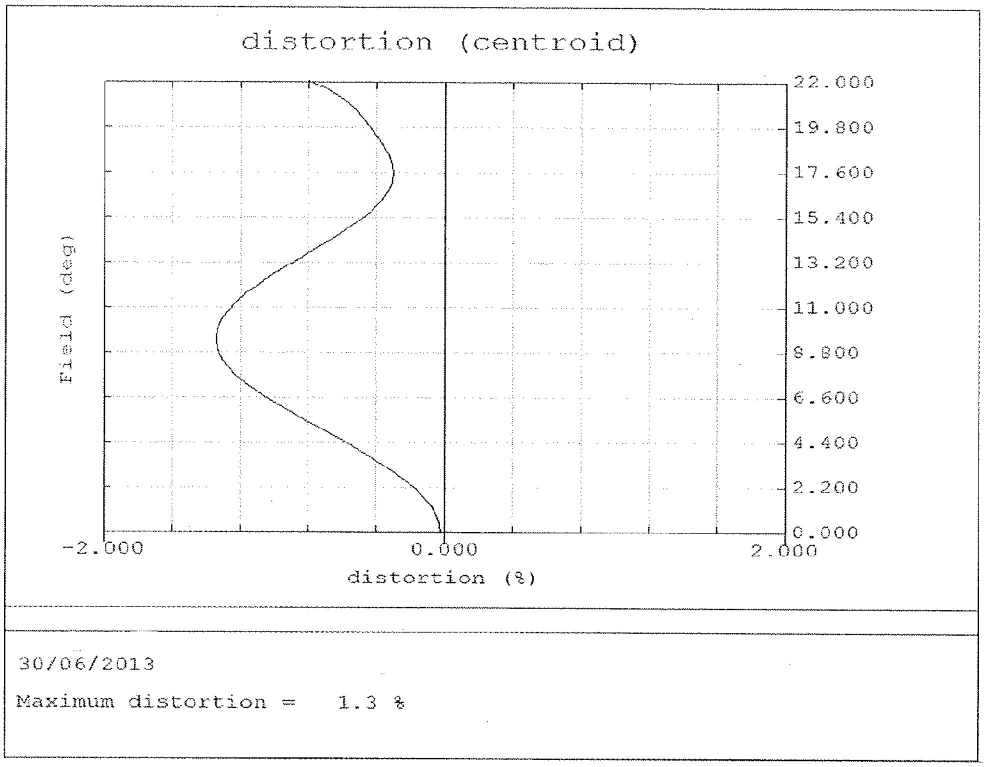
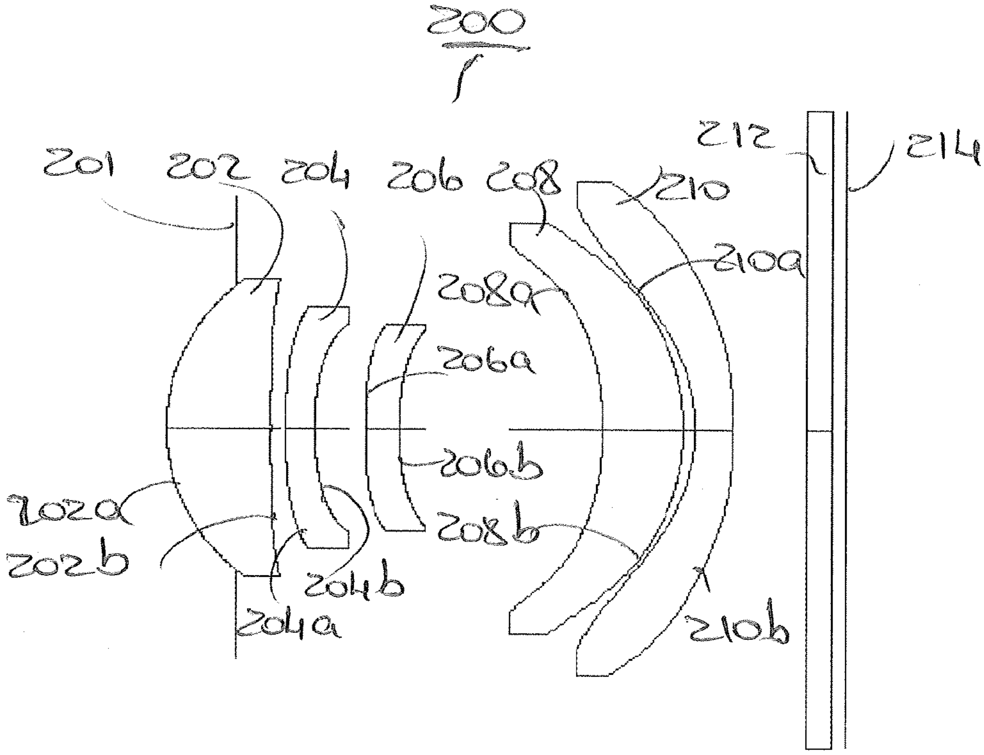

distortion (centroid)
22.000
19.800
17.600
15.400
13.200
11.000
8.800
6.600
4.400
2.200
0.000
Field (deg)
-2.000
0.000
2.000
distortion (%)
30/06/2013
Maximum distortion = 1.3 %

FIG. 1C


200
201
202
204
206
208
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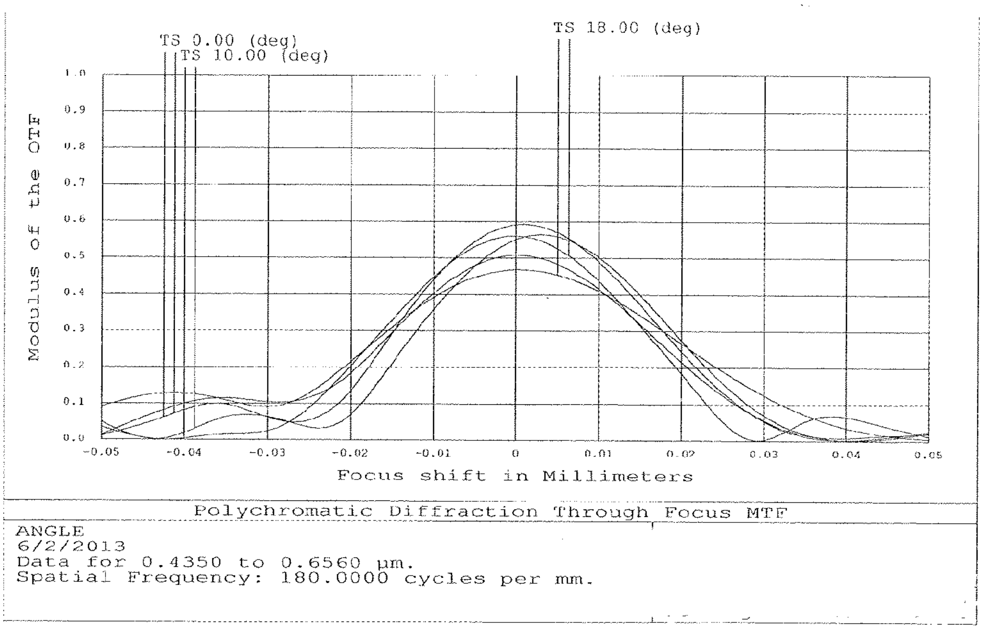
212
214
208a
210a
206a
206b
202a
202b
204b
208b
204a
210b

FIG. 2A


TS 0.00 (deg)
TS 10.00 (deg)
TS 18.00 (deg)
Modulus of the OTF
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0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Focus shift in Millimeters
Polychromatic Diffraction Through Focus MTF
ANGLE
6/2/2013
Data for 0.4350 to 0.6560 µm.
Spatial Frequency: 180.0000 cycles per mm.

FIG.2B

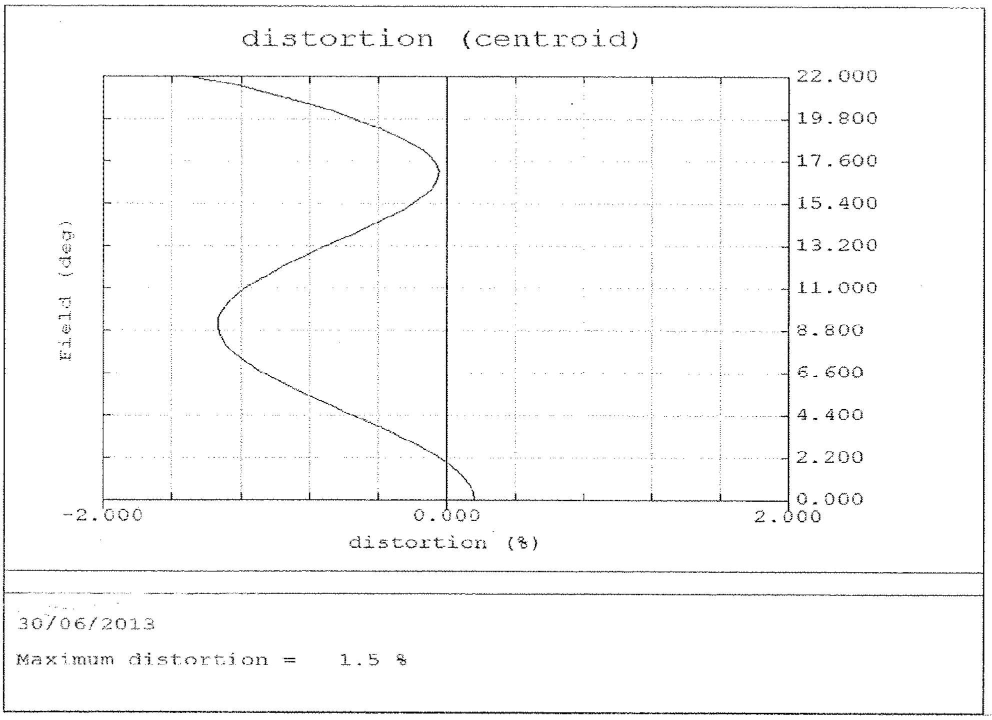
distortion (centroid)
Field (deg)
22.000
19.800
17.600
15.400
13.200
11.000
8.800
6.600
4.400
2.200
0.000
-2.000
0.000
2.000
distortion (%)
30/06/2013
Maximum distortion = 1.5 %

FIG. 2C

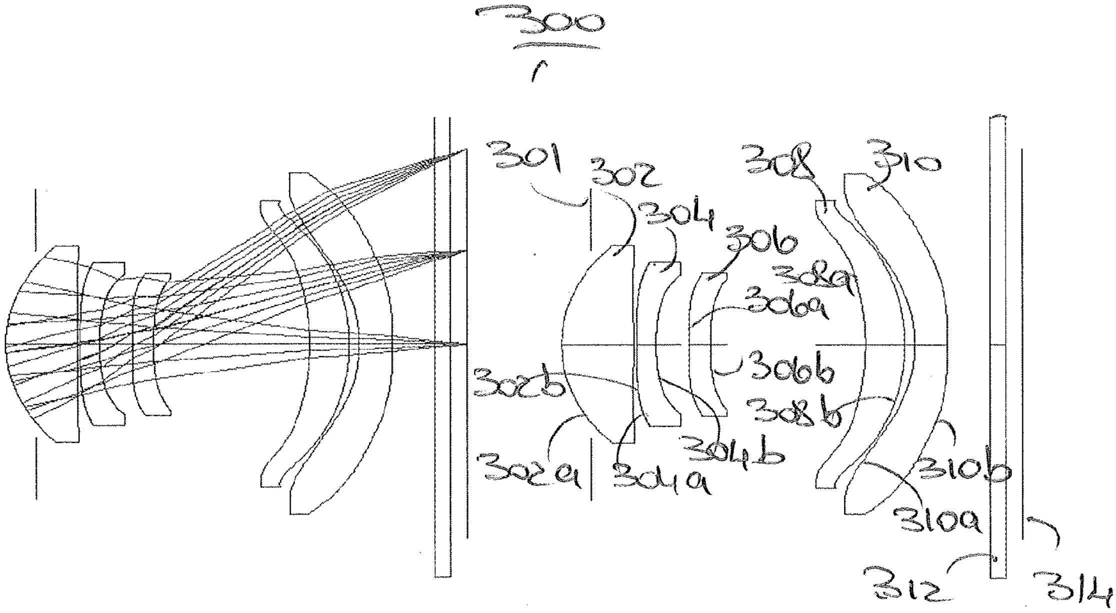
300
301
302
304
306
308
310
308a
306a
306b
302b
308b
302a
304a
304b
310b
310a
312
314

FIG. 3A

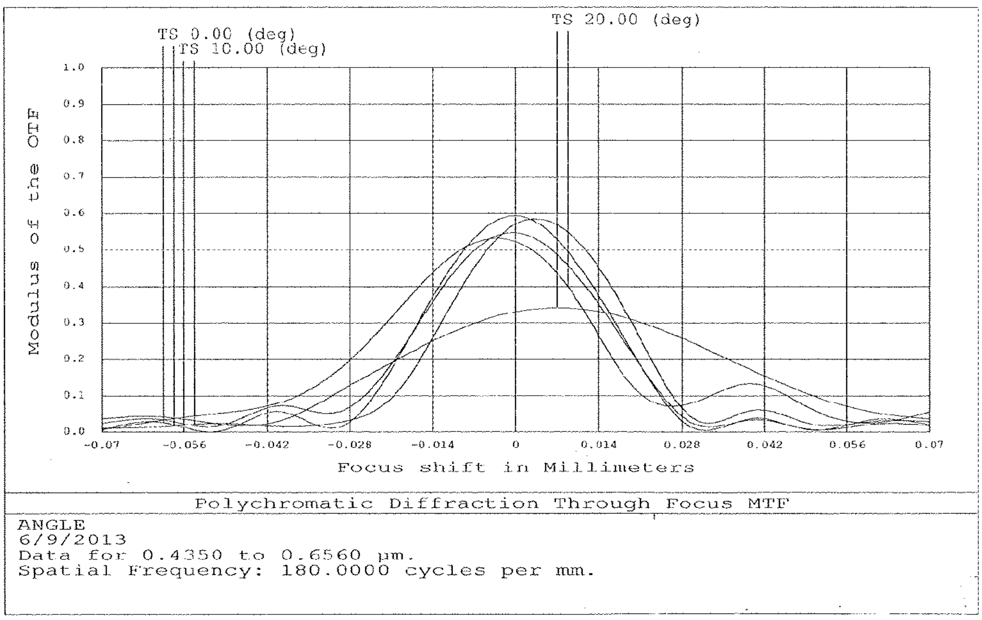
TS 0.00 (deg)
TS 10.00 (deg)
TS 20.00 (deg)
Modulus of the OTF
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.07
-0.056
-0.042
-0.028
-0.014
0
0.014
0.028
0.042
0.056
0.07
Focus shift in Millimeters
Polychromatic Diffraction Through Focus MTF
ANGLE
6/9/2013
Data for 0.4350 to 0.6560 µm.
Spatial Frequency: 180.0000 cycles per mm.

FIG. 3B

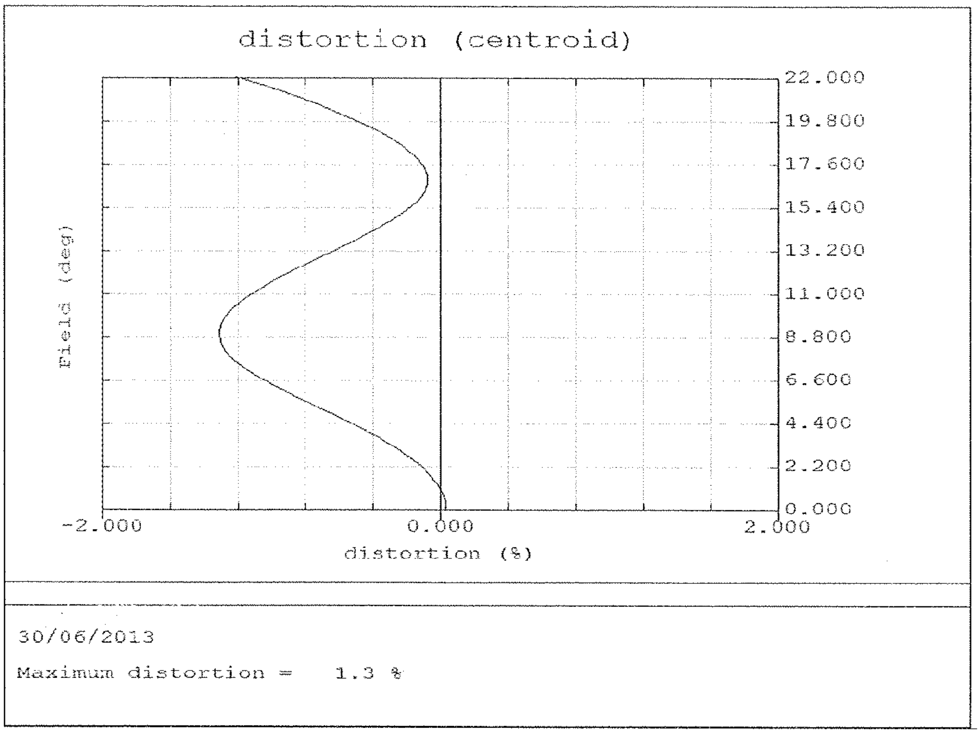
distortion (centroid)
Field (deg)
22.000
19.800
17.600
15.400
13.200
11.000
8.800
6.600
4.400
2.200
0.000
-2.000
0.000
2.000
distortion (%)
30/06/2013
Maximum distortion = 1.3 %

FIG. 3C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2014/062465

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02B 3/02 (2014.01)
CPC - G02B 13/18 (2014.09)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G02B 3/02, 13/18, 13/04 (2014.01)
USPC - 359/714, 745, 746, 753, 764, 762

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G02B 13/18, 9/60, 13/0045 (2014.09)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, ProQuest

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/0314296 A1 (SHABTAY et al) 13 December 2012 (13.12.2012) entire document	1-20
Y	WO 2013/063097 A1 (CAHALL et al) 02 May 2013 (02.05.2013) entire document	1-20
Y	US 2012/0087020 A1 (TANG et al) 12 April 2012 (12.04.2012) entire document	8-9
Y	US 5,946,142 A (HIRATA et al) 31 August 1999 (31.08.1999) entire document	16-19
A	US 2013/0038947 A1 (TSAI et al) 14 February 2013 (14.02.2013) entire document	1-20
A	US 2007/0229987 A1 (SHINOHARA) 04 October 2007 (04.10.2007) entire document	1-20
A	US 2010/0091384 A1 (DENG et al) 15 April 2010 (15.04.2010) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2014	29 OCT 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774