IPR2020-00878

Apple Inc. v. Corephotonics, Ltd.

U.S. Patent No. 10,330,897

Grounds at Issue

- **Ground 2: Claims 2, 5, 6, 18, and 21–23**
  Obviousness over Ogino and Baraeu
- **Ground 3: Claims 3, 8, 19, and 24**
  Obviousness over Ogino, Bareau, and Kingslake
- **Ground 4: Claims 16 and 30**
  Obviousness over Chen, Iwasaki, and Beich

Overview of Argument

- **Ground 2:**
  - **Proposed modification of Ogino example 5 with reduced F# is:**
    - **Contrary to the teachings of Bareau**
    - **Not manufacturable: thin lens edge, large center-to-edge ratio, steep edge angle, lack of oversizing, sharp corners**
- **Ground 3:**
  - **No motivation for modification from concave to convex image-side surface**
  - **Sasián analysis is unreliable**
- **Ground 4:**
  - **Proposed combination requires unachievable manufacturing precision and will leak light**

Ground 2

Independent Claims 1 and 17

US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.: US 10,330,897 B2**
(45) **Date of Patent: *Jun. 25, 2019**

(54) **MINIATURE TELEPHOTO LENS ASSEMBLY**

(71) Applicant: **Corephotonics Ltd.**, Tel-Aviv (IL)

(72) Inventors: **Michael Dror**, Nes Ziona (IL); **Ephraim Goldenberg**, Ashdod (IL); **Gal Shabtay**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/976,391**

(22) Filed: **May 10, 2018**

(65) **Prior Publication Data**

US 2018/0275374 A1 Sep. 27, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/817,235, filed on Nov. 19, 2017, which is a continuation of application

(Continued)

(51) **Int. Cl.**
G02B 13/00 (2006.01)
G02B 13/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 13/0045*** (2013.01); ***G02B 1/041*** (2013.01); ***G02B 9/60*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041;
(Continued)

(56) **References Cited**

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2,378,170 A 6/1945 Aklin
(Continued)

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CN 104297906 A 1/2015
JP 1966006865 4/1966
(Continued)

OTHER PUBLICATIONS

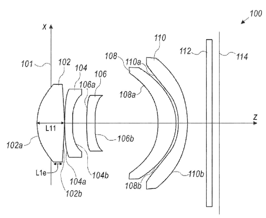
A compact and cost effective design for cell phone zoom lens, Chang et al., Sep. 2007, 8 pages.
(Continued)

Primary Examiner — Evelyn A Lester
(74) *Attorney, Agent, or Firm* — Nathan & Associates; Menachem Nathan

(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 f1<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.

30 Claims, 6 Drawing Sheets



1. A lens assembly, comprising: a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), a total track length (TTL) of 6.5 millimeters or less and a ratio TTL/EFL<1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements L_{1_1}, L_{1_2} and L_{1_3} with respective focal lengths f_{1_1}, f_{1_2} and f_{1_3} and a second group comprising lens elements L_{2_1} and L_{2_2}, wherein the first and second groups of lens elements are separated by a gap that is larger than twice any other gap between lens elements, wherein lens element L_{1_1} has positive refractive power and lens element L_{1_2} has negative refractive power and wherein lens elements L_{2_1} and L_{2_2} have opposite refractive powers.

Ex. 1001, 8:22–37

Dependent Claims 2, 5, 6, 18, 21, 23 – F#<2.9 or F#=2.8

US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.: US 10,330,897 B2**
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(Continued)

(58) **Field of Classification Search**
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(Continued)

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(Continued)

FOREIGN PATENT DOCUMENTS

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OTHER PUBLICATIONS

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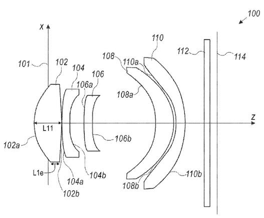
(57) **ABSTRACT**

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 f1<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.

30 Claims, 6 Drawing Sheets



Ex. 1001, 8:37–10:17

2. The lens assembly of claim **1**, wherein the TTL is equal or smaller than 6.0 mm and wherein the lens assembly has a f-number F#<2.9.

5. The lens assembly of claim **1**, wherein the lens assembly has a f-number F#<2.9.

6. The lens assembly of claim **5**, wherein lens element L_{1_1} has a concave image-side surface.

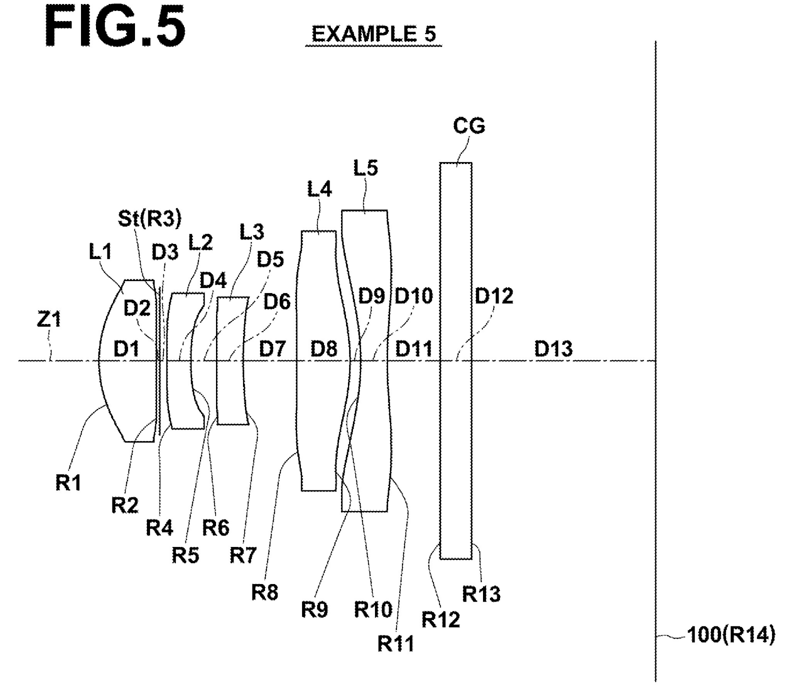
18. The lens assembly of claim **17**, wherein the TTL is equal or smaller than 6.0 mm and wherein the lens assembly has a f-number F#<2.9.

21. The lens assembly of claim **17**, wherein the lens assembly has a f-number F#<2.9.

23. The lens assembly of claim **17**, wherein the lens assembly has a f-number F#=2.8.

Ogino Example 5

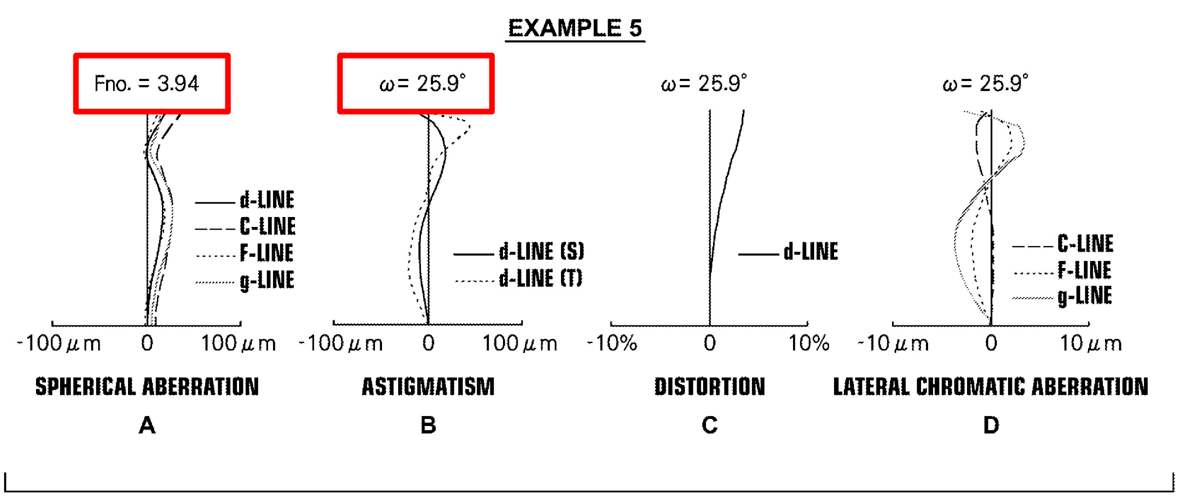
FIG.5



POR at 19; Ex. 1005, Fig. 5

Ogino Example 5: F# = 3.94

FIG.12



POR at 19–20; Ex. 1005, Fig. 12

Bareau "Typical Lens Specifications"

4. Specifications

The following are typical lens specifications for a ¼" sensor format:

FOV	60 degrees
Image Circle	4.6 mm diam.
TTL	5.0mm
f/no	f/2.8
Distortion	<2%
Chief Ray Angle	<22 degrees
Relative Illumination	>50%

FOV - The field of view for these systems is typically 60 to 66 degrees across the sensor diagonal, but the design must include a slightly larger angle to allow for correction over the image circle.

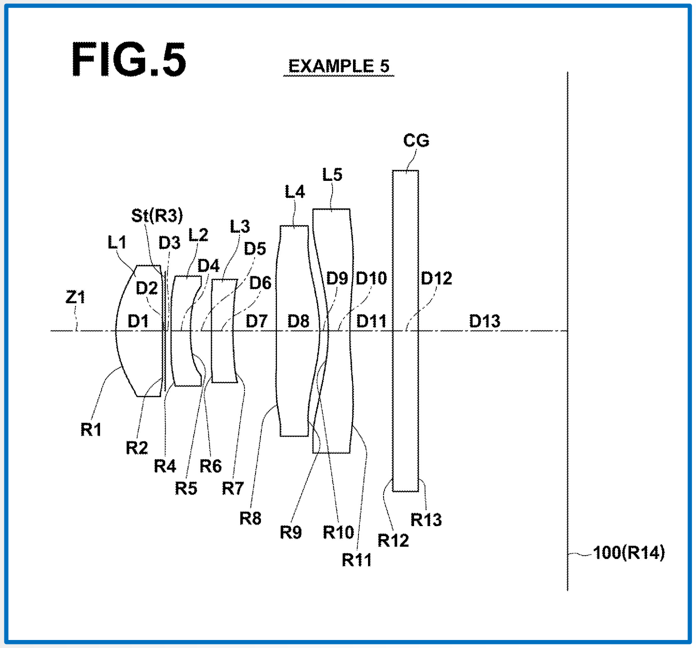
POR at 22, 31; Ex. 1012 at 3

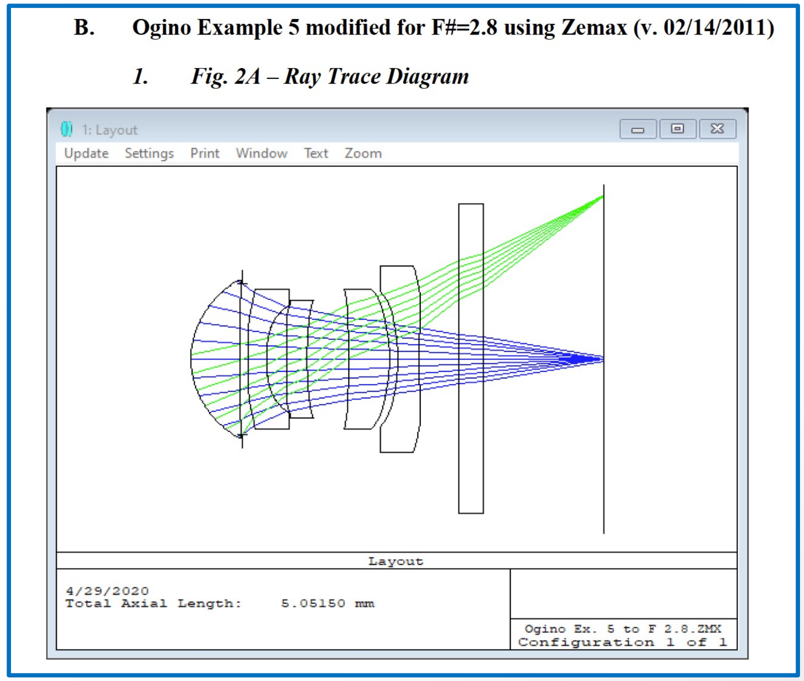
Ogino Examples: Other F# Values

EXAMPLE 1			
Fno. = 2.47	ω= 35.2°	ω= 35.2°	ω= 35.2°
EXAMPLE 2			
Fno. = 2.46	ω= 35.1°	ω= 35.1°	ω= 35.1°
EXAMPLE 3			
Fno. = 2.45	ω= 35.2°	ω= 35.2°	ω= 35.2°
EXAMPLE 4			
Fno. = 3.04	ω= 32.5°	ω= 32.5°	ω= 32.5°
EXAMPLE 5			
Fno. = 3.94	ω= 25.9°	ω= 25.9°	ω= 25.9°
EXAMPLE 6			
Fno. = 2.64	ω= 29.8°	ω= 29.8°	ω= 29.8°

POR at 30–31; Ex. 1005, Figs. 8–13

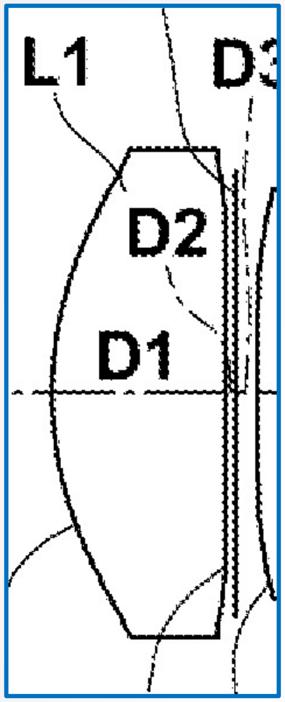
Modifying Ogino Example 5:

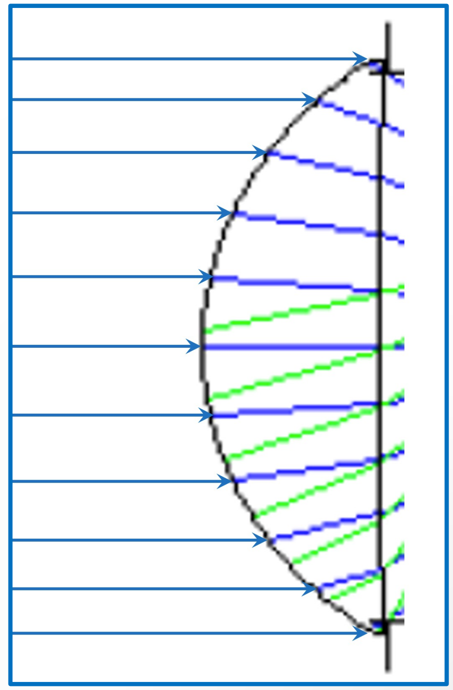




POR at 37–38; Ex. 1005, Fig. 5; Ex. 1003 at 104

Modifying Ogino Example 5: First Lens Element





POR at 37–38; Ex. 1005, Fig. 5; Ex. 1003 at 104

Modifying Ogino Example 5: Field of View Too Narrow

Bareau (Ex. 1012 at 3): FOV=60–66 degrees

FOV - The field of view for these systems is typically 60 to 66 degrees across the sensor diagonal, but the design must include a slightly larger angle to allow for correction over the image circle.

Ogino Example 5: FOV=51.8 degrees

EXAMPLE 5

Fno. = 3.94 ω= 25.9° ω= 25.9° ω= 25.9°

Dr. Sasián's Lens: FOV=40 degrees

Steps for modification:

1) Open the aperture to support f-number at 2.8 and set FOV to +/- 20°,

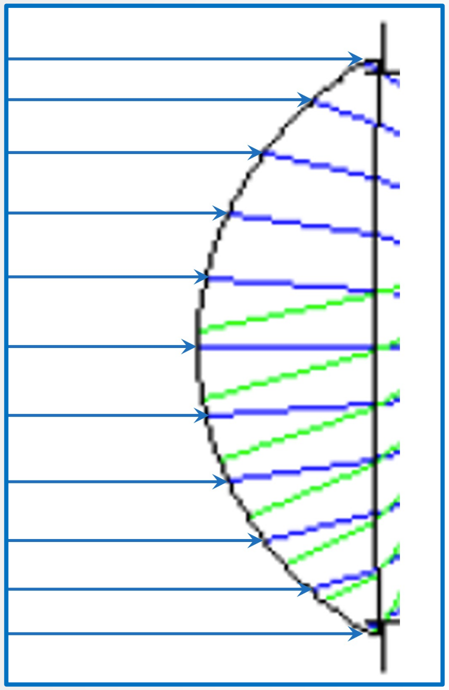
POR at 31–32; Ex. 1012 at 3; Ex. 1005, Fig. 12; Ex. 1003 at 104

Ogino Examples: Other Designs Are Closer to Bareau's F# and FOV

	EXAMPLE 1		
Fno. = 2.47	ω= 35.2°	ω= 35.2°	ω= 35.2°
	EXAMPLE 2		
Fno. = 2.46	ω= 35.1°	ω= 35.1°	ω= 35.1°
	EXAMPLE 3		
Fno. = 2.45	ω= 35.2°	ω= 35.2°	ω= 35.2°
	EXAMPLE 4		
Fno. = 3.04	ω= 32.5°	ω= 32.5°	ω= 32.5°
	EXAMPLE 5		
Fno. = 3.94	ω= 25.9°	ω= 25.9°	ω= 25.9°
	EXAMPLE 6		
Fno. = 2.64	ω= 29.8°	ω= 29.8°	ω= 29.8°

POR at 30–31, 34; Ex. 1005, Figs. 8–13

Modifying Ogino Example 5: First Lens Element Unmanufacturable



- Microscopic lens edge
- Steep edge slope
- High center-to-edge ratio
- No ability to oversize
- Sharp corners

Not manufacturable using ***<u>any</u>***
technique for lens manufacture

POR at 39; SR at 2

Ogino Lenses Would Preferably Be Plastic Injection Molded

Dr. Jose Sasian
Petitioner's Expert

"While Ogino does not specifically indicate that its lens elements can be plastic, a POSITA would recognize that the index of refraction and Abbe number of the lens elements specified in Example 6 of Ogino are within the range of values of plastic materials used for cell phone lenses.

"Further lens elements of the sizes and asphericities described in Ogino would preferably be made of plastic via injection molding processes. See Ex.1019, p.34.14 (pdf p.80). A POSITA would also recognize that when designing lens elements for crafting via injection molding, a number of manufacturing realities apply that all promote maximizing the thickness of the lens element at the edge."

POR at 35; Ex. 2009 at 69

Bareau Teaches Plastic Injection Molded Lenses

The three-element form is very common (fig.9), and a good place to start. Just about every camera module lens manufacturer has a lens of this form in their offerings. Designs tend not to be stop-symmetric. The aperture stop is usually towards the front of the lens, often before the first element, which helps CRA and TTL. The majority of these lenses are all-plastic although some incorporate one glass element (usually the front element) for the advantages of high-index refraction and color correction. Plastic elements are almost always bi-aspheric, and frequently the aspheres are not subtle! The shape of the last lens surface in the design above is typical. Four element systems provide high performance, but are only viable when the TTL is relatively large (>6.0mm), otherwise the performance degradation due to tolerances cancels out the nominal gain. Four element systems are mostly found in cameras with ¼" sensor formats or larger, though they are becoming less common. Likewise, the effectiveness of a 3-element approach decreases to the point that a 2-element system becomes more practical when the TTL is less than 4 mm.

POR at 35–36; Ex. 1012 at 8

But Dr. Milster's Manufacturability Analysis Addresses All Techniques of Manufacture

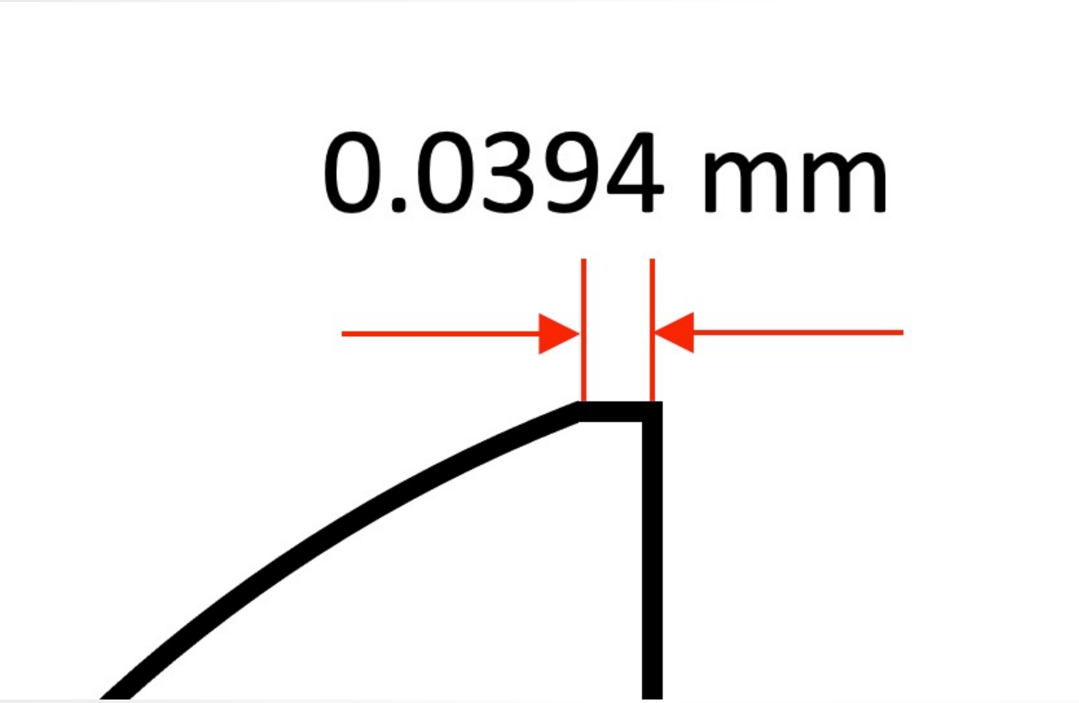
Dr. Tom Milster
Patent Owner's Expert

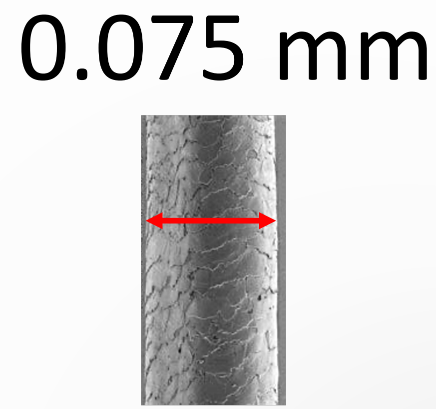
- Injection Molding of Plastic
  (Ex. 2001, ¶¶ 60, 62, 77-78, 103-108, 112, 117, 121)
- Injection Molding of Glass
  (*Id.*, ¶¶ 60, 63, 103-108, 112, 117, 119, 120)
- Grinding or Polishing of Glass
  (*Id.*, ¶¶ 60, 63, 104-107, 110, 117, 119, 120)
- Diamond Turning
  (*Id.*, ¶¶ 104, 107, 117, 120, 121)
- Any Other Technology
  (*Id.*, ¶¶ 106-107, 117)

Apple does not identify ***any*** technique that would overcome the manufacturability problems

SR at 2; Ex. 2001

Ground 2 – Narrow Edge

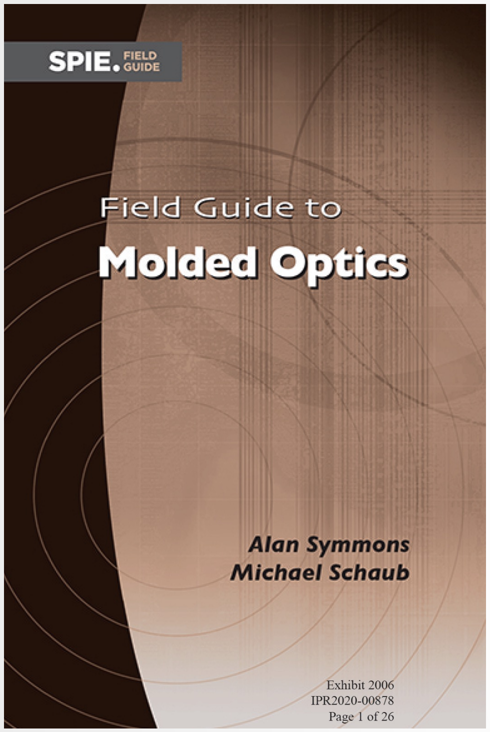




Human Hair

POR at 40-41; Ex. 2001, ¶ 99

Ground 2 – Narrow Edge



> The minimum thickness required will depend on the size and shape of the part, as well as the material it is made from. Small lenses such as those used for cellphone cameras can have extremely small minimum cross sections, on the order of a few hundred microns. Larger parts will typically require correspondingly larger minimum thicknesses.

The edge of Dr. Sasián's lens is <u>39.4 microns</u>

POR at 51; Ex. 2006 at 102 (copyright 2016)

Ground 2 – Narrow Edge

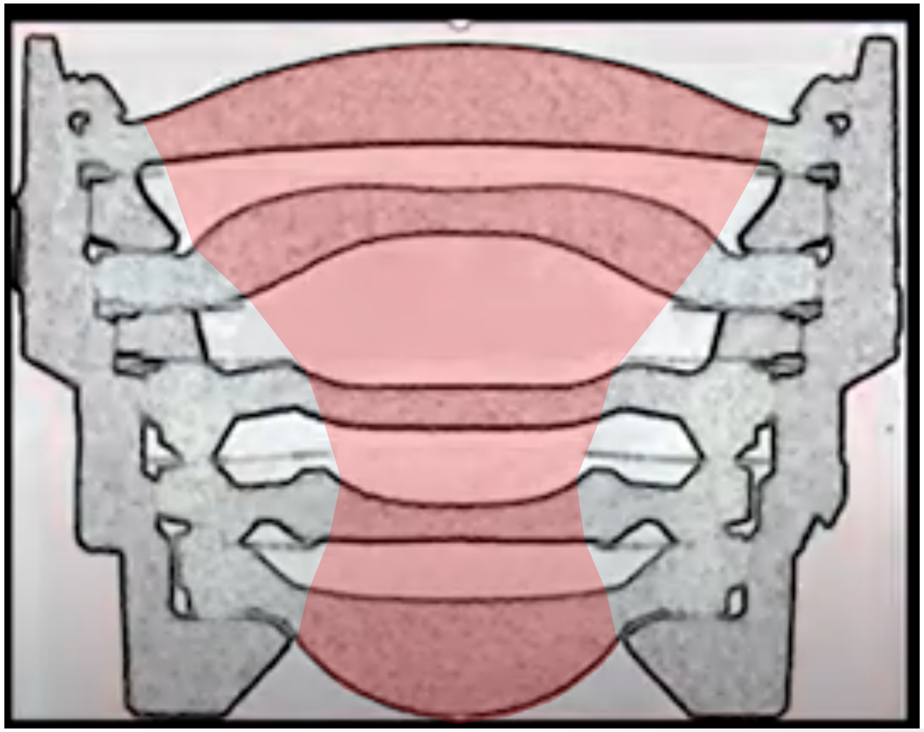
Dr. Tom Milster
Patent Owner's Expert

"This is not the edge of a realistic, practical lens"

POR at 41; Ex. 2001, ¶ 99

Ground 2 – Narrow Edge

Dr. Tom Milster
Patent Owner's Expert



POR at 42; Ex. 2001, ¶ 100

Ground 2 – Narrow Edge

Dr. Tom Milster
Patent Owner's Expert

"Oversizing is necessary because a lens cannot be made with perfectly sharp corners and edges. In molded lenses, one reason for this is surface tension of the lens material. If one attempted to inject plastic or glass into a mold with sharp corners such as shown in the Zemax drawing, the liquid would not fill the corners, but would rather form a rounded surface, which would bend light differently than the ideal shape in Zemax"

POR at 41; Ex. 2001, ¶ 99

Ground 2 – Narrow Edge

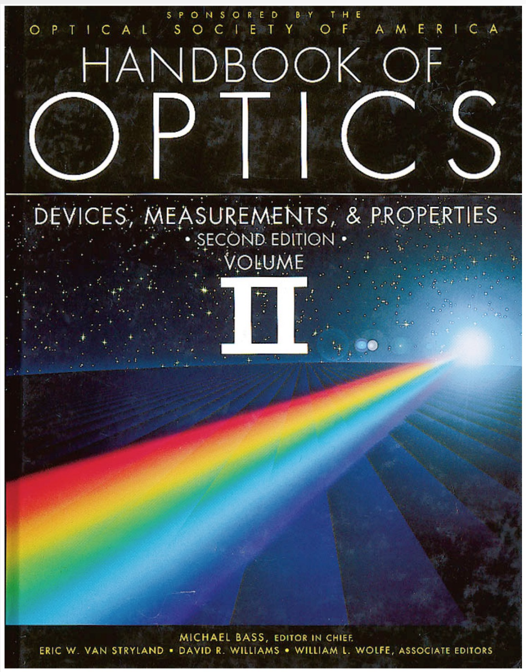
Dr. Tom Milster
Patent Owner's Expert

"Even if the surface tension and other limitations of injection molding were not a factor, practical lenses will have rounded or chamfered corners rather than sharp 90° corners, regardless of the technology used to make them. As Dr. Sasián notes in his textbook, '[i]t is imperative that a bevel, or protective chamfer, is specified to avoid the lens edge easily chipping.' (Ex. 2004, Sasián at 112.)

"A sharp corner is mechanically much weaker than a rounded or chamfered corner. . . . Making extremely sharp corners without chipping the lens is difficult regardless of the manufacturing technique used."

POR at 45-46; Ex. 2001, ¶ 106-107

Ground 2 – The Need to Oversize

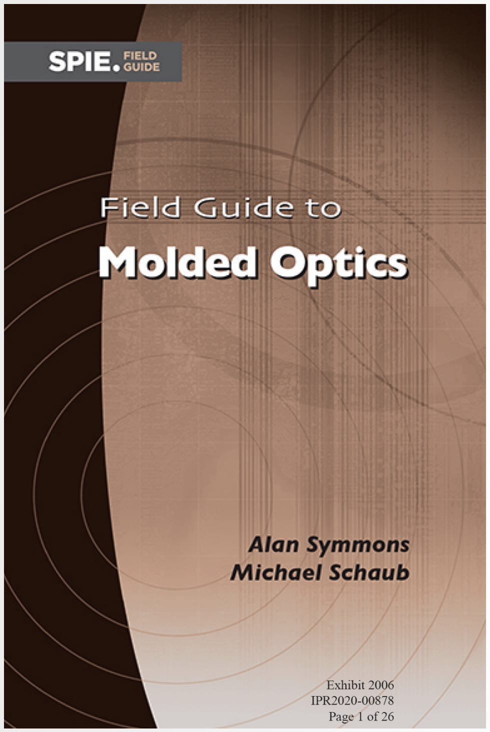


Shrinkage

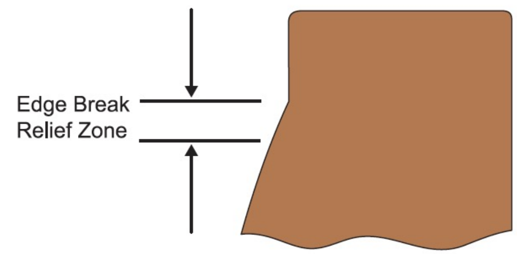
Surface-tension effects may play a significant role in the accuracy to which a precision optical surface may be molded.[33,34] Particularly in areas of the part where the ratio of surface area/volume is locally high (corners, edges), surface tension may create nonuniform shrinkage which propagates inward into the clear aperture, resulting in an edge rollback condition similar to that which is familiar to glass opticians. Surface tension and volumetric shrinkage may, however, actually aid in the production of accurate surfaces. Strongly curved surfaces are frequently easier to mold to interferometric tolerances than those having little or no curvature. These phenomena provide motivation to oversize optical elements, if possible, to a dimension considerably beyond the clear apertures. A buffer region, or an integrally molded flange provides the additional benefit of harmlessly absorbing optical inhomogeneities which typically form near the injection gate. Figure 2 depicts several optical element forms exhibiting favorable (*a–e*) and unfavorable (*f–j*) molding geometries. In some cases, a process combining injection and compression molding may be used to improve optical figure quality. Several variants of this hybrid process are in use worldwide, with some injection molding presses being specifically fitted at the factory to implement this procedure.[35]

POR at 46; Ex. 1019, at 34.16

Ground 2 – The Need to Oversize



The reason for limited specification is the nonuniform **shrinkage** that occurs at **transition zones** of the part, such as where the optical surface joins the flange. This shrinkage effect is known as **edge break**.

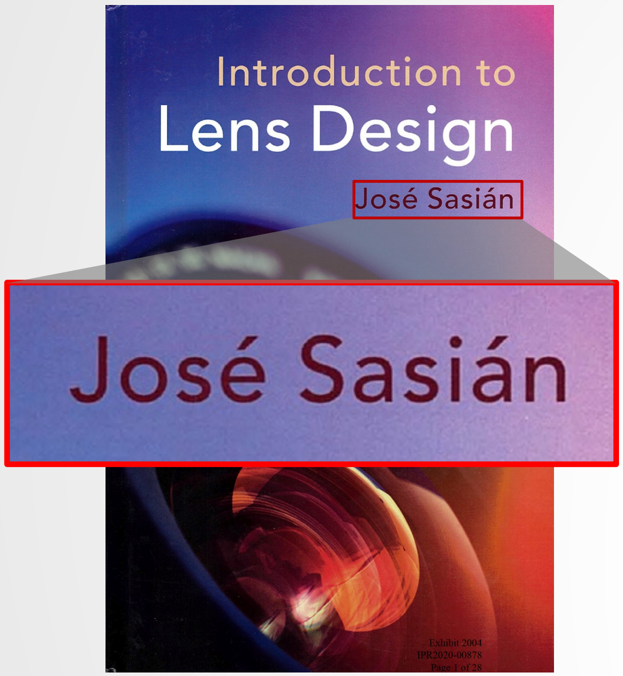


Because of the impact of edge break, molders will require the CA size to be smaller than the full optical surface that is molded. The amount of **edge relief** will depend on the part size, but one millimeter or more in the radial direction is desired for parts of approximately 10 to 25 mm in diameter.

This much relief is often impractical for smaller parts, where it would be a substantial portion of their diameter. In this case, the edge break relief zone will need to scale down with the part size.

POR at 47; Ex. 2006 at 103

Ground 2 – The Need to Oversize



Petitioner's Expert

The lens diameter refers to the actual lens diameter, in comparison to the clear aperture of the lens that performs the optical function of refracting or reflecting light rays. A common surface polishing problem is to have the very edge of the surface turned down. To overcome this figuring problem, there is a tendency to specify a lens diameter larger, say 10–20% larger, than the clear aperture. However, usually packaging requirements and lens cost win and the

POR at 47–48; Ex. 2004 at 111

Ground 2 – Impractical Slope

Part of the selection process, when considering materials, is the cost of satisfying the manufacturing constraints. Plastic injection molded optics have minimum edge thicknesses, minimum center thickness and a range of acceptability for their center to edge thickness ratio that must be met in order that they can be molded. Additionally, the maximum slope that can be diamond-turned in mold inserts and measured in either the lens or the mold is around 45 degrees. One big advantage of plastic is that flanges with mechanical details can be molded that eliminate the need for spacers and allow for mechanically driven centering of one element to another. One disadvantage is that there are very few plastic materials that lend themselves to precision optical molding with stability over large ranges of temperature and humidity, so the choices are limited.

POR at 40, 53; Ex. 2006 at 94; Ex. 2001, ¶ 98

Ground 2 – Impractical Slope

"While this discussion appears in the section on glass molding, each of these problems applies equally to molding plastic and indeed to almost any manufacturing technique. . . . A POSITA would recognize that the 58.86° slope in Dr. Sasián's modified lens is not practical."

Dr. Tom Milster
Patent Owner's Expert

POR at 53; Ex. 2001, ¶ 121

Ground 2 – Limits of Manufacturing Precision

Attribute	Rules of Thumb Tolerances
Radius of Curvature	± 0.50%
EFL	± 1.0%
Center Thickness	± 0.020mm
Diameter	± 0.020mm
Wedge (TIR) in the Element	< 0.010mm
S1 to S2 Displacement (across the parting line)	< 0.020mm
Surface Figure Error	≤ 2 fringes per 25.4mm (2 fringes = 1 wave @ 632nm)
Surface Irregularity	≤ 1 fringes per 25.4mm (2 fringes = 1 wave @ 632nm)
Scratch-Dig Specification	40-20
Surface Roughness (RMS)	≤ 100 Å
Diameter to Center Thickness Ratio	< 4:1
Center Thickness to Edge Thickness Ratio	< 3:1
Part to Part Repeatability (in a one cavity mold)	< 0.50%

Beich Manufacturing Tolerances

POR at 48; Ex. 1007 at 7

Ground 2 – Limits of Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"While this discussion appears in the section on glass molding, each of these problems applies equally to molding plastic and indeed to almost any manufacturing technique. . . . A POSITA would recognize that the 58.86° slope in Dr. Sasián's modified lens is not practical."

POR at 53; Ex. 2001, ¶ 121

Ground 2 – Limits of Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"Tolerances for glass molding are similar. (Ex. 2006, Symmons at 95.) As the Field Guide notes, 'high repeatability from component to component' is an advantage of molded lenses over other techniques, so other techniques have tolerance issues as well. (Ex. 2006, Symmons at 2.)"

POR at 48–49; Ex. 2001, ¶ 112

Ground 2 – Limits of Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"Manufacturing tolerances add up. . . . [T]hese four variances add under the root sum square rule to yield an error that goes as the square root of the number of errors. (Ex. 2004, Sasián at 116–117.) Even if the first lens is slightly oversized, these additive errors can easily lead to a situation where there is an open gap between the first lens and the aperture, allowing light to leak through and adding a diffuse haze to the image, something that is highly undesirable."

POR at 48–49; Ex. 2001, ¶ 112

Ground 2 – Center-to-Edge Thickness

Dr. Tom Milster
Patent Owner's Expert

"These many issues with thin lens edges lead to a rule of thumb in the Beich paper, which Dr. Sasián himself cites as something that a POSITA would be motivated to follow: the 'Center Thickness to Edge Thickness Ratio' should be less than 3:1. (Ex. 1007, Beich at 7; Ex. 1003, Sasián Decl., ¶ 78.) Dr. Sasián's textbook gives a similar rule of thumb, saying 'the ratio of lens central thickness to edge thickness should [not be more] than than 3.2.' (Ex. 2004, Sasián at 194.) My chapter in the Handbook of Optics likewise says to use 'a center/edge thickness ratio less than 3.' (Ex. 2008, Handbook of Optics at 7.11.) By contrast, Dr. Sasián's design has a ratio of 0.6 mm / 0.039375 mm = 15.238, far outside the range of what a POSITA would consider manufacturable."

POR at 51—52; Ex. 2001, ¶ 118

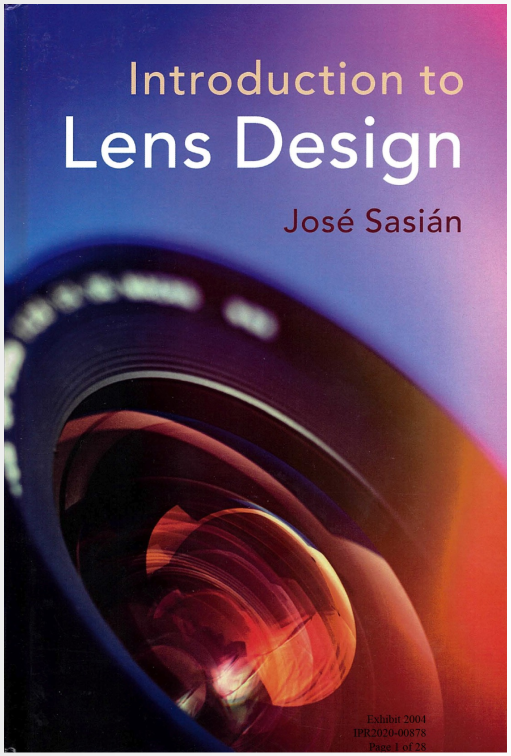
Ground 2 – Center-to-Edge Thickness

Dr. Tom Milster
Patent Owner's Expert

"While that rule of thumb applies to plastic lenses, a POSITA would recognize that the tiny edge thickness is similarly problematic for glass lenses. For example, the Field Guide states that 'Very small edge thicknesses (<0.4 mm) should be avoided, as these lenses become very difficult to handle and can chip easily.' This chipping issue is not unique to molded glasses, but will also apply to glass lenses formed other ways. Bareau recognizes this as a general problem for glass lenses when it warns that '[f]or glass elements, the edge thicknesses will become too thin to be fabricated without chipping.' (Ex. 1012, Bareau at 1.) A POSITA would recognize that the edge of Dr. Sasián's lens (0.0394 mm) is too small by a factor of ten for a glass lens."

POR at 52; Ex. 2001, ¶ 119

Ground 2 – Apple's Argument that a POSITA Would Not Have Known It Was Impossible to Manufacture the Proposed Lens



reflecting light rays. A common surface polishing problem is to have the very edge of the surface turned down. To overcome this figuring problem, there is a tendency to specify a lens diameter larger, say 10–20% larger, than the clear aperture. However, usually packaging requirements and lens cost win and the

diameter of the lens is minimized to only allow for enough clearance to properly mount the lens. It is imperative that a bevel, or protective chamfer, is specified to avoid the lens edge easily chipping.

17.3 Lens Manufacturing Considerations

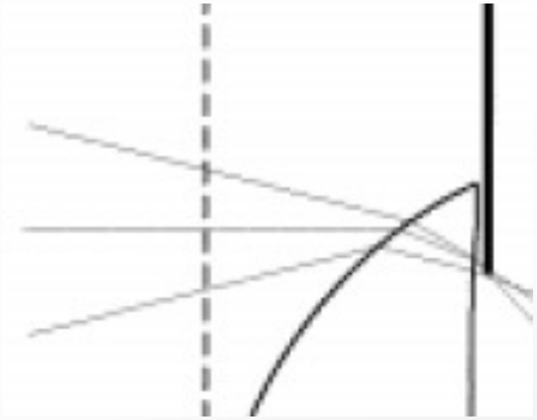
For proper plastic flow and cooling, plastic lens manufacturers have some requirements for the aspect ratio of positive and negative lenses. Some guidelines are as follows: for positive lenses the ratio of lens central thickness to edge thickness should not be more than 3.2, and the edge thickness should not be less than 0.32 mm; for negative lenses the ratio of the maximum thickness

SR at 4–5; Ex. 2004 at 111–112, 194

Ground 2 – Apple's Arguments Based on Konno and Mercado Fail

Ground 2 Lens

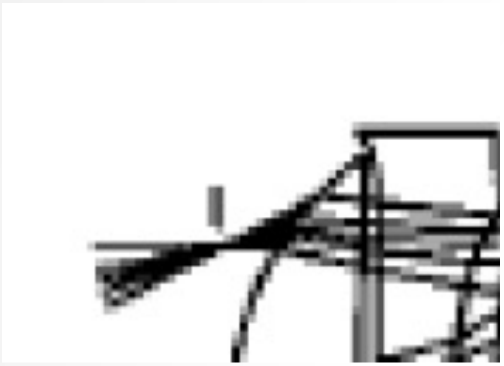
Konno Lens



Mercado Lens

POR at 38; SR at 6; Ex. 2001, ¶ 95; Ex. 1035, Fig. 11; Ex. 1036, Fig. 13

Ground 2 – Apple's Arguments Based on Konno and Mercado Fail



Konno Lens
Drawing

Dr. Sasián's Simulation
of Konno Lens

SR at 6-8; Ex. 1035, Fig. 11; IPR2020-00906, Ex. 1021 at 31

Ground 2 – Apple's Arguments Based on Konno and Mercado Fail

Dr. Jose Sasian
Petitioner's Expert

Q. So at least to the extent that Figure 11 of Konno is describing an injection-molded plastic lens, one skilled in the art would understand that the lens actually being represented by Figure 11 wouldn't have the front and back surfaces of the first lens meeting at a sharp edge, but there would be some other shape there, right?

A. Yes. They would incorporate a flange, F-L-A-N-G-E. They would adjust the lens for the fabrication process at hand.

SR at 8; Ex. 2012 at 115:3–24

Ground 2 – Apple's Arguments Based on Konno and Mercado Fail

Q. And so one skilled in the art, looking at Figure 13 of Mercado, and wanting to build that lens using injection-molded plastic, would they understand that the actual shape of the lens outside of the clear aperture would be different than what's shown in Figure 13 so that the lens could have, for example, a flange?

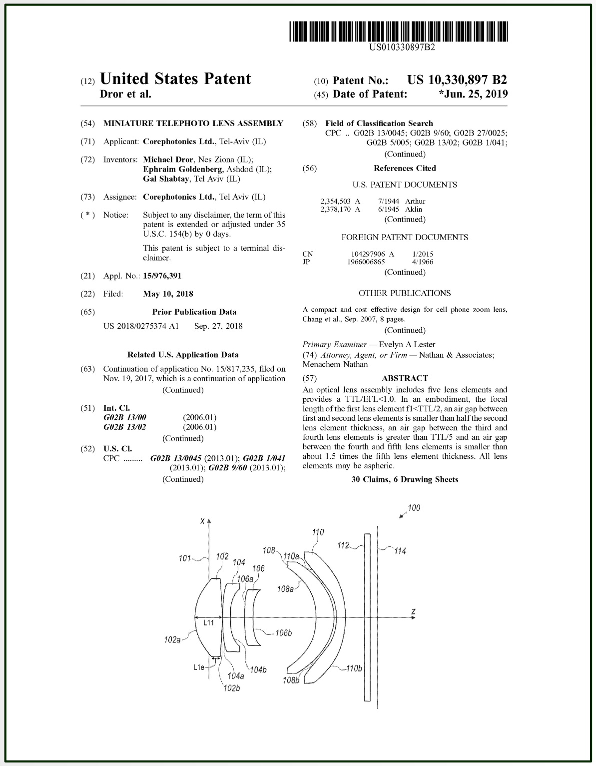
A. I wouldn't say that would understand. They would adjust the lens for the fabrication process at hand.

Dr. Jose Sasian
Petitioner's Expert

SR at 8-9; Ex. 2012 at 117:11–118:1

Ground 3

Dependent Claims 3, 8, 19, and 24 – Image-Side Surface



US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.: US 10,330,897 B2**
(45) **Date of Patent: *Jun. 25, 2019**

(54) **MINIATURE TELEPHOTO LENS ASSEMBLY**

(71) Applicant: **Corephotonics Ltd.**, Tel-Aviv (IL)

(72) Inventors: **Michael Dror**, Nes Ziona (IL); **Ephraim Goldenberg**, Ashdod (IL); **Gal Shabtay**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/976,391**

(22) Filed: **May 10, 2018**

(65) **Prior Publication Data**
US 2018/0275374 A1 Sep. 27, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/817,235, filed on Nov. 19, 2017, which is a continuation of application
(Continued)

(51) **Int. Cl.**
G02B 13/00 (2006.01)
G02B 13/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 13/0045*** (2013.01); ***G02B 1/041*** (2013.01); ***G02B 9/60*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041;
(Continued)

(56) **References Cited**

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(Continued)

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JP 1966006865 4/1966
(Continued)

OTHER PUBLICATIONS

A compact and cost effective design for cell phone zoom lens, Chang et al., Sep. 2007, 8 pages.
(Continued)

Primary Examiner — Evelyn A Lester
(74) *Attorney, Agent, or Firm* — Nathan & Associates; Menachem Nathan

(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 f1<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.

30 Claims, 6 Drawing Sheets

3. The lens assembly of claim **1**, wherein the TTL is equal or smaller than 6.0 mm and wherein lens element L_{1_1} has an image-side surface diameter between 2.3 mm and 2.5 mm.

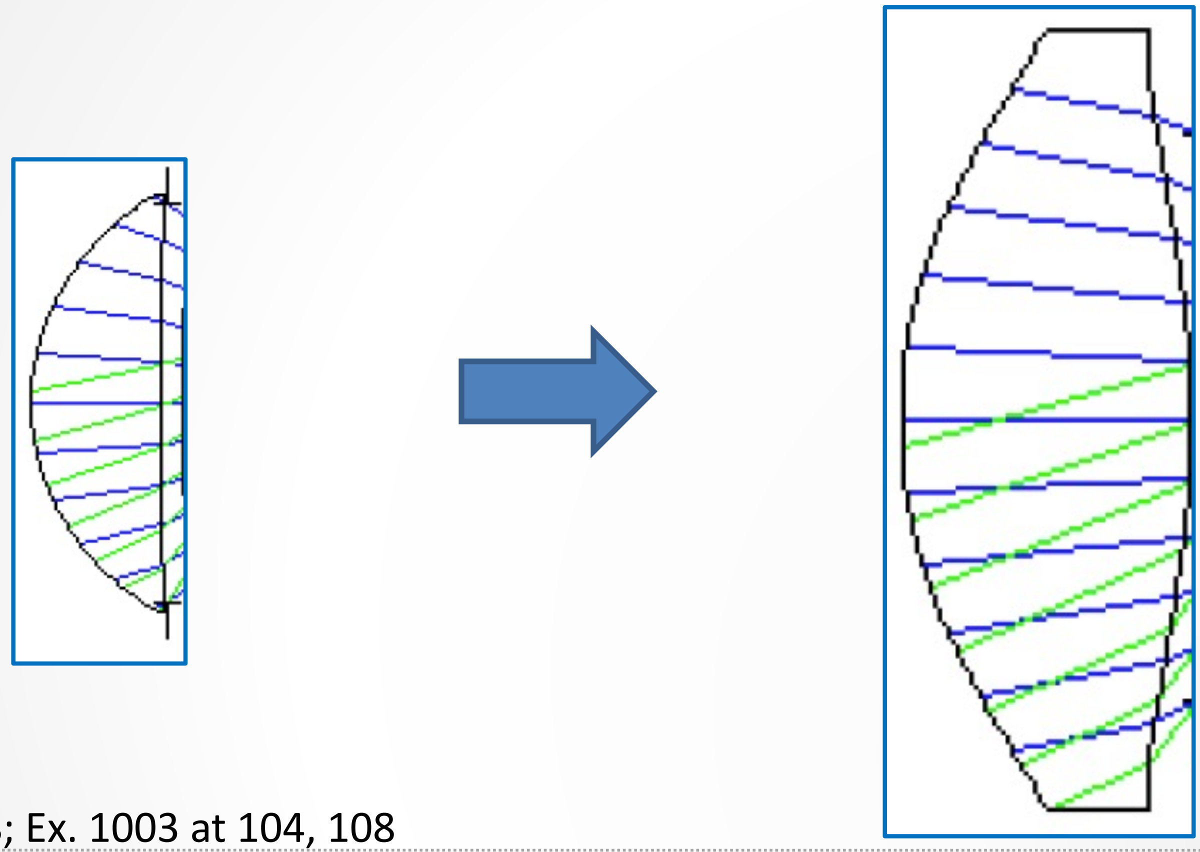
8. The lens assembly of claim **5**, wherein lens element L_{1_1} has a convex image-side surface.

19. The lens assembly of claim **17**, wherein the TTL is equal or smaller than 6.0 mm and wherein lens element L_{1_1} has an image-side surface diameter between 2.3 mm and 2.5 mm.

24. The lens assembly of claim **21**, wherein lens element L_{1_1} has a convex image-side surface.

Ex. 1001, 8:40–10:19

Modifying Ogino Example 5, Again: First Lens Element



POR at 57–58; Ex. 1003 at 104, 108

Modifying Ogino Example 5, Again: First Lens Element

Dr. Jose Sasian
Petitioner's Expert

Q. Am I correct that the only values on Page 11 from the rows defining the first lens element that match any values in Ogino Example 5 are the index of refraction and the Abbe number of the glass used?

A. And the question refers to the first lens?

Q. Correct.

A. Yes. I believe so.

POR at 58; Ex. 2003 at 48:15–24

Ogino Examples: Other F# Values

EXAMPLE 1			
Fno. = 2.47	ω= 35.2°	ω= 35.2°	ω= 35.2°
EXAMPLE 2			
Fno. = 2.46	ω= 35.1°	ω= 35.1°	ω= 35.1°
EXAMPLE 3			
Fno. = 2.45	ω= 35.2°	ω= 35.2°	ω= 35.2°
EXAMPLE 4			
Fno. = 3.04	ω= 32.5°	ω= 32.5°	ω= 32.5°
EXAMPLE 5			
Fno. = 3.94	ω= 25.9°	ω= 25.9°	ω= 25.9°
EXAMPLE 6			
Fno. = 2.64	ω= 29.8°	ω= 29.8°	ω= 29.8°

POR at 60; Ex. 1005, Figs. 8–13

Ogino First Lens Element Has Concave Image Surface

In the imaging lens L, the first lens L1 has a positive refractive power in the vicinity of the optical axis, and has a meniscus shape which is convex toward the object side in the vicinity of the optical axis. As shown in the embodiments, by making the first lens L1, which is a lens closest to the object, have a positive refractive power and have a meniscus shape which is convex toward the object side in the vicinity of the optical axis, the position of the rear side principal point of the first lens L1 can be set to be close to the object, and thus it is possible to appropriately reduce the total length.

POR at 56–57; Ex. 1005 at 7:31–37

Ogino First Lens Element Has Concave Image Surface

Dr. Tom Milster
Patent Owner's Expert

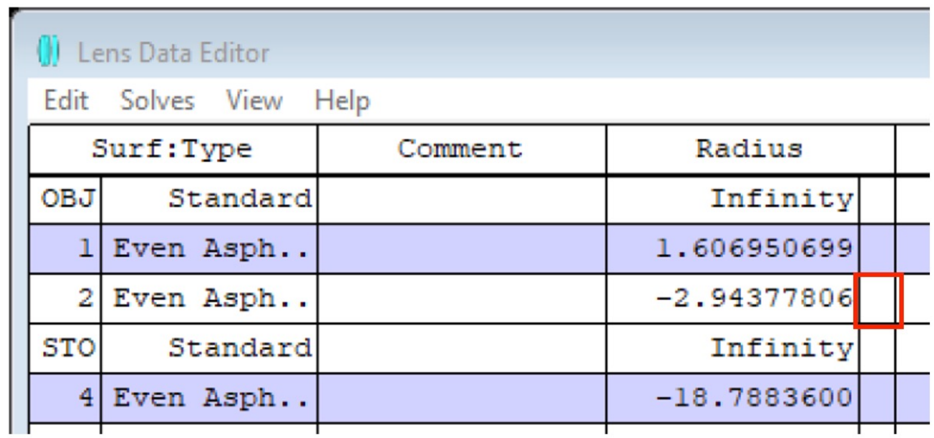
"The fact that the first lens element has a concave image-side surface is a feature of every example in Ogino and is described by Ogino as a defining feature of its invention."

POR at 56; Ex. 2001, ¶ 126

Dr. Sasián Produced a Convex Image-Side Surface By Fixing the Radius of Curvature to Be Negative

Dr. Tom Milster
Patent Owner's Expert

"The blank box to the right of the radius of curvature for this image-side surface indicates that this value was fixed (and thus that that surface was fixed to be convex) during the run of Zemax that produced the screen capture:"



Lens Data Editor

Edit Solves View Help

Surf:Type		Comment	Radius
OBJ	Standard		Infinity
1	Even Asph..		1.606950699
2	Even Asph..		-2.94377806
STO	Standard		Infinity
4	Even Asph..		-18.7883600

POR at 61; Ex. 2001, ¶ 136; Ex. 1003 at 111

Dr. Sasián Did Not Explain and Could Not Remember How He Obtained a Negative Radius of Curvature

Dr. Jose Sasian
Petitioner's Expert

Q. So is it correct that they were generated automatically by the program and then you told Zemax to stop changing them as you performed further optimization?

A. Probably.

Q. And so the particular output we see on Page 111 reflects an optimization step where the aspheric coefficients were allowed to vary but the radii and thicknesses were not; is that right?

A. Perhaps. Perhaps.

Q. Why do you say, "Perhaps"?

A. It appears so that -- because I don't remember exactly the -- the sequence. . . .

POR at 62; Ex. 2003 at 50:18–53:9

No Motivation or Explanation for Changing Ogino's Lens from Concave to Convex

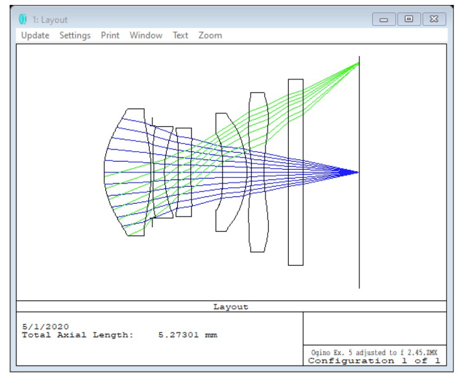
- No explanation for why a POSITA would ignore Ogino's teachings on lens shape
- Only explanation for even changing radius of curvature is vague statement "due to location of the aperture"
- No examples cited of prior art with bi-convex first lens shape
- No benefits or other motivation cited for bi-convex shape
- The fact that the Board found it obvious to change Ogino Example 6's second lens from biconcave to menicus based on Chen II in IPR2018-01140 does not make it obvious to change the shape of Ogino Example 5's first lens based on nothing at all.

POR at 63; SR at 13–15

What F# Did Dr. Sasián Actually Use? 2.45 or 2.12?

Dr. Jose Sasian
Petitioner's Expert

C. Ogino Example 5 modified for F#=2.45 using Zemax (v. 02/14/2011)



Steps for modification:

1) Starting with Ogino Ex. 5 at F#=2.8;
2) Re-optimize lens with only lens L1 radii (due to location of the aperture), airspaces, and aspheric coefficients;

EFL=5.49; TTL=5.273; EPD=2.59; F#=2.12; f1=2.064 mm; f2-f5 remain unchanged (data calculated for standard wavelength of 587 nm).

Apple v. Corephotonics 108 APPL-1003

POR at 60–61; SR at 16–17; Ex. 1003 at 108

What F# Did Dr. Sasián Actually Use? 2.45 or 2.12?

Dr. Jose Sasian
Petitioner's Expert

EFL=5.48951
TTL=5.27301
ENPD=2.23915
F/#=2.45
F1=2.063807

San-serif, proportional font
Manually typed by Sasián
from memory

Merit Function Editor: 4.334918E-003

Edit Tools View Help

Oper #					Target	Weight	Value	% Contrib
10: TOTR					0.0000000000000	0.0000000000000	5.2730112105151	0.0000000000000
11: EFFL					0.0000000000000	0.0000000000000	5.4859093491707	0.0000000000000
12: EFLY					0.0000000000000	0.0000000000000	2.0638078250490	0.0000000000000
13: EFLY					0.0000000000000	0.0000000000000	-3.166282996806	0.0000000000000
14: EFLY					0.0000000000000	0.0000000000000	-6.952349725125	0.0000000000000
15: EFLY					0.0000000000000	0.0000000000000	2.7359223736945	0.0000000000000
16: EFLY					0.0000000000000	0.0000000000000	-2.453953198435	0.0000000000000

Serif, fixed-width font
Zemax screen shoot

SR at 16–17; Ex. 1037, ¶ 33

What F# Did Dr. Sasián Actually Use? 2.45 or 2.12?

Q. If I could -- yeah. I mean, if I could interrupt, I think the EFL, TTL, and F1 values in that list of five values match, subject to rounding values, from the screen capture below that list of values. But I don't see the entrance pupil diameter or the f-number in that table.

A. Okay.

Q. So -- and -- yeah. And I was just wondering where this came from. It doesn't seem to be the font that ZEMAX uses in its output. It looks like ZEMAX uses a serif font, and this font is sans serif. So where did this list of five values in your paragraph 33 come from?

A. Yes. The font is not the same, because I manually wrote those lines on --

Dr. Jose Sasian
Petitioner's Expert

SR at 16–17; Ex. 2012 at 101:1–15

What F# Did Dr. Sasián Actually Use? 2.45 or 2.12?

Q. And the f-number equal to 2.45, what were you looking at when you typed in those numbers?

A. I think, in this case, you have to tell the program what would be the f-number, and you just request the f-number to be 2.45, and then you know it's 2.45.

Q. So 2.45, you believe, is a number that you typed into ZEMAX sometime back in April or May of 2020, when you were doing the original work for the original declaration?

A. As I recall right now, yes.

Dr. Jose Sasian
Petitioner's Expert

No motivation provided for modifying Ogino Example 5 to have an F# of 2.12

SR at 13–15

Ground 4

Dependent Claims 16 and 30 – F# 2.9 and L11/L1e < 3

US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.:** **US 10,330,897 B2**
(45) **Date of Patent:** ***Jun. 25, 2019**

(54) **MINIATURE TELEPHOTO LENS ASSEMBLY**

(71) Applicant: **Corephotonics Ltd.**, Tel-Aviv (IL)

(72) Inventors: **Michael Dror**, Nes Ziona (IL); **Ephraim Goldenberg**, Ashdod (IL); **Gal Shabtay**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/976,391**

(22) Filed: **May 10, 2018**

(65) **Prior Publication Data**

US 2018/0275374 A1 Sep. 27, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/817,235, filed on Nov. 19, 2017, which is a continuation of application
(Continued)

(51) **Int. Cl.**
G02B 13/00 (2006.01)
G02B 13/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 13/0045*** (2013.01); ***G02B 1/041*** (2013.01); ***G02B 9/60*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041;
(Continued)

(56) **References Cited**

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(Continued)

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JP 1966006865 4/1966
(Continued)

OTHER PUBLICATIONS

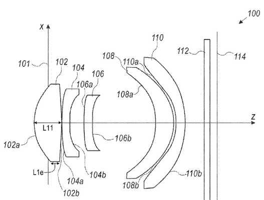
A compact and cost effective design for cell phone zoom lens, Chang et al., Sep. 2007, 8 pages.
(Continued)

Primary Examiner — Evelyn A Lester
(74) *Attorney, Agent, or Firm* — Nathan & Associates; Menachem Nathan

(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 f1<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.

30 Claims, 6 Drawing Sheets



2. The lens assembly of claim **1**, wherein the TTL is equal or smaller than 6.0 mm and wherein the lens assembly has a f-number F#<2.9.

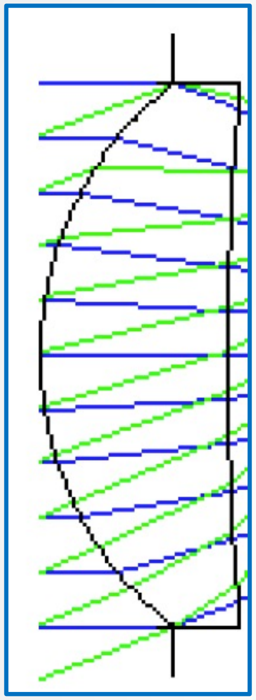
16. The lens assembly of claim **2**, wherein the lens assembly further includes a ratio between a largest optical axis thickness L**11** and a circumferential edge thickness Lle of lens element L_{11} of L**11**/L**1***e*<3.

18. The lens assembly of claim **17**, wherein the TTL is equal or smaller than 6.0 mm and wherein the lens assembly has a f-number F#<2.9.

30. The lens assembly of claim **18**, wherein the lens assembly further includes a ratio between a largest optical axis thickness L**11** and a circumferential edge thickness L**1***e* of lens element L_{1_1} of L**11**/L**1***e*<3.

Ex. 1001, 8:37–10:37

Setting Chen's Unspecified Object-Side Lens Diameter



1.2375 mm = Semi-Diameter First Lens Object-Side Surface

1.2333 mm = Semi-Diameter of Aperture Stop

Difference = 0.0042 mm

POR at 64, 66; Ex. 1003 at 115; Ex. 2001, ¶ 142

Setting Chen's Unspecified Object-Side Lens Diameter

Dr. Tom Milster
Patent Owner's Expert

"As this shows, the bundle, and thus the entrance pupil, extends all the way across the left surface of the lens. Apple has not proposed making the lens smaller, but if it had, the lens cannot be made smaller without reducing the entrance pupil diameter and increasing the f-number.

"Likewise, Apple has not proposed making the lens larger. But, if it had, the largest that the lens semi-diameter could be without increasing the center-to-edge thickness ratio above 3 would be less than 1.249 mm, approximately 0.012 mm larger (less than 1% larger) than Dr. Sasián proposes."

POR at 65–66; Ex. 2001, ¶¶ 144–145

Apple's Ground 4 Obviousness Theory Rests on Beich and on Using Injection Molded Plastic

Dr. Jose Sasian
Petitioner's Expert

"Since Example 1 would preferably have been manufactured via injection molding, as discussed above, and to the extent that Chen does not provide manufacturing parameters, a POSITA would have looked to polymer injection molding references such as Beich, which 'discuss[es] the polymer optics manufacturing process and examine[s] the best practices to use when working with a polymer optics manufacturer.'"

POR at 6; Ex. 1003, ¶ 81

Ground 4 – Limits of Manufacturing Precision

Beich Manufacturing Tolerances:

Attribute	Rules of Thumb Tolerances
Radius of Curvature	± 0.50%
EFL	± 1.0%
Center Thickness	± 0.020mm
Diameter	± 0.020mm
Wedge (TIR) in the Element	< 0.010mm
S1 to S2 Displacement (across the parting line)	< 0.020mm
Surface Figure Error	≤ 2 fringes per 25.4mm (2 fringes = 1 wave @ 632nm)
Surface Irregularity	≤ 1 fringes per 25.4mm (2 fringes = 1 wave @ 632nm)
Scratch-Dig Specification	40-20
Surface Roughness (RMS)	≤ 100 Å
Diameter to Center Thickness Ratio	< 4:1
Center Thickness to Edge Thickness Ratio	< 3:1
Part to Part Repeatability (in a one cavity mold)	< 0.50%

Difference in diameter between first lens and aperture stop is only 0.008 mm.

POR at 66–67; Ex. 1007 at 7

Ground 4 – Theory Requires Unachievable Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"As noted above, the semi-diameter of the first lens is only 0.004 mm larger than the stop. If the lens is too small by 0.020 mm in diameter (0.010 mm in semi-diameter), this will make the semi-diameter of the first lens smaller than the semi-diameter of the stop by 6 µm [0.006 mm]. This is even without taking into account other sources of variation in the diameter of the stop and the alignment of the components. A first lens smaller than the stop will mean that light will leak and scatter around the lens and cause a haze in the image that is highly undesirable. For this reason alone, a POSITA would make the first lens from Chen larger in diameter than Dr. Sasián proposes, something that Dr. Sasián does not consider."

POR at 66–67; Ex. 2001, ¶ 147

Ground 4 – Theory Requires Unachievable Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"But even if Dr. Sasián had proposed increasing the size of the lens to be as large as possible while keeping the thickness ratio under 3, the largest possible semidiameter (under 1.249 mm) would be less than 0.016 mm larger than the stop. A POSITA would recognize that this is unacceptable, given the multiple sources of manufacturing variation of the order of 0.010 mm in semidiameter and adding under the root sum square rule. (Ex. 2004, Sasián at 116–117.)"

POR at 67; Ex. 2001, ¶ 148

Ground 4 – Theory Requires Unachievable Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"The lens is unacceptable even without taking into account the need to oversize 'considerably beyond the clear apertures' (Ex. 1019, Handbook of Optics, Vol. 2 at 34.16.) or by around 4–10% (Ex. 2006, Symmons at 103), or the need for room for rounded corners, discussed in connection with ground 2."

POR at 67; Ex. 2001, ¶ 149

Ground 4 – Theory Requires Unachievable Manufacturing Precision

Dr. Tom Milster
Patent Owner's Expert

"[A] POSITA would recognize that the combination of Chen, Iwasaki, and Beich proposed by Dr. Sasián would not be a practical lens, based on the very manufacturing rules of thumb in Beich, among other reasons. Even if a POSITA was motivated to make a lens with center-to-edge thickness ratio less than 3, that POSITA would not have been motivated to make the Chen Example 1 lens with that ratio, as proposed by Dr. Sasián."

POR at 68; Ex. 2001, ¶ 151

Apple's Response: Manufacturing Considerations Do Not Matter

would have been possible for a POSITA to produce. Instead, Patent Owner complains that the lens design cannot be oversized to meet various alleged manufacturing tolerances for injection molded lenses. *See* Response, pp.65-67. As discussed above, these manufacturing considerations are not included in claims 16 and 30 or anywhere else in the '897 patent. *See* APPL-1028, 85:20-86:9.

But manufacturing considerations are the <u>entire justification</u> for combining Chen and Iwasaki with Beich

SR 18-20; Reply at 28

Apple's Argument That '897 Patent Examples Are Unmanufacturable Ignores Its Disclosures and Rests on Faulty Calculations

Dr. Jose Sasian
Petitioner's Expert

SR at 24–25;
Ex. 2012, 88:13–89:15

Q. So the numbers in the patent are a little different than the numbers that you calculated. In particular, for Example Number 2, according to paragraph 40 of your declaration, you calculated an L11/L1e ratio of 3.049, whereas the patent says that ratio is 2.916; would you agree?

. . .

A. Okay. Thank you. Yeah, I see there is a difference.

Q. Prior to the last few minutes, were you aware of this difference between the numbers that you gave for the ratio in your declaration and the number given for the ratio in the patent itself?

A. No, I wasn't aware of the difference.

Apple's Argument That '897 Patent Examples Are Unmanufacturable Ignores Its Disclosures and Rests on Faulty Calculations

Dr. Jose Sasian
Petitioner's Expert

Q. So would one explanation for the difference be that the calculation of L11/L1e that resulted in the values in Column 2 of the patent used diameters that weren't exactly the values shown in the tables but simply round to be the values in the table?

A. Well, rounding could be the answer. Yes, it could be a rounding issue.

Q. So to speak concretely about Example 2 from the patent, in Table 3, the first and second surfaces of the first lens are listed as having a diameter of 2.6, but if the -- and that's what you used to calculate the ratio in your declaration. But if the lens diameter were a little bit less than 2.6 but greater than 2.55, somewhere in there, you might get the centered-edge-thickness ratio that's reported in Column 2 of the patent?

A. Yeah, that would be the case.

SR at 26–27;
Ex. 2012, 90:17–91:14

’897 Patent Examples Are Manufacturable

US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.: US 10,330,897 B2**
(45) **Date of Patent: *Jun. 25, 2019**

(54) **MINIATURE TELEPHOTO LENS ASSEMBLY**

(71) Applicant: **Corephotonics Ltd.**, Tel-Aviv (IL)

(72) Inventors: **Michael Dror**, Nes Ziona (IL); **Ephraim Goldenberg**, Ashdod (IL); **Gal Shabtay**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

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This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/976,391**

(22) Filed: **May 10, 2018**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 15/817,235, filed on Nov. 19, 2017, which is a continuation of application
(Continued)

(51) **Int. Cl.**
G02B 13/00 (2006.01)
G02B 13/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 13/0045*** (2013.01); ***G02B 1/041*** (2013.01); ***G02B 9/60*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041;
(Continued)

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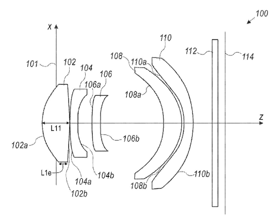
Primary Examiner — Evelyn A Lester
(74) *Attorney, Agent, or Firm* — Nathan & Associates; Menachem Nathan

(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 f1<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.

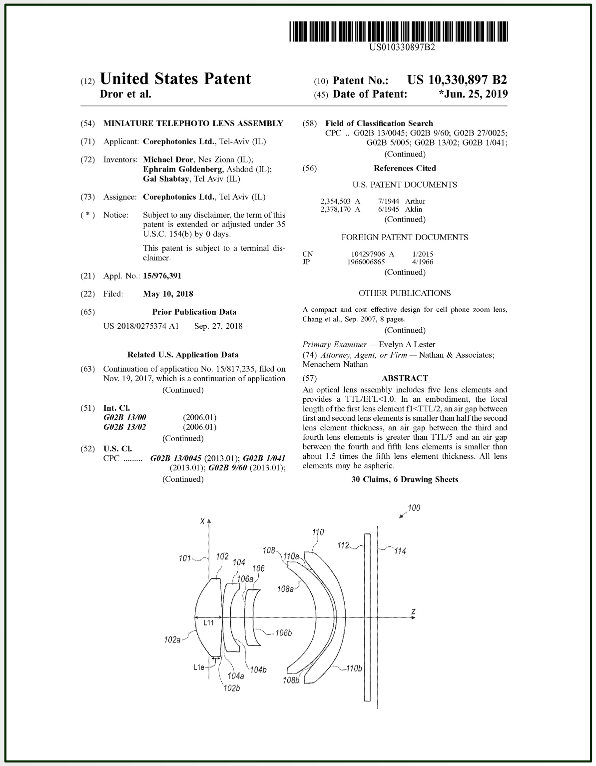
30 Claims, 6 Drawing Sheets



ability of the lens and its quality. Advantageously, the present inventors have succeeded in designing the first lens element to have a L**11**/L**1***e* ratio smaller than 4, smaller than 3.5, smaller than 3.2, smaller than 3.1 (respectively 3.01 for element **102** and 3.08 for element **302**) and even smaller than 3.0 (2.916 for element **202**). The significant reduction in the L**11**/L**1***e* ratio improves the manufacturability and increases the quality of lens assemblies disclosed herein.

SR at 23; Ex. 1001, 2:43–50

’897 Patent Examples Are Manufacturable



US010330897B2

(12) **United States Patent**
Dror et al.

(10) **Patent No.: US 10,330,897 B2**
(45) **Date of Patent: *Jun. 25, 2019**

(54) **MINIATURE TELEPHOTO LENS ASSEMBLY**

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(72) Inventors: **Michael Dror**, Nes Ziona (IL); **Ephraim Goldenberg**, Ashdod (IL); **Gal Shabtay**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(Continued)

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(Continued)

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30 Claims, 6 Drawing Sheets

TABLE 3

#	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

’897 Patent Example 2 first lens semi-diameter is 0.050 mm greater than stop semi-diameter.

Ground 4 combination first lens semi-diameter is only 0.004 mm greater than stop semi-diameter.

Beich semi-diameter tolerance is ±0.010 mm.

SR at 26, 28–29; Ex. 1001, 6:5–24

Thank You