

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MOTOROLA MOBILITY LLC,
Petitioner,

v.

LARGAN PRECISION CO., LTD.,
Patent Owner.

U.S. Patent No. 9,366,845
Issued: June 14, 2016
Application No. 14/488,106
Filed: September 16, 2014

Title: PHOTOGRAPHING OPTICAL LENS ASSEMBLY,
IMAGE CAPTURING UNIT AND ELECTRONIC DEVICE

DECLARATION OF TOM D. MILSTER, Ph.D.

MOTOROLA MOBILITY
EXHIBIT 1003

TABLE OF CONTENTS

	Page
I. INTRODUCTION AND ENGAGEMENT	8
II. BACKGROUND AND QUALIFICATIONS	8
III. MATERIALS CONSIDERED AND INFORMATION RELIED UPON REGARDING '845 PATENT.....	15
IV. UNDERSTANDING OF PATENT LAW	17
V. SUMMARY OF OPINIONS.....	21
VI. LEVEL OF ORDINARY SKILL IN THE ART.....	22
A. Publications Reflecting The Knowledge Of A POSITA	24
VII. STATE OF THE ART	25
A. The Lens Design Process Typically Involves Use Of Highly Sophisticated Software To Optimize Older Designs	25
B. Gullwing Lenses Were Often Used In Optical Systems, Especially Compact Camera Modules For Cell Phones, To Perform Field Corrections And Control Chief Ray Angles	30
1. Compact Lens Designs In The 2000s Included At Least One Gullwing Lens As The Last Lens.....	33
2. Lens Designs In The 2010s Included More Lenses, And More Gullwing Lenses, I n Response To Market Demand For Better Performance.....	35
3. By 2014, Lens Designer Knew That Gullwing Lens Pairs With Meniscus On-Axis Curvature Would Achieve Better Aberration Correction And Chief Ray Angle Control	36
VIII. OVERVIEW OF THE '845 PATENT	39
A. The '845 Specification	39
B. The Prosecution History.....	42

C.	The Challenged Claims	44
IX.	CLAIM CONSTRUCTION	46
X.	GROUND 1: CLAIMS 1-14, 16-27, 30, AND 32-34 ARE OBVIOUS OVER FUKAYA AND THE KNOWLEDGE OF A POSITA	46
A.	Fukaya (EX1004)	46
B.	Implementing Fukaya With A Gullwing Sixth Lens	48
C.	Claim Mapping.....	62
1.	Claim 1	62
a)	Element 1.1	62
b)	Element 1.2	63
c)	Element 1.3	64
d)	Element 1.4.....	66
e)	Element 1.5	67
f)	Element 1.6.....	69
g)	Element 1.7.....	71
h)	Element 1.8.....	74
i)	Element 1.9	75
j)	Element 1.10.....	76
2.	Claim 2.....	79
3.	Claim 3.....	80
4.	Claim 4.....	81
5.	Claim 5.....	82
a)	Element 5.1	82
b)	Element 5.2	83

6.	Claim 6.....	84
7.	Claim 7.....	85
8.	Claim 8.....	86
9.	Claim 9.....	88
10.	Claim 10.....	89
11.	Claim 11.....	90
12.	Claim 12.....	91
13.	Claim 13.....	92
14.	Claim 14.....	93
15.	Claim 16.....	95
16.	Claim 17.....	95
17.	Claim 18.....	97
	a) Element 18.1.....	97
	b) Element 18.2.....	98
	c) Element 18.3.....	98
18.	Claim 19.....	99
	a) Element 19.1.....	99
	b) Element 19.2.....	100
19.	Claim 20.....	100
	a) Elements 20.1-20.6.....	100
	b) Element 20.7.....	100
	c) Elements 20.8-20.9.....	101
	d) Element 20.10.....	102
20.	Claim 21.....	103
21.	Claim 22.....	104

22.	Claim 23	105
23.	Claim 24	105
24.	Claim 25	105
25.	Claim 26	106
26.	Claim 27	107
27.	Claim 30	108
28.	Claim 32	109
29.	Claim 33	110
30.	Claim 34	111
XI.	GROUND 2: CLAIMS 1-4, 7, 9-13, 15-16, 18-21, 23-24, AND 28-31 ARE OBVIOUS OVER CAI AND THE KNOWLEDGE OF A POSITA	112
A.	Cai (EX1005)	112
B.	Implementing Cai With A Gullwing Sixth Lens	115
C.	Claim Mapping	128
1.	Claim 1	128
a)	Element 1.1	129
b)	Element 1.2	130
c)	Element 1.3	131
d)	Element 1.4	133
e)	Element 1.5	134
f)	Element 1.6	136
g)	Element 1.7	138
h)	Element 1.8	141
i)	Element 1.9	143

j)	Element 1.10.....	144
2.	Claim 2.....	147
3.	Claim 3.....	148
4.	Claim 4.....	149
5.	Claim 7.....	150
6.	Claim 9.....	151
7.	Claim 10.....	153
8.	Claim 11.....	155
9.	Claim 12.....	156
10.	Claim 13.....	157
11.	Claim 15.....	158
12.	Claim 16.....	160
13.	Claim 18.....	161
a)	Element 18.1.....	161
b)	Element 18.2.....	162
c)	Element 18.3.....	162
14.	Claim 19.....	163
a)	Element 19.1.....	163
b)	Element 19.2.....	163
15.	Claim 20.....	163
a)	Elements 20.1-20.6.....	163
b)	Element 20.7.....	163
c)	Elements 20.8-20.9.....	164
d)	Element 20.10.....	164
16.	Claim 21.....	165

17.	Claim 23	167
18.	Claim 24	167
19.	Claim 28	167
20.	Claim 29	169
21.	Claim 30	171
22.	Claim 31	172

I, Tom D. Milster, Ph.D., do hereby declare as follows:

I. INTRODUCTION AND ENGAGEMENT

1. I have been retained as an independent expert on behalf of Motorola Mobility LLC in connection with the above-captioned Petition for *Inter Partes* Review (“IPR”) to provide my analyses and opinions on certain technical issues related to U.S. Patent No. 9,366,845 (hereinafter “the ’845 Patent”).

2. I am being compensated at my usual and customary rate for the time I spent in connection with this IPR. My compensation is not affected by the outcome of this IPR.

3. Specifically, I have been asked to provide my opinions regarding whether claims 1-34 (each a “Challenged Claim” and collectively the “Challenged Claims”) of the ’845 patent would have been obvious to a person having ordinary skill in the art (“POSITA”) as of August 1, 2014. It is my opinion that each Challenged Claim would have been obvious to a POSITA after reviewing the prior art discussed herein.

II. BACKGROUND AND QUALIFICATIONS

4. I am a Professor of Optical Sciences in the College of Optical Sciences at the University of Arizona. My areas of expertise include the design and optimization of multi-lens optical systems, and the field of optical engineering more

generally. I worked in lens system design and the field of optical engineering for over thirty years. A copy of my curriculum vitae is appended to this declaration as Appendix A and provides a description of my professional experience, including my academic and employment history, publications, conference participation, awards and honors, and more. In formulating my opinions, I have relied upon my training, knowledge, and experience in the relevant art. The following paragraphs provide a brief summary of my relevant qualifications and professional experience.

5. I received a Bachelor of Science degree in Electrical Engineering from the University of Missouri in 1981 and a Doctorate in Optical Sciences from the University of Arizona in 1987. I worked for IBM as a staff optical engineer from 1986 to 1989, and I worked during the summer of 1989 for Lawrence Livermore National Laboratories. I joined the faculty at the University of Arizona's Wyant College of Optical Sciences in 1989.

6. For 40 years, I have been working, teaching, or researching in the field of optical devices. I worked for IBM for three years on the subject of optical storage developing miniature optical systems, and I have been teaching and researching at the University of Arizona for about 35 years.

7. I have written over 100 peer-reviewed papers in the field of optics. A number of these papers relate specifically to miniature optical devices and systems. My technical research has earned several recognitions and awards. For example, my

1995 paper entitled “Linear behavior of a near-field optical scanning system” was selected as a landmark paper in near-field optics.¹ My 1997 paper entitled “Objective lens design for multiple-layer optical data storage” was selected as one of the most 300 influential papers in lens design.² A recent paper entitled “Multiple-order diffractive engineered surface lenses” has been on the Applied Optics ‘Top Downloads’ list for three consecutive months.³ Two related papers, “Design aspects of large-aperture MODE lenses” in OSA Continuum,⁴ and “High-harmonic

¹ Kann, J. L., Milster, T. D., Froehlich, F. F., Ziolkowski, R. W., & Judkins, J. B. (1995). Linear behavior of a near-field optical scanning system. *JOSA A*, 12(8), 1677-1682.

² Milster, T. D., Upton, R. S., & Luo, H. (1999). Objective lens design for multiple-layer optical data storage. *Optical Engineering*, 38, 295-301.

³ Milster, T. D., Kim, Y. S., Wang, Z., & Purvin, K. (2020). Multiple-order diffractive engineered surface lenses. *Applied Optics*, 59(26), 7900-7906.

⁴ Milster, T. D., Wang, Z., & Kim, Y. S. (2021). Design aspects of large-aperture MODE lenses. *OSA Continuum*, 4(1), 171-181.

diffractive lens color compensation” in *Applied Optics*⁵ were also editor’s picks and top downloads.

8. I am a named inventor on 17 US patents concerning various advanced optical systems, like data detectors and systems for optical data storage that include miniature optics (US 4,823,220, US 6,111,839, US 6,577,584, US 6,577,584, US 7,796,487, US 7,974,170, US 8,003,187, US 11,456,010), miniature lens designs for fiber communications (US 6,498,875), vacuum ultraviolet systems (US 7,916,291, US 8,472,111, US 9,081,193), miniature-optic blood sensors (9,072,473), near-field sensors (US 8,737,178), diffractive lenses (US 11,671,706), and holography (US 9,116,303, US 10,866,406).

9. I have contributed chapters to eleven books about optics, including one chapter entitled “Miniature and Micro Optics,” which has been published in the last three editions of the *Handbook of Optics*. This chapter discusses the design and use of miniature optical elements, included molded elements, that are similar to those found in cell phone cameras. Material for this chapter was derived from a popular short course I taught for a professional society over a period of about 10 years, and

⁵ Wang, Z., Kim, Y. S., & Milster, T. D. (2021). High-harmonic diffractive lens color compensation. *Applied Optics*, 60(19), D73-D82.

it drew on the experience I received working for IBM and my first several years working as faculty at the University of Arizona.

10. One significant accomplishment I have achieved through my research is breaking the “diffraction barrier” by applying the techniques of near-field scanning optical microscopy (NSOM)⁶ (*see* Footnote 1), developing specialized near-field probes⁷, and applying the solid immersion lens (SIL) in various ways^{8,9}. This work led me to develop new, more efficient miniature optical probes and high-

⁶ Froehlich, F. F., & Milster, T. D. (1995). Detection of probe dither motion in near-field scanning optical microscopy. *Applied Optics*, 34(31), 7273-7279.

⁷ Hirota, K., Milster, T. D., Zhang, Y., & Erwin, J. K. (2000). Design of a near-field probe for optical recording using a 3-dimensional finite difference time domain method. *Japanese Journal of Applied Physics*, 39(2S), 973.

⁸ Shimura, K., Milster, T. D., Jo, J. S., & Hirota, K. (2000). Pupil plane filtering for optical pickup heads with effective numerical aperture of 1.1 and 2.0. *Japanese Journal of Applied Physics*, 39(2S), 897.

⁹ Zhang, J., Kim, Y., Kim, Y., Valencia, R., Milster, T. D., & Dozer, D. (2009). High resolution semiconductor inspection by using solid immersion lenses. *Japanese Journal of Applied Physics*, 48(3S1), 03A043.

performance miniature optical systems.¹⁰ In these projects, my students and I applied a mixture of theory, optical design and fabrication techniques to produce real examples of the miniature and micro-optical lenses that we envisioned. One of my recent conference presentations entitled “Practical measurement of cell-phone camera focal length,” specifically addresses the properties of modern cell-phone camera lenses.¹¹

11. One of my current projects is directly related to molding optical elements. A recent paper entitled “Precision glass molding of diffractive optical elements with high surface quality” specifically addresses issues for molding small

¹⁰ Zhang, Y., Milster, T. D., Kim, J. S., & Park, S. K. (2004). Advanced lens design for bit-wise volumetric optical data storage. *Japanese Journal of Applied Physics*, 43(7S), 4929.

¹¹ Milster, T. D., & Kuhn, W. P. (2020, August). Practical measurement of cell-phone camera lens focal length. In *Optical System Alignment, Tolerancing, and Verification XIII* (Vol. 11488, p. 1148807). International Society for Optics and Photonics.

glass structures.¹² My students, staff and I developed a complete process for molding glass structures with micrometer-size structures and extremely high quality. Although not mentioned in the publication, we also worked on molding plastic lens structures. This experience relates directly to the fabrication of miniature optical components, like those under review for this case.

12. I am a Fellow member of the Optical Society of America and the SPIE-International Society for Optics and Photonics. I am also a Senior Member of the National Association of Inventors.

13. In addition to my research, I have served as a technical expert in both district courts and ITC patent litigation in the United States of America. In the last 10 years, I have testified in the following matters: *American Medical Systems, Inc. and Laserscope v. Laser Peripherals, LLC*, Civil Action No. 08-CV-4798, United States District Court for the District of Minnesota; *American Medical Systems, Inc. and Laserscope v. Biolitec, Inc., Biolitec AG, Biolitec SIA, Ceramoptec Industries, Inc., Ceramoptec GmbH and Andaoptec, LTD*, Civil Action No. 3:08-CV-30061-MAP, United States District Court for the District of Massachusetts, as well in an

¹² Zhang, Y., Liang, R., Spires, O. J., Yin, S., Yi, A., & Milster, T. D. (2020). Precision glass molding of diffractive optical elements with high surface quality. *Optics Letters*, 45(23), 6438-6441.

arbitration matter between Corephotonics Ltd. and Ningbo Sunny Opotech Co., Ltd., Case No. HKIAC/A19025; *Apple vs. Corephotonics, Ltd.*, Case Nos. IPR2020-00878, IPR2020-00896, and IPR2020-00897; *Motorola Mobility LLC v. Largan Precision Co., Ltd.*, IPR Nos. IPR2022-01023, IPR2022-01022, IPR2022-01156, IPR2022-01170, IPR2022-01172, and IPR2024-00688.

14. Further detail on my work and other experience can be found in my CV, attached as Appendix A.

III. MATERIALS CONSIDERED AND INFORMATION RELIED UPON REGARDING '845 PATENT

15. In preparing this declaration and arriving at my opinions, I have reviewed the following materials bearing Exhibit Nos. that I understand are being referenced in an IPR proceeding where my declaration may be referenced.

LIST OF EXHIBITS

No.	Description
1001	U.S. Patent No. 9,366,845 (“ the '845 patent ”)
1002	File History of U.S. Patent No. 9,366,845
1003	N/A
1004	U.S. Patent Application No. 2014/0139719 (“ Fukaya ”)
1005	Certified Translation and Original Copy of Chinese Patent Grant No. CN 202886720 U (“ Cai ”)
1006	U.S. Patent Application No. 2014/0376105 (“ Sekine ”)

No.	Description
1007	U.S. Patent Application No. 2015/0103414 (“ Baik ”)
1008	U.S. Patent Application No. 2014/0211324 (“ Ishizaka ”)
1009	Michael P. Schaub, <i>The Design of Plastic Optical Systems</i> (SPIE Press 2009) (excerpts) (“ Schaub ”)
1010	Warren J. Smith, <i>Modern Lens Design</i> (2d ed. 2005) (excerpts) (“ Smith ”)
1011	Robert E. Fischer et al., <i>Optical System Design</i> (2008) (excerpts) (“ Fischer ”)
1012	Joseph M. Geary, <i>Introduction to Lens Design With Practical ZEMAX® Examples</i> (2002) (excerpts) (“ Geary ”)
1013	Jane Bareau & Peter P. Clark, <i>The Optics of Miniature Digital Camera Modules</i> (2006) (“ Bareau ”)
1014	Rob Bates, <i>Performance and Tolerance Sensitivity Optimization of Highly Aspheric Miniature Camera Lenses</i> , Proc. SPIE 7793 (Aug. 23, 2010) (“ Bates ”)
1015	Stefan Bäumer, <i>Handbook of Plastic Optics</i> (2d ed. 2010) (excerpts) (“ Bäumer ”)
1016	Julie Bentley & Craig Olson, <i>Field Guide to Lens Design</i> (2012) (“ Bentley Guide ”)
1017	Rudolf Kingslake, <i>A History of the Photographic Lens</i> (1989) (“ Kingslake ”)
1018	Deposition Transcript of Julie L. Bentley, Ph.D. dated May 18, 2023 (“ Bentley Transcript ”)
1019	U.S. Patent No. 8,094,231 (“ Tsai-231 ”)

No.	Description
1020	U.S. Patent No. 7,394,602 (“ Chen-602 ”)
1021	U.S. Patent No. 7,738,186 (“ Chen-186 ”)
1022	U.S. Patent No. 8,023,203 (“ Shyu ”)
1023	Thomas Steinich & Vladan Blahnik, <i>Optical Design of Camera Optics for Mobile Phones</i> (2012) (“ Steinich ”)
1024	U.S. Patent Application No. 2015/0212298 (“ Shinohara-298 ”)
1025	U.S. Patent No. 9,507,125 (“ Hashimoto ”)
1026	U.S. Patent No. 9,383,553 (“ Shinohara-553 ”)
1027	U.S. Patent No. 9,448,386 (“ Kubota-386 ”)
1028	U.S. Patent No. 8,780,464 (“ Huang-464 ”)
1029	U.S. Patent No. 9,146,380 (“ Kubota-380 ”)
1030	Kingslake & Johnson, <i>Lens Design Fundamentals</i> (2d ed. 2010) (“ Kingslake Fundamentals ”)
1031	List of Challenged Claims
1032	U.S. Patent No. 8,599,495 (“ Tsai ”)

IV. UNDERSTANDING OF PATENT LAW

16. I am not an attorney. For the purposes of this declaration, I have been informed about certain aspects of the law that are relevant to my opinions. My understanding of the law was provided to me by the Petitioner’s attorneys.

17. I understand that when considering the scope of the claims of a patent that the patent claim terms should generally be given the ordinary meaning that the

terms would have to a person of ordinary skill in the art in question after reading the patent as of the earliest claimed priority date.

18. I understand that the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the term appears, but in the context of the entire patent, including the specification. I further understand that the principal considerations regarding the scope and meaning of the claims are the plain language of the claim (including the surrounding claim language and context), the patent specification, and the prosecution history. I understand that while a claim is to be read in light of the specification, one must generally avoid importing limitations into the claim from the specification. I am also informed that the prosecution history can often inform the meaning of the claim by demonstrating how the inventor understood the invention and whether the inventor limited the invention in the course of prosecution, making the claim scope narrower than it would otherwise be. I applied these understandings when considering the scope and meaning of the claims of the '845 patent.

19. I understand that a prior art reference anticipates an asserted claim, and thus renders the claim unpatentable, if all elements of the claim are disclosed in that prior art reference, either explicitly or inherently (i.e., necessarily present or implied).

20. I further understand that a claim is unpatentable if it would have been obvious. Obviousness of a claim requires that the claim would have been obvious from the perspective of a POSITA at the time the alleged invention was made. I understand that a claim could have been obvious from a single prior art reference or from a combination of two or more prior art references.

21. I understand that an obviousness analysis requires an understanding of the scope and content of the prior art, any differences between the alleged invention and the prior art, and the level of ordinary skill in evaluating the pertinent art.

22. I further understand that a claim would have been obvious if it unites old elements with no change to their respective functions, or merely substitutes one element for another known in the field, and that combination yields predictable results. While it may be helpful to identify a reason for this combination, I understand that there is no strict requirement of finding an express teaching, suggestion, or motivation to combine within the references. When a product is available, design incentives and other market forces can prompt variations of it, either in the same field or different one. If a POSITA can implement a predictable variation, obviousness likely bars its patentability. For the same reason, if a technique has been used to improve one device and a POSITA would recognize that it would improve similar devices in the same way, using the technique would have been obvious. I understand that a claim would have been obvious if common sense

directs one to combine multiple prior art references or add missing features to reproduce the alleged invention recited in the claims.

23. I further understand that certain factors may support or rebut the obviousness of a claim. I understand that such secondary considerations include, among other things, commercial success of the patented invention, skepticism of those having ordinary skill in the art at the time of invention, unexpected results of the invention, any long-felt but unsolved need in the art that was satisfied by the alleged invention, the failure of others to make the alleged invention, praise of the alleged invention by those having ordinary skill in the art, and copying of the alleged invention by others in the field. I understand that there must be a nexus—a connection—between any such secondary considerations and the alleged invention. I also understand that contemporaneous and independent invention by others is a secondary consideration tending to show obviousness.

24. I am not aware of any allegations by the named inventors of the '845 patent or any assignee of the '845 patent that any secondary considerations tend to rebut the obviousness of any Challenged Claim of the '845 patent.

25. I understand that in considering obviousness, it is important not to determine obviousness using the benefit of hindsight derived from the descriptions found in the patent being considered.

26. I understand that other challenges to the patentability of a patent, including patent ineligibility, enablement, written description, and definiteness or clarity of claim language, cannot be raised in IPR proceedings before the Board.

27. I understand that Petitioner has the burden of proving unpatentability by a preponderance of evidence, which means that the claims are more likely than not unpatentable.

28. The analysis in this declaration is in accordance with the above-stated legal principles.

V. SUMMARY OF OPINIONS

29. In forming the opinions set forth herein, I have considered:

- a) The documents listed above;
- b) My education, knowledge, skills, and experience in the fields of optics and lens design; and
- c) The level of skill of a person having ordinary skill in the art (“POSITA”) at the time of the alleged invention of the ’845 patent, which I have assumed is August 1, 2014.

30. As I explain in further detail below, it is my professional and expert opinion that claims 1-34 of the ’845 patent are obvious over the prior art.

VI. LEVEL OF ORDINARY SKILL IN THE ART

31. I understand that in evaluating the validity of the '845 patent claims, the content of a patent or printed publication prior art should be interpreted the way a person of ordinary skill in the art ("POSITA") would have interpreted the prior art as of the effective filing date of the challenged patent claims. I assume that the effective filing date is the date of the Taiwanese patent application to which the '845 patent alleges priority, namely August 1, 2014. My understanding of a POSITA, as set forth below, would not materially differ if the effective filing date were the U.S. application date of the '845 patent, namely September 16, 2014.

32. I understand that factors that may be considered in determining the level of ordinary skill in the art at the time of the effective filing date of the challenged patents include: (1) the educational level of the inventor; (2) type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology; and (6) educational level of active workers in the field.

33. A person having ordinary skill in the art ("POSITA") would include someone who had, in August 2014, (i) a Bachelor's degree in Physics, Optical Sciences, or equivalent training, as well as (ii) approximately three years of experience in designing multi-lens optical systems. More education, e.g., a Master's or Ph.D., would compensate for less work experience and vice versa.

34. A POSITA would have had experience in analyzing, tolerancing, adjusting, and optimizing multi-lens systems for manufacturing, and would have been familiar with the specifications of lens systems and their fabrication. In addition, a POSITA would have known how to use lens design software such as Code V, Oslo, and Zemax, and would have taken a lens design course or had equivalent training. A POSITA would have regularly used such software to create new lens designs, often using pre-existing lens designs as a starting point and then performing routine optimizations to reach a desired design. A POSITA would have followed and regularly consulted books, articles, and other publications by the Society of Photo-Optical Instrumentation Engineers (“SPIE”).

35. Further, a POSITA would have understood the fundamentals of optical aberration theory and understood and used standard techniques for making lenses cheaper and more effective, especially for lens systems used in mobile devices.

36. Additional knowledge and skills possessed by a POSITA are discussed below in Section VII.

37. I would have met the requirements of a POSITA during the pertinent timeframe. Some of my past students would also have qualified as POSITAs on these dates. Thus, I am qualified to opine on the issues discussed below.

A. Publications Reflecting The Knowledge Of A POSITA

38. The knowledge of a POSITA is reflected in several known books on lens design, including Schaub (EX1009), Smith (EX1010), Fischer (EX1011), and Bentley (EX1016). Other well-known industry publications also reflect the knowledge of a POSITA. These books and publications, which confirm my own opinions as to the knowledge of a POSITA, are noted in the following paragraphs.

39. Schaub (EX1009) was published by SPIE in 2009, as part of the SPIE “Tutorial Texts” series (*e.g.*, EX1009, v). Schaub discusses many aspects of designing optical systems with plastic lenses. At least due to its publication by SPIE, Schaub would have been known and readily available to a POSITA in August 2014.

40. Smith (EX1010) published in 2005, and has been a well-known and frequently consulted treatise on lens design. It would have been known and readily available to a POSITA in August 2014.

41. Fischer (EX1011) published in 2008, and has been a well-known and consulted treatise on lens design. It would have been known and readily available to a POSITA in August 2014.

42. Bentley (EX1016) was published by SPIE in 2012 as a part of its “SPIE Field Guides” series, which are “written directly for the practicing engineer or scientist” as “a hand desk or briefcase reference that provides basic, essential

information about optical principles, techniques, or phenomena.” EX1016, iii. It would have been known and readily available to a POSITA in August 2014.

VII. STATE OF THE ART

A. The Lens Design Process Typically Involves Use Of Highly Sophisticated Software To Optimize Older Designs

43. At a high level, the camera lens design process is analogous to the process you experience at the optometrist. The optometrist begins by programming a system with your old lens prescription, and then flips through a series of modifications, asking for each, “which is better, number 1 or number 2?” After testing a series of possible changes, the optometrist develops a new, optimized, lens prescription that suits your current visual needs (improved distance vision, correction of astigmatism, etc.).

44. Similarly, a skilled lens designer begins with an older starting point design, and then implements and tests various modifications to develop a new, optimized lens system that suits particular needs of an end-user (improved image quality, shorter track length, increased field of view, etc.). Modern lens design relies on ZEMAX or other software programs, which “are highly sophisticated and enable the designer to perform a wide range of designs and analyses.” EX1009, 80. This process is shown below:

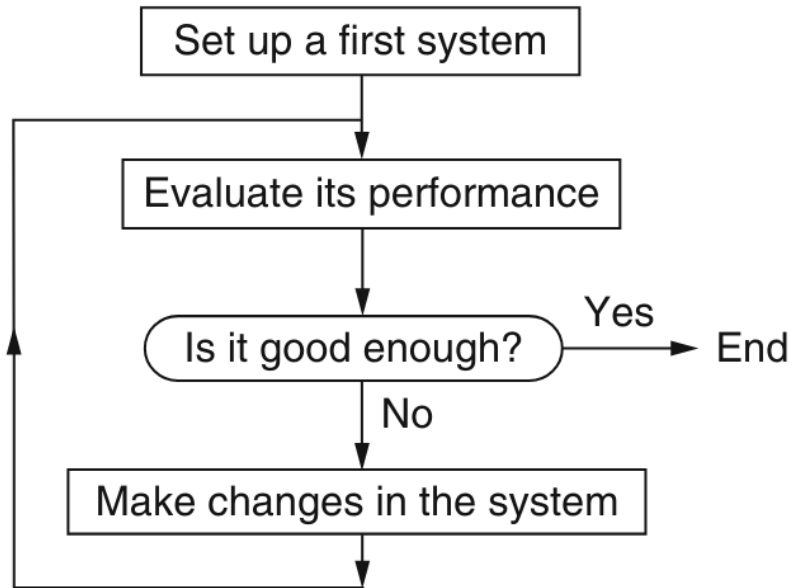


Figure 1.4 Lens design flow chart.

EX1030, 9; EX1010, 11-69.

45. Another lens design book provides a more detailed flow chart that also shows the iterative, incremental nature of the lens design and optimization process:

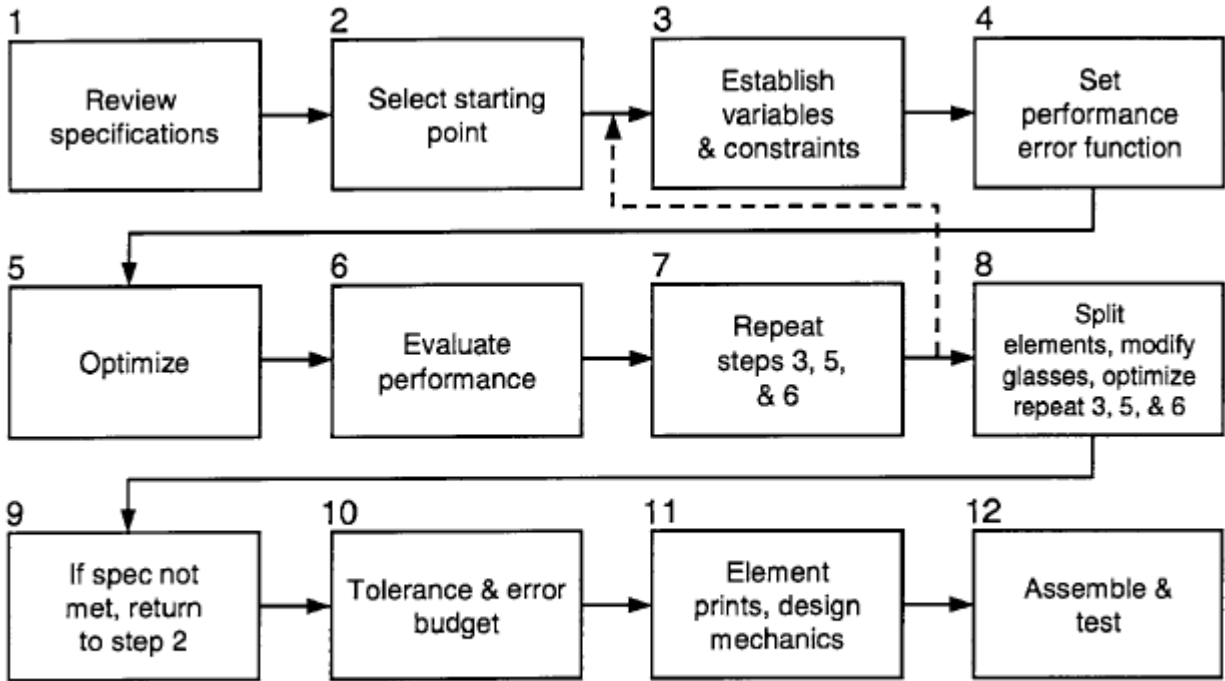


Figure 9.2

Lens Design and Optimization Procedure

EX1011, 172; *see also id.*, 171-76 (describing this lens design process), 168 (describing lens design optimization, where variables are “changed a small amount, called an *increment*, and the effect to performance is then computed”) (emphasis original).

46. Modern lens design relies on ZEMAX or other software programs, which are “highly sophisticated and enable the designer to perform a wide range of designs and analyses.” EX1009, 80. Textbooks encouraged POSITAs to consult patents for a “starting point” design, and then optimize that design to “come up with

a better design.” EX1011, 172-73.¹³ A POSITA would have known how to best implement changes, and in what order, to optimize the design and meet requisite specifications (e.g., size, FOV, cost, image quality) for a given system. EX1010, 3-4 (possible specification checklist) and 41-43 (common requirements); EX1012, 6-7. These lens design fundamentals are described in textbooks such as Smith, Kingslake, and Fischer, and the POSITA would have regularly employed them “to control/redirect the optimization path being taken by the lens design program.” EX1030 (Kingslake), 513; EX1010 (Smith), 6, 85-86 (ZEMAX has made it “a simple matter to optimize” lens designs described in patents); EX1011 (Fischer), 168 (“Computers have made what was once a tedious and time-consuming task at least manageable.”).

47. Below are some common and easily implemented design optimization techniques known and used by a POSITA. Using ZEMAX or similar software, designers with even a modest amount of experience would have naturally used them without issue in 2014.

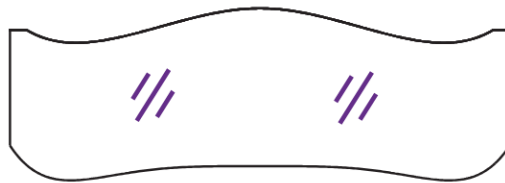
¹³The Federal Circuit has noted this design approach. *Corephotonics, Ltd. v. Apple Inc.*, 2021 WL 4944467, at *5 (Fed. Cir. Oct. 25, 2021) (affirming obviousness of “a routine lens adjustment”).

48. *Aberrations.* Certain lens shapes or configurations tended to increase aberrations (defects), and thus were prime candidates for modification of curvature, material, or number of lenses. EX1010, 50; EX1030, 10, 516.

49. *Aspheric surfaces.* Optical lenses commonly have highly aspheric surfaces to enable aberration correction across the surface of the lens. EX1009, 8, 11. The values defining the aspheric shape of a lens surface (curvature radius, conic constant, and aspheric coefficients) are typical variables used by lens designers when optimizing a lens to improve its performance. EX1010, 7, 31, 35-36. A POSITA understood the role of aspheric surfaces in multi-element lens designs and knew how to control these variables when optimizing a lens design. EX1009, 98 (“Of course, in a multielement system, it is the combined aberration content that ultimately determines the image quality. If we place an aspheric surface on one element (for instance, near the stop), the ability to control spherical aberration through this asphere means that the other elements do not need to ‘worry’ about spherical aberration as much, and we can change their shape to work on other aberrations.”); EX1016, 49 (noting that one technique for improving an optical design is to “[a]spherize a surface”), 69 (“Aspheric coefficients are important variables for aberration correction in modern designs.”).

B. Gullwing Lenses Were Often Used In Optical Systems, Especially Compact Camera Modules For Cell Phones, To Perform Field Corrections And Control Chief Ray Angles

50. A highly aspheric lens shape that changes / inflects curvature from convex to concave (or vice versa) across the lens surface is sometimes referred to as a “gullwing asphere” or “gullwing lens” because the shape looks like the outspread wings of a flying gull. EX1018, 66:22-24 (explaining that the “highly aspheric” shape is called a “gullwing asphere because it looks like a gullwing”), 76:12-13 (“We call it a gullwing because it looks like a gull.”); EX1011, 125 (depicting lens surface with gullwing shape). The “Field Guide to Lens Design” depicts an example of such a gullwing lens:

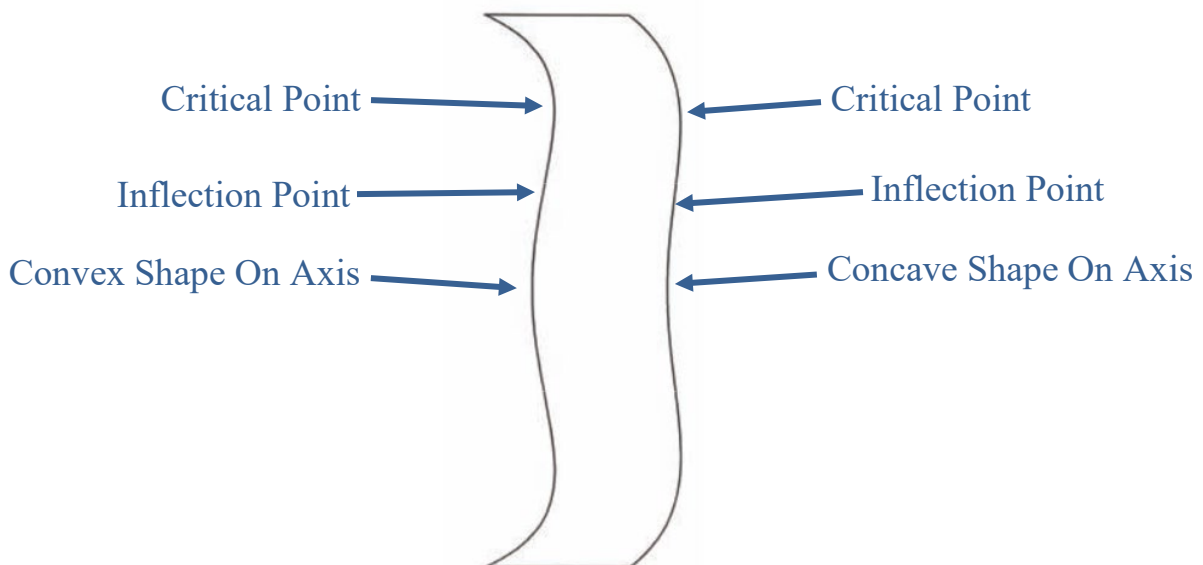


**Dual Gull Wing Asphere
w/ Inflection Points**

EX1016, 61 (explaining that “aspheres are ‘nonspherical’ surfaces” which “are used to increase performance or reduce the size and weight of a system.”).

51. By at least 2009, the gullwing lens was often used in compact camera modules, such as those for cell phones. EX1009, 93-94 (describing in 2009 a gullwing lens for a cell phone camera lens design as “unfamiliar to those used to

working with glass lenses” but “considered perfectly normal to those familiar with plastic optical design”); *id.*, 94 (explaining that gullwing lenses are “not just design study curiosities, as [gullwing lenses] have been put into high-volume production”); EX1015, 78-79 (explaining in 2010 that a “W-shaped aspheric surface” is “quite common in recent designs for camera modules for cell phone cameras”). Advancements in plastics made the use of gullwing shapes possible and easy for mass production. EX1011, 121 (“Today, with the significant development of new plastic materials, low-cost molded aspheric refractive optics are finding their place in the large consumer market.”); EX1014, 4 (“molded plastics produce highly aspheric surfaces without much difficulty”). Schaub provided the following example lens design with a “perfectly normal” lens shape “from a cell phone camera design” as of 2009:



EX1009, 94 (annotations added).

52. The seemingly peculiar shape of a gullwing lens naturally arose to accommodate the physical constraints of cell phone camera systems, namely the increasingly compact size and the increasingly dense pixels / microlens arrays of image sensors. Schaub explained in 2009 that cell phone camera designs are “heavily constrained, with overall length being a driving factor,” and that image sensors “limit the chief ray angle of incidence on the image plane.” EX1009, 164. These limitations “result in unusual-looking ... rear elements, which bend the ray bundles over to meet the angle of incidence constraint.” *Id.*; *id.*, 165 (depicting gullwing lens in three-element cell phone camera design); *see also* EX1023, 51, 53-54, 56-57 (discussing differences in design features and limitations of compact camera modules (CCMs) versus traditional 35mm format lenses, such as stop-asymmetry of CCMs and typical gullwing-shaped lens closer to the image plane to help limit the chief ray angle).

53. The highly aspheric shape of gullwing lenses was known to be “extremely useful in the correction of field aberrations such as astigmatism, field curvature, and also distortion.” EX1011, 123; *id.* (explaining that aspheric surfaces closer to aperture stop help with spherical aberration while away from the stop they help with off-axis aberrations such as coma and astigmatism); *see also* EX1016, 21 (explaining that “[m]odern designs ... often incorporat[e] aspheres to reduce package size, improve performance, and/or increase the aperture or field size”), 61 (explaining that gullwing lenses “can be used to correct astigmatism or distortion”

when positioned “[n]ear an image plane”); EX1018, 67:15–69:2 (explaining that increasingly compact and fast lens systems typically have the aperture stop in the front and one or more gullwing lenses at the back to help with field corrections), 67:17-20 (explaining that gullwing lenses are used in “small electronic devices with the aperture stop at the front ... for distortion correction, astigmatism correction, telecentricity correction”), 75:11-16 (explaining that the gullwing shape helps with astigmatism correction by controlling chief ray angle).

**1. Compact Lens Designs In The 2000s Included
At Least One Gullwing Lens As The Last Lens**

54. Compact camera modules therefore typically included at least one gullwing lens near the image plane to perform field corrections and thus improve imaging performance across the image plane (i.e., across the field of view). Bareau observed that, as of 2006, a “typical” three-element lens system for a cell phone camera included a “typical” gullwing surface near the image plane. EX1013, 8 (“The shape of the last lens surface in the design [below] is typical.”).

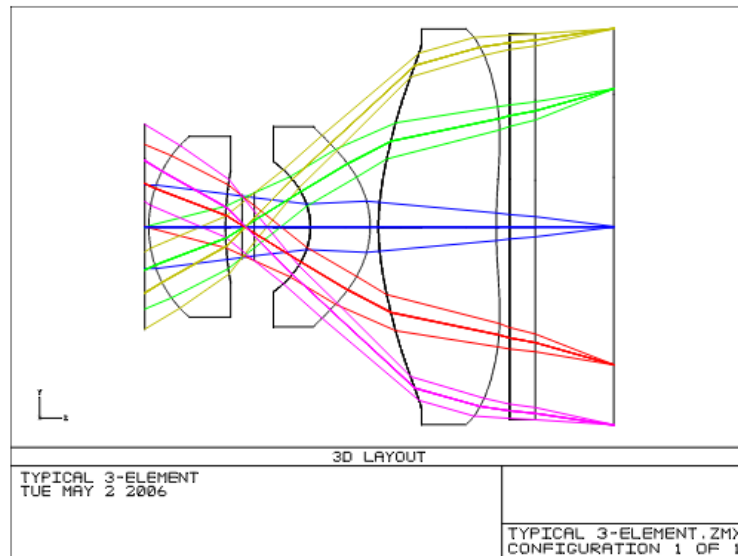


Fig.9: A typical 3-plastic element (3p) imaging system.

EX1013, 7. The last surface of the third lens is a gullwing shape, where the surface is concave at the optical axis and convex towards the periphery.

55. Throughout the 2000s, numerous designs for compact lens systems, typically with three or four lenses, included at least one gullwing lens to perform off-axis field corrections. *See, e.g.*, EX1019, 2:53-57, FIG. 1A (U.S. application filed May 7, 2010, with priority to Taiwanese application filed October 28, 2009, showing a gullwing field lens “with at least one inflection point” so that “the angle at which the light is projected onto the sensor from the off-axis field can be effectively reduced to further correct the off-axis aberrations”); EX1020, 2:18-21, FIG. 1 (U.S. application filed December 25, 2006, showing a gullwing field lens with “at least one inflection point” on the image-side surface “to contribute to a better correction of the incident angle of the off axis light”); EX1021, 2:20-23, FIG.

1 (U.S. application filed February 12, 2008, showing a gullwing field lens with inflection points on the image-side surface for “correcting off axis aberration”); EX1022, 4:46-64, FIGS. 1-2 (U.S. application filed June 18, 2010, showing a gullwing field lens and explaining that “[i]n order to have better image, the preferred ratio [of the inflection point to the maximum optical effective point] is between 38% and 70%”).

**2. Lens Designs In The 2010s Included
More Lenses, And More Gullwing Lenses,
In Response To Market Demand For Better Performance**

56. Although Bareau observed the emphasis on compact size over image quality in 2006 (EX1013, 8), market demand in the 2010s began to also emphasize performance as measured by f-number, field of view, image quality, etc., which has driven lens designers to add additional lenses, including additional gullwing lenses, to meet this demand. *E.g.*, EX1006, [0005]-[0013]; EX1007, [0003]-[0010]; EX1008, [0005]-[0011]; EX1018, 71:5-15 (explaining that for compact camera modules, “depending on the f-number and the field of view ... sometimes there’s one [gullwing lens]. Sometimes there’s two. Sometimes there’s three.”).

57. By at least 2013, lens designers recognized that these additional lenses should be gullwing lenses, and lens designs began to commonly include seven lenses with two gullwing lenses near the image plane. *E.g.*, EX1006, FIG. 1, [0035]-[0038]; EX1007, FIG. 1, [0090]-[0091]; EX1008, [0018] (“Both the surfaces of each of the

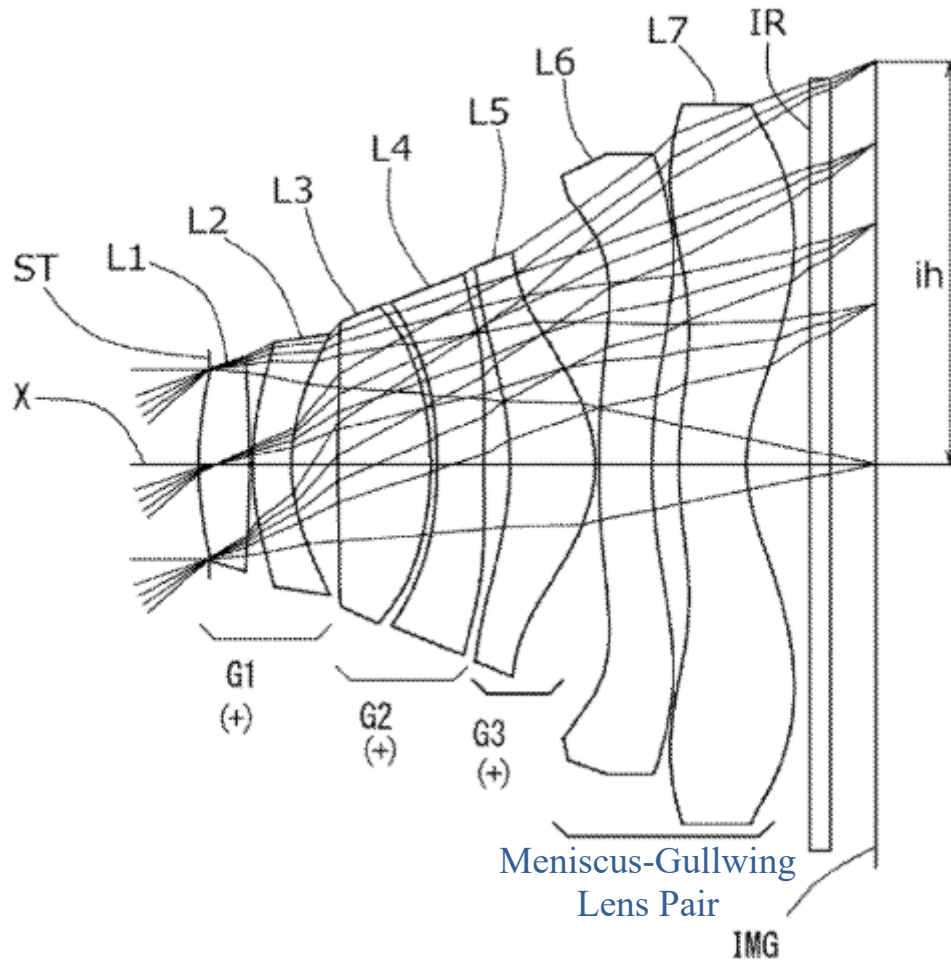
sixth lens and the seventh lens have adequate aspheric shapes to control the angle of light rays emitted from the fifth lens in the area from the low image height point to the maximum image height point properly to form an image on the image plane. At the same time, these lenses are responsible for final correction of spherical aberrations in the lens peripheral portion, astigmatism, astigmatic difference, and distortion.”), [0034]-[0035] (describing the gullwing shapes of the sixth and seventh lenses); EX1024, FIG. 1, [0064]-[0068] (discussing shapes and advantages of sixth and seventh lenses); EX1025, FIG. 7, 4:37-58 (discussing shape of sixth lens), 6:41-62 (discussing shape of seventh lens), 9:22-53 (discussing meniscus shapes of gullwing sixth and seventh lenses); EX1026, FIG. 4, 7:4-67 (discussing meniscus shapes of gullwing sixth and seventh lenses); EX1027, FIG. 1, 3:18-29, 7:24-42; EX1028, FIG. 13; EX1029, FIG. 1.

3. By 2014, Lens Designer Knew That Gullwing Lens Pairs With Meniscus On-Axis Curvature Would Achieve Better Aberration Correction And Chief Ray Angle Control

58. In 2013, Sekine expressly recognized the benefits of implementing the last two lenses of a seven-lens system with gullwing shapes, where “the sixth lens plays a very important role in reducing the burden on the seventh lens, located nearest to the image plane, for correction of aberrations and control of the chief ray angle.” EX1006, [0036]; EX1027, 4:11-30 (“Since the sixth lens and the seventh lens have the [gullwing] lens shapes, it is possible to suitably restrain the incident

angle of a light beam emitted from the imaging lens to an image plane within the range of CRA.”).

FIG. 1



EX1006, FIG. 1 (annotations added).

59. As reflected in numerous patent applications filed throughout 2013 and 2014, POSITAs understood the specific advantages of using two gullwing lenses with meniscus shapes on the optical axis, with convex curvature on the object side and concave curvature on the image side: shorter track lengths, better off- and on-

axis aberration correction and suppression, constrained incident angles and chief ray angle. EX1006, [0023]-[0024] (meniscus-gullwing sixth and seventh lenses correct residual chromatic aberrations, coma aberrations, astigmatism, distortion, field curvature, and controlling CRA), [0102], [0104], [0110]-[0111]; EX1024, [0064]-[0068] (gullwing sixth and seventh lenses with “meniscus shape having a concave surface toward the image side” is “more advantageous [for] realizing a shortening of the total length” and “suppressing the generation of astigmatism”); EX1025, 6:1-22 (explaining how refractive power of sixth and seventh lenses with these shapes is strong enough “to correct axial chromatic aberrations” but not so strong that it would be “difficult to correct distortion and field curvature”), 9:22-53 (meniscus gullwing sixth and seventh lenses “more effective in mainly correcting distortion and field curvature and controlling the angle of rays incident on the image sensor”); EX1026, FIG. 4, 7:4-67 (discussing meniscus shapes of gullwing sixth and seventh lenses for correcting aberrations and shortening total length by allowing weaker refractive power); EX1027, 10:17-54 (explaining that gullwing sixth and seventh lenses with meniscus shapes on-axis “satisfactorily correct an off-axis chromatic aberration of magnification as well as an axial chromatic aberration”), 10:54-58 (explaining that gullwing-shaped image-side surfaces of the sixth and seventh lenses are necessary for better optical performance and compact size).

VIII. OVERVIEW OF THE '845 PATENT

60. The '845 patent issued June 14, 2016, from an application filed September 16, 2014, and alleges priority to a Taiwanese patent application filed August 1, 2014. EX1001, Cover.

A. The '845 Specification

61. The '845 patent disclosed a seven-lens system where the image-side surfaces of the sixth and seventh lenses are both “concave in a paraxial region thereof” and include “at least one inflection point.” EX1001, 2:14-33. It notes that this shape for the sixth lens “is favorable for further correcting the astigmatism” as well as “avoid[ing] excess aberration and improv[ing] the image quality.” *Id.*, 4:38-47. It similarly notes that this shape for this seventh lens is “favorable for reducing a back focal length ... so as to keep a compact size” and “for correcting the aberration of the off-axis so as to improve the image quality.” *Id.*, 4:48-59.

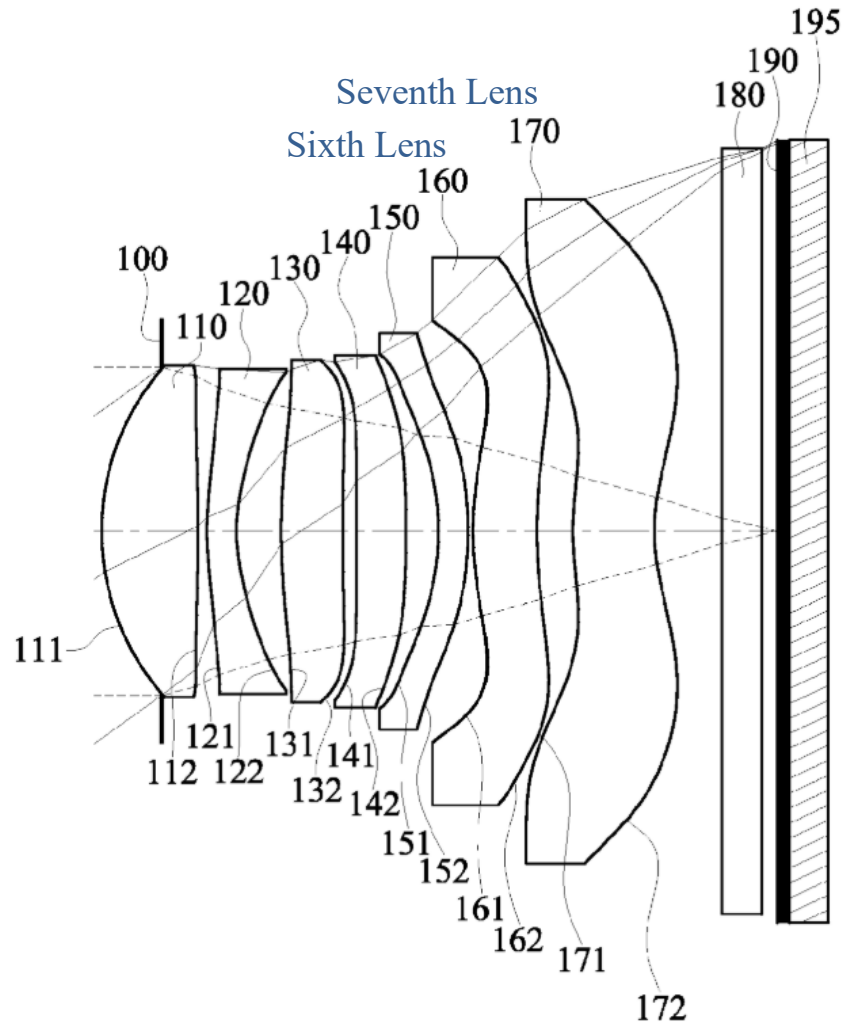


FIG.1

EX1001, FIG. 1 (annotations added).

62. The '845 patent characterizes the gullwing shapes of the sixth and seventh lenses through vertical distances Y_{c61} and Y_{c62} for the sixth lens and Y_{c72} for the seventh lens, these distances measured from the optical axis to non-axial critical points on the surfaces of the sixth and seventh lenses. *Id.*, 9:35-52. It specifies that the seventh lens satisfies a condition on Y_{c72}/f that is “favorable for controlling

the incident angle of the light ... so as to keep sufficient illumination in the peripheral region of the image” as well as for “correcting the aberration of the off-axis.” *Id.*, 4:60-5:2. It also specifies that the sixth lens satisfies a condition on $Yc62/Yc72$ that “is favorable for correcting the aberration of the off-axis so as to improve the image quality.” *Id.*, 6:20-27.

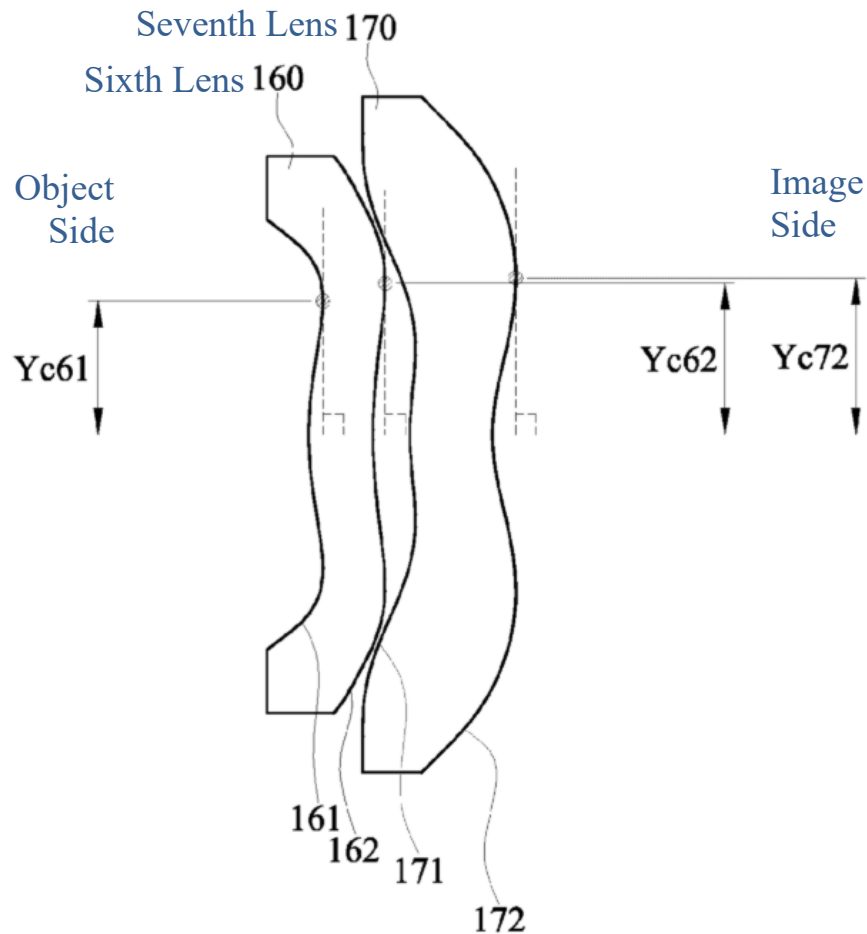


FIG.27

EX1001, FIG. 27 (annotations added).

B. The Prosecution History

63. The original application was filed on September 16, 2014. Applicant filed with the original application an Information Disclosure Statement (“IDS”) listing Fukaya (EX1004). EX1002, 142. Applicant submitted a supplemental IDS on August 20, 2015, listing Baik (EX1007). EX1002, 701.

64. In the sole non-final Office action mailed October 22, 2015 (“Action”), the Examiner rejected claims 1–13, 15, 17, 18, 21–25, 27, 29–31, 33–35, 38, and 39 as obvious over Baik in view of Tsai (EX1032). EX1002, 809–22. In particular, the Examiner rejected claim 7 (“wherein the fourth lens element has positive refractive power”), citing Baik’s fifth disclosed embodiment (“Baik-E5”) that includes a fourth lens element having a positive refractive power. *Id.*, 812; *see* EX1007, [0116] (“a focal length of the fourth lens 40 may be 73.896”).

65. In the Action, the Examiner indicated that claims 14, 16, 19, 20, 26, 28, 32, 36, and 37 contained allowable subject matter. EX1002, 822–25. In particular, the Examiner indicated that claim 16 contained allowable subject matter because none of the cited art allegedly disclosed or taught, “wherein a vertical distance between a non-axial critical point on the image-side surface of the sixth lens element and an optical axis is Yc62, the vertical distance between a non-axial critical point on the image-side surface of the seventh lens element and the optical axis is Yc72, and the following condition is satisfied: $0.5 < Yc62/Yc72 < 1.5$.” *Id.*, 823. The

Examiner also indicated in the Action that claim 26 contained allowable subject matter because none of the cited art allegedly disclosed or taught, “wherein the sixth lens element has positive refractive power.” *Id.*, 824.

66. On January 15, 2016, Applicant amended independent claim 1 to incorporate the allegedly allowable subject matter of claims 16 and 28 and previously rejected claims 3, 4, 7, and 29. *Id.*, 852. However, Applicant failed to explain in its response *how*—or even *if*—the incorporation of the previously rejected claims rendered claim 1 patentable; indeed, Applicant did not even *attempt* to distinguish the previously rejected claims over Baik or Tsai. *See id.*, 852–83. Applicant also amended claim 24 to incorporate the subject matter of claim 26 and previously rejected claims 6 and 7. *Id.* Similarly, Applicant failed to explain how the subject matter of the previously rejected claims is distinguishable over the prior art and how or even if the incorporation of previously rejected claims rendered claim 24 patentable. *Id.*

67. The Examiner allowed all remaining claims thereafter, citing the incorporation of claims 16 and 28 into independent claim 1 and the incorporation of claim 26 into independent claim 20 as the specific reasons for allowability. *Id.*, 863–64.

68. From my review of the cited art and the prosecution history, the Examiner made material errors in allowing the claims. For example, the Examiner

erroneously concluded that “none of the prior art either alone or in combination disclose or teach” the elements relating to the condition “ $0.5 < Y_{c62}/Y_{c72} < 1.5$.” EX1002, 823/880; *id.*, 863-874/880 (allowing the claims amended to incorporate this element). But Baik actually disclosed lens arrangements satisfying this Y_{c62}/Y_{c72} condition. *E.g.*, EX1007, [0090]-[0091] (discussing the shapes of the image-side surfaces of the sixth and seventh lenses), FIG. 13 (depicting sixth and seventh lenses with non-axial critical points visually satisfying the condition). Although Baik did not list specific values for Y_{c62} and Y_{c72} , a lens designer would have readily determined these values from the lens data disclosed by Baik (*e.g.*, EX1007, [0119]-[0120]), such as by inputting the lens data into the aspheric surface equation disclosed by Baik (EX1007, [0056]), via Excel or another spreadsheet software, using lens design software, or even by hand. Any approach would have confirmed that Baik discloses what is clearly shown in Baik’s FIG. 13, namely non-axial critical points on the image-side surfaces of the sixth and seventh lenses that satisfy the Y_{c62}/Y_{c72} condition.

C. The Challenged Claims

69. Challenged claim 1 is representative and is listed here, with element numbering added in the lefthand column:

[1.1]	A photographing optical lens assembly comprising, in order from an object side to an image side:
[1.2]	a first lens element having positive refractive power;

[1.3]	a second lens element having negative refractive power;
[1.4]	a third lens element;
[1.5]	a fourth lens element having positive refractive power;
[1.6]	a fifth lens element with negative refractive power having an object-side surface being concave in a paraxial region thereof and an image-side surface being convex in a paraxial region thereof;
[1.7]	a sixth lens element having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the sixth lens element are aspheric, and the image-side surface of the sixth lens element has at least one inflection point; and
[1.8]	a seventh lens element having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the seventh lens element are aspheric, and the image-side surface of the seventh lens element has at least one inflection point;
[1.9]	wherein the photographing optical lens assembly has a total of seven lens elements,
[1.10]	there is a non-axial critical point on the image-side surface of the sixth lens element at which a tangent to the image-side surface of the sixth lens element is perpendicular to an optical axis, there is a non-axial critical point on the image-side surface of the seventh lens element at which a tangent to the image-side surface of the seventh lens element is perpendicular to the optical axis, a vertical distance between the non-axial critical point on the image-side surface of the sixth lens element and the optical axis is $Yc62$, a vertical distance between the non-axial critical point on the image-side surface of the seventh lens element and the optical axis is $Yc72$, a focal length of the photographing optical lens assembly is f , a focal length of the first lens element is $f1$, a focal length of the seventh lens element is $f7$, and the following conditions are satisfied: $0.5 < Yc62/Yc72 < 1.5$; $0.1 < Yc72/f < 0.9$; and $ f1/f7 < 3.0$.

70. A full claims listing is submitted as Exhibit 1031.

IX. CLAIM CONSTRUCTION

71. I understand that, in IPR, claim terms should be given the ordinary meaning that the terms would have to a person of ordinary skill in the art on the earliest effective filing date, in view of the specification and file history.

72. For this declaration, I apply the plain and ordinary meaning of all claim terms and do not rely on any specific constructions. I reserve the right to offer my opinions on any constructions or construction issues presented by Patent Owner Largan.

X. GROUND 1: CLAIMS 1-14, 16-27, 30, AND 32-34 ARE OBVIOUS OVER FUKAYA AND THE KNOWLEDGE OF A POSITA

73. As explained below, claims 1-14, 16-27, 30, and 32-34 are obvious over Fukaya in view of the knowledge of a POSITA. For these challenged claims, Fukaya satisfies all elements except for those relating to the gullwing shape of the sixth and seventh lenses. For reasons explained below, however, a POSITA would have found it obvious to implement Fukaya with a gullwing-shaped sixth lens, thus rendering the challenged claims obvious.

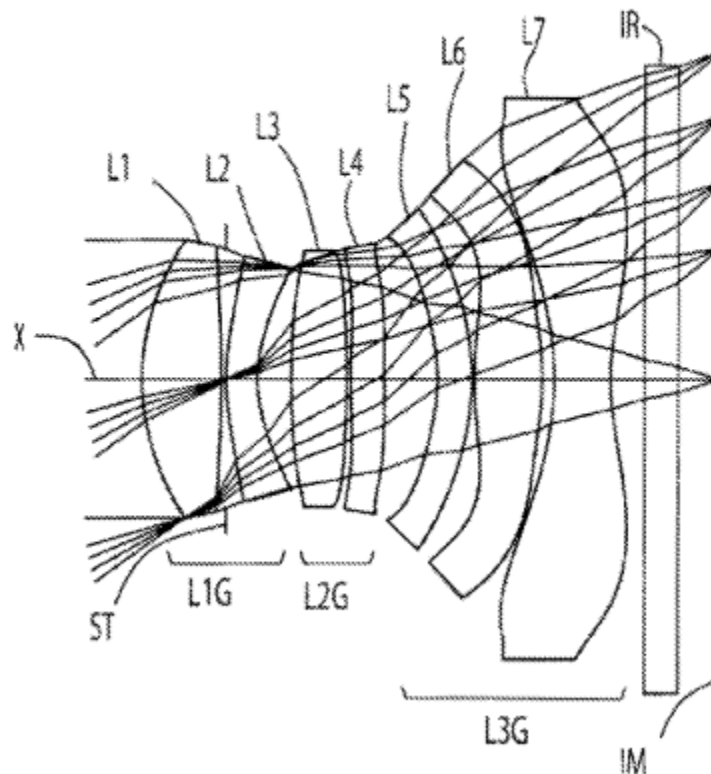
A. Fukaya (EX1004)

74. U.S. Patent application 2014/0139719 (EX1004, “Fukaya”) was filed September 17, 2013, published May 22, 2014, and claims priority to a Japanese patent application filed November 21, 2012. EX1004, Cover. Fukaya thus qualifies as prior art under at least Sections 102(a)(1-2). Fukaya is analogous art to the ’845

patent because both are within the same field of endeavor of lens assemblies with seven lens elements. EX1004, [0003], [0012]-[0014]; EX1001, 1:14-18, 1:52-56.

75. Fukaya discloses a seven-element lens system with the objective of providing “a low-cost imaging lens which can correct various aberrations properly in spite of a small F-number [that] is more low-profile than ever though it uses more lenses than ever to achieve higher performance and also offers a relatively wide angle of view.” EX1004, [0012]. Fukaya discloses a gullwing seventh lens where the image-side surface has an aspheric shape that “changes from concave to convex” from the optical axis to the periphery. *Id.*, [0014].

FIG. 1



EX1004, FIG. 1.

76. Fukaya satisfies all elements of claim 1, aside from those pertaining to a gullwing sixth lens ([1.7], “a sixth lens element having an image-side surface being concave in a paraxial region thereof”; [1.10], “ $0.5 < Y_{c62}/Y_{c72} < 1.5$ ”). Nevertheless, as explained in the following sub-sections, Fukaya in view of the knowledge of a POSITA renders all challenged claims obvious.

B. Implementing Fukaya With A Gullwing Sixth Lens

77. As discussed below and herein, a POSITA would have been motivated, with a reasonable expectation of success, to implement the imaging lens of Fukaya with two gullwing lenses, rather than just one, because doing so would reduce the burden on the lenses for correcting aberrations and controlling the chief ray angle across the image height. A POSITA would have been motivated to obtain this improved control over the chief ray angle in order to improve the relative illumination across the image plane, thereby allowing higher resolution and better imaging performance in the entire image. The resulting double-gullwing Fukaya imaging lens satisfies the challenged claims. *Infra* Section X.C.

78. As discussed *supra* Section VII.B, a POSITA knew that gullwing lenses were useful for performing off-axis field corrections. Further, shortly after Fukaya was filed, POSITAs recognized that using two gullwing lenses in combination for a seven-lens system would more effectively perform these off-axis field corrections,

because the gullwing sixth lens would “reduc[e] the burden on the seventh lens ... for correction of aberrations and control of the chief ray angle.” EX1004, [0036]; *supra* Sections VII.B.2-VII.B.3. Fukaya itself recognized that when “both the surfaces of the sixth lens are aspheric with their peripheral areas inclined toward the object, it is easy to suppress various aberrations and control the angle of principal light rays incident on the image sensor properly.” EX1004, [0022]. Fukaya similarly recognized that, for the image-side surface of the seventh lens, the “shape changes from concave to convex as the distance from the optical axis increases, so it is easy to correct various aberrations at high image height and the angle of principal light rays incident on the image sensor can be properly controlled.” *Id.*, [0023].

79. However, while the seventh lens of Fukaya is a gullwing lens and the object-side surface of the sixth lens has a gullwing shape, the highly aspheric image-side surface of the sixth lens does not have a gullwing shape because it is convex near the optical axis. EX1004, [0022]-[0023], FIG. 1. Given the numerous advancements in double-gullwing lens pairs between the filing of Fukaya and the filing date of the '845 patent (*supra* Section VII.B.2), a POSITA would have recognized at the time that simply making the image-side surface of the sixth lens concave near the optical axis would result in a gullwing shape for that surface because of its highly aspheric shape, thereby providing even further control over the chief ray angles and further improvements to off-axis aberrations. A POSITA

therefore would have found it obvious to use the known technique of using a double-gullwing lens pair to predictably achieve the desired goal of performing field corrections and controlling the chief ray angle.

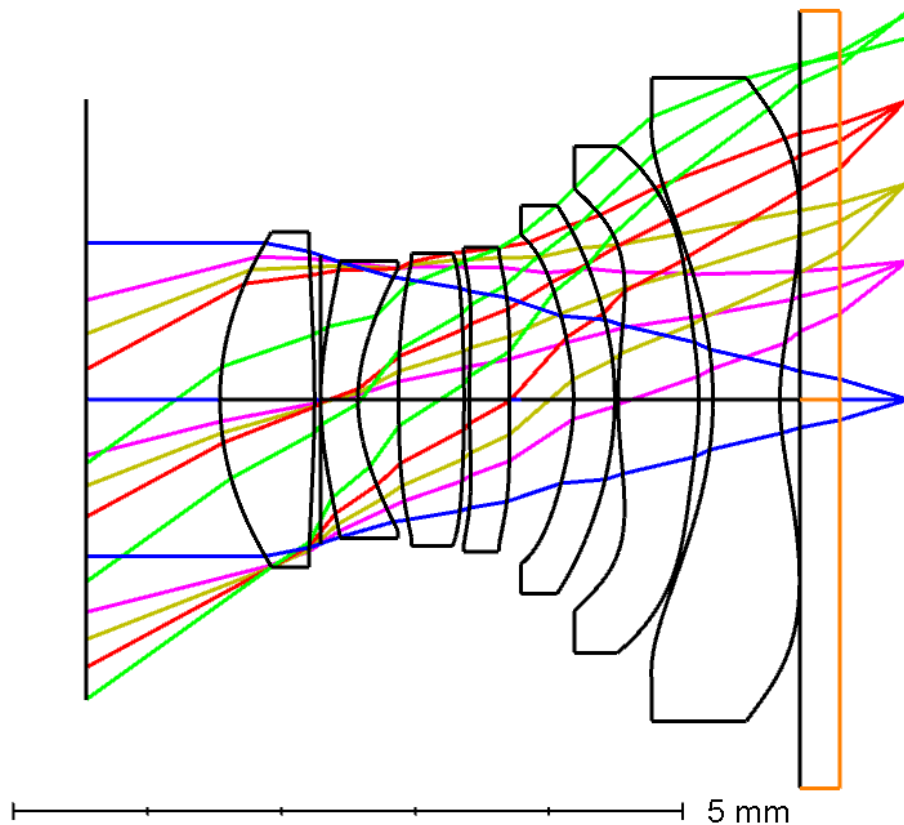
80. When changing the curvature of the image-side surface of the sixth lens from convex to concave to achieve a gullwing shape for the sixth lens, the POSITA would have further recognized that simply making the object-side surface of the seventh lens convex at the optical axis would complement and balance the change to the image-side surface curvature on the sixth lens. *E.g.*, EX1010, 47 (explaining that when applying standard improvement techniques to a lens design, “complementary changes to the balance of the system” would be necessary “to restore (and hopefully improve) the design”). In addition to being a standard technique for a lens designer implementing changes to a lens design (*id.*), the POSITA would have found it obvious to adjust and optimize the curvature radius of the object-side surface of the seventh lens from concave to convex in order to achieve a meniscus shape on-axis for the seventh lens, thereby correcting axial chromatic aberrations that would arise from the corresponding change to the sixth lens. *E.g.*, EX1027, 10:17-58 (discussing how meniscus shapes on-axis for gullwing sixth and seventh lenses correct on-axis aberrations). A POSITA thus would have been motivated to adjust the sixth and seventh lenses together to implement Fukaya with a double-gullwing lens pair that is meniscus on-axis, with convex surfaces

towards the object side and concave surfaces towards the image side, in order to achieve the many known advantages of this configuration, such as aberration correction, improved control over chief ray angle and thus improved illumination, and ease of achieving a compact size. *Supra* Section VII.B.3 (explaining how meniscus-gullwing lens pairs were common and well-understood by 2014).

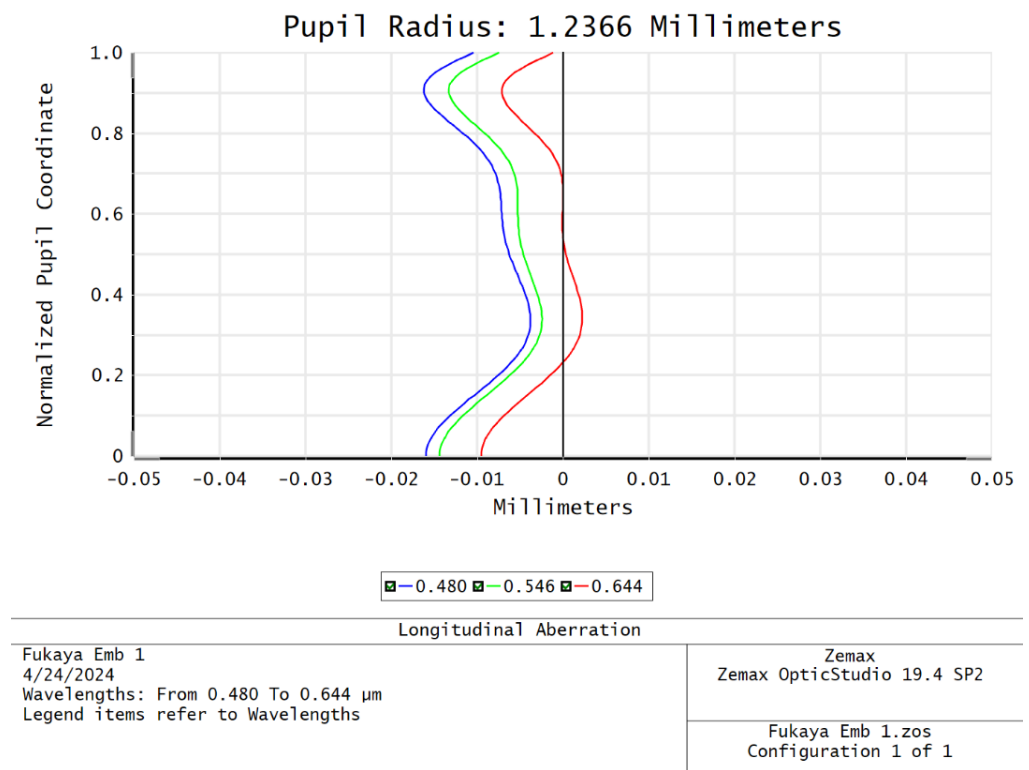
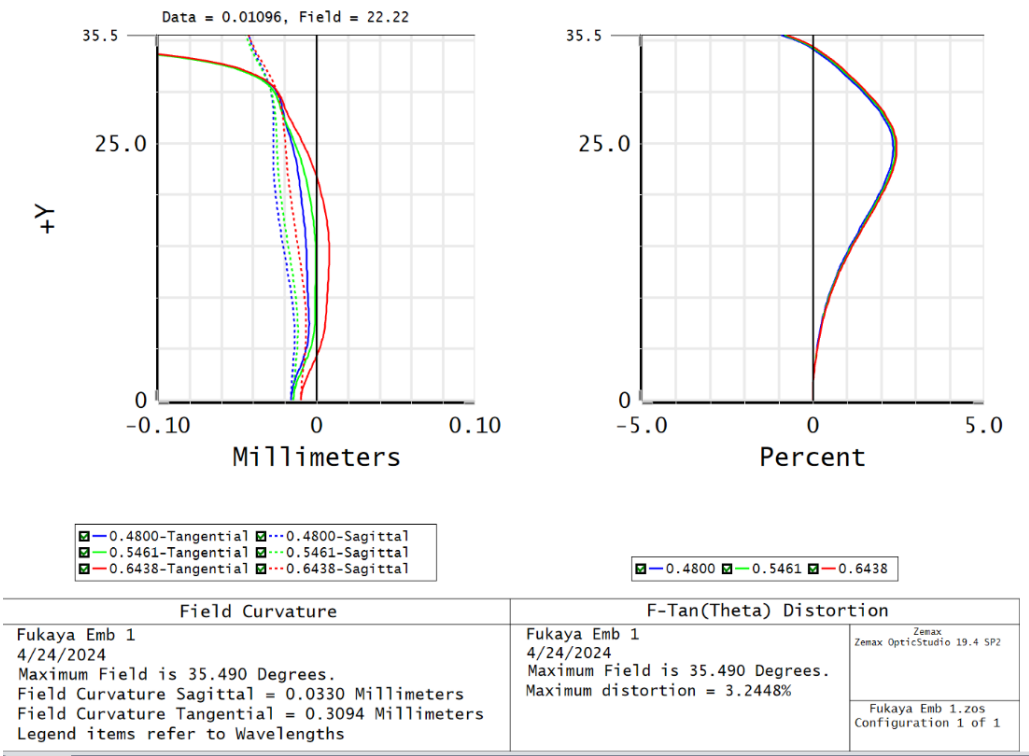
81. A POSITA would have had a reasonable expectation of success implementing Fukaya with a concave image-side surface on the sixth lens and a convex object-side surface on the seventh lens, because implementing these changes would be a straightforward application of the incremental, iterative lens design process to improve a known starting point. *Supra* Section VII.A. A POSITA further would have had a reasonable expectation of success because the resulting configuration (a double-gullwing lens pair with meniscus shapes on-axis) was well understood as reflected by prior art designs with this configuration. *Supra* Section VII.B.3.

82. Zemax modeling confirms that a POSITA would have easily implemented Fukaya with a concave image-side surface of the sixth lens and a convex object-side surface of the seventh lens. In the following paragraphs, I explain my approach for implementing Fukaya with a gullwing sixth lens, which is consistent with how a POSITA at the time would have approached improving Fukaya. A POSITA would have started by inputting the lens data for Fukaya's

Embodiment 1 provided in Table 1 for Fukaya's Embodiment 1 into lens design software such as Zemax. *See* EX1004, [0125] (Table 1). The following Zemax ray-trace diagram depicts the unoptimized Fukaya Embodiment 1 starting point:



While the rays appear to focus well at the image plane for most of the field angles, a POSITA would have noticed from the green rays above that the lens system does not work well at the larger field angles. This is confirmed by comparing the following performance graphs, which indicate how the Fukaya Embodiment 1 system performs without any optimization, to the performance graphs in FIG. 2 of Fukaya:



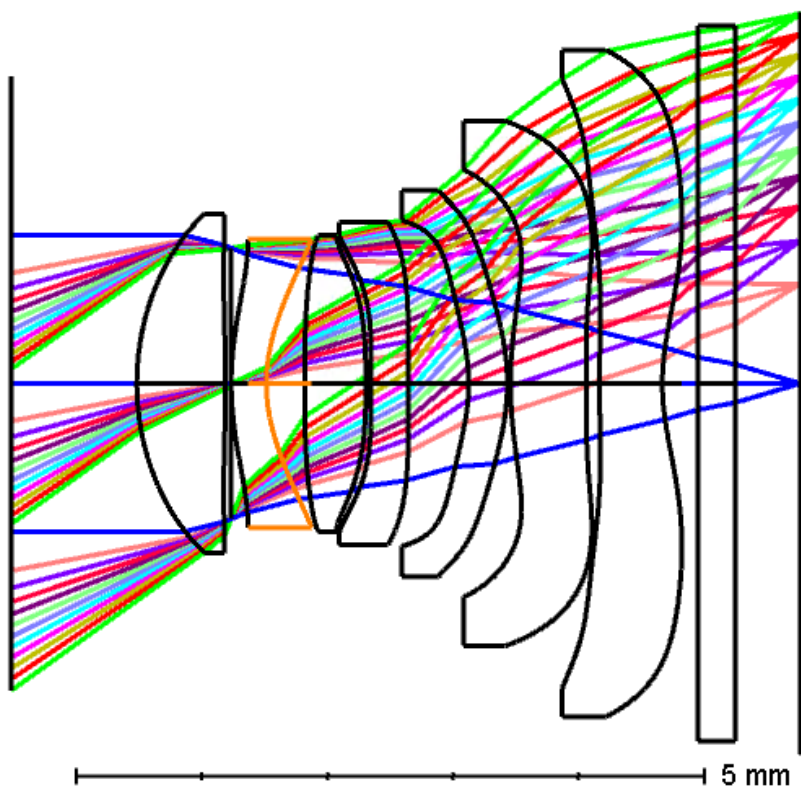
83. This off-axis performance of the unoptimized Fukaya system would have further motivated a POSITA to implement Fukaya with a gullwing sixth lens, so that the off-axis performance can be improved. To re-optimize the Fukaya system, I started by increasing the number of analysis field points to 12 based on equal area between sampling zones, which is the maximum for my version of Zemax. This change creates a more uniform coverage of the lens surfaces with respect to overlapping ray traces. It is clear that most of the performance degradation is at large field angles; from this, a POSITA would have recognized that elements 5-7, which control performance at large field angles, are the most likely candidates to modify in order to improve performance. However, changing the aspherics on any of the lenses generally requires that all aspherics be varied in order to find an optimal balance. As long as the lens is close to the desired performance, like this Fukaya lens system, this large number of variables will not produce large changes in the shapes of the elements, because the system is already close to an optimal solution.

84. Initially, I modified lens six only, because that lens is not the more modern gullwing sixth lens that was known at the time as discussed above. However, optimization of the sixth lens aspherics alone did not produce a significant change in performance. I noticed that the focal length values in Fukaya Table 1 did not match up to the values in this lens, so I added CARD operands in the merit function to change the curvature radius values on the lens surfaces to meet the Table 1 values.

Note that there is an older equivalent operand in Zemax, but I used CARD and would expect the older operand to perform the same. I also added FTGT operands to control spacing between the lenses and lens thicknesses, CENY to set the field height, and used a 20x20 rectangular grid of rays for the spot rms part of the merit function. I also made all aspherics and conics variable, except on the object-side surface of the seventh lens, which was not well behaved in the earlier, initial optimization. To avoid ray trace failures, I increased the f-number to 2 and increased sampling to 40x40. To achieve the gullwing shape on the image-side surface of the sixth lens, I targeted a positive curvature on that surface with the CVGT 0 operand. I also noticed that lens 7 was too close to the filter, so I increased FTGT to 0.2 on that surface. It looked like the Fukaya table value for the focal length on lens 6 was too small (merit function value larger than other operands), so I increased the focal length to 3mm. Lenses 6 and 7 looked too close, so I targeted a positive curvature on the object side of lens 7 with the CVGT 0 operand, knowing that this change would complement the targeted positive curvature on the image-side surface of lens 6, and reduced the power (increased the focal length) of lens 7. In optimization, the lens 6 power was still too strong, so I increased the target focal length on lens 6. I released the focal length constraint on lens 7, because it was well behaved (low merit function value). There was still some lateral chromatic aberration, so I thought that I needed more modification on lens 5, which has a different Abbe number than lenses 6 and 7. I

released the focal length constraints on lenses 5 and 6, which led to a better result in optimization. I then reduced f-number in steps to 1.65. There was some distortion, so I added DIMX operands. The conics on surfaces 10 and 14 were not well behaved, so I froze them. There was some remaining field curvature, so I added FCGT and FCGS commands to limit field curvature. I also added LONAs into the merit function to limit any residual longitudinal spherical aberration. This optimization process resulted in the Fukaya lens system with a meniscus-gullwing lens pair (for lenses 6 and 7) and achieved reasonably good performance results, especially in comparison to Fukaya FIG. 2.

85. The modified Fukaya imaging lens maintains the overall design of the original Fukaya imaging lens, but with improved off-axis performance, as expected, from the meniscus-gullwing lens pair:

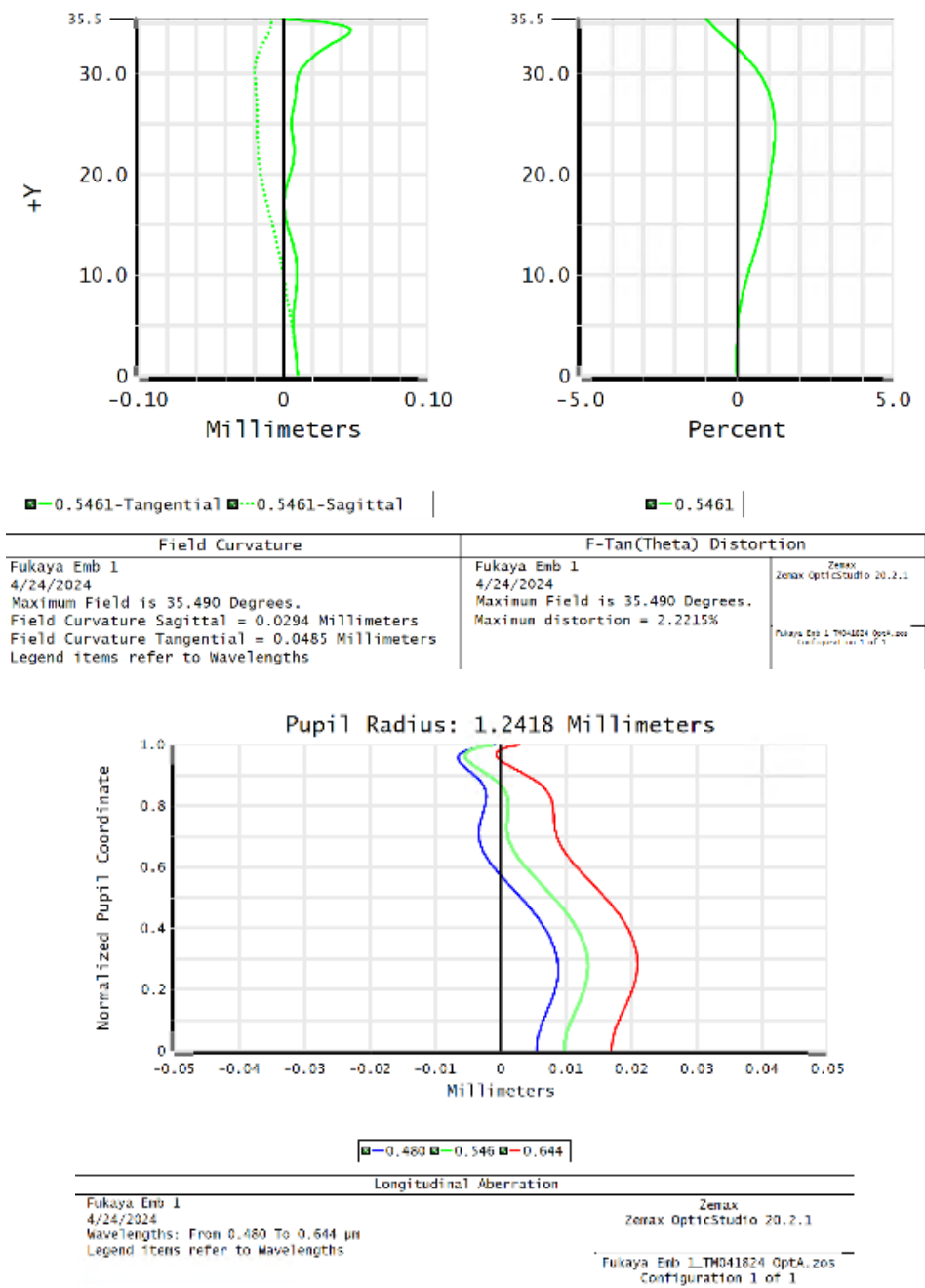


The following Zemax table provides lens data for the optimized Fukaya lens system:

	Radius	Thickness	Material	Clear Semi-Dia	Conic
0	Infinity	Infinity		Infinity	0.000
1	Infinity	1.000		2.442	0.000
2	2.057 V	0.706	1.53,56.2 M	1.346	-0.152 V
3	-10.071 V	0.045		1.212	0.000
4	Infinity	0.000		1.076	0.000
5	2.419 V	0.280	1.64,23.9 M	1.097	-13.857 V
6	1.307 V	0.304		1.145	-4.197 V
7	18.231 V	0.488	1.53,56.2 P	1.168	60.863 V
8	-10.103 V	0.040		1.181	-640.164 V
9	14.354 V	0.300	1.53,56.2 P	1.185	74.169 V
10	-15.024 V	0.479		1.282	-5.090E+35
11	-1.477 V	0.308	1.64,23.9 P	1.294	0.168 V
12	-1.699 V	0.025		1.534	-0.260 V
13	3.067 V	0.603	1.53,56.2 P	1.698	-23.389 V
14	10.000 V	0.106		2.085	-7.557E+25
15	10.000 V	0.500	1.53,56.2 P	2.426	-3.711
16	1.738 V	0.282 V		2.647	-9.713 V
17	Infinity	0.300	1.52,64.2 M	2.801	0.000
18	Infinity	0.517		2.842	0.000
19	Infinity	-		2.950	0.000

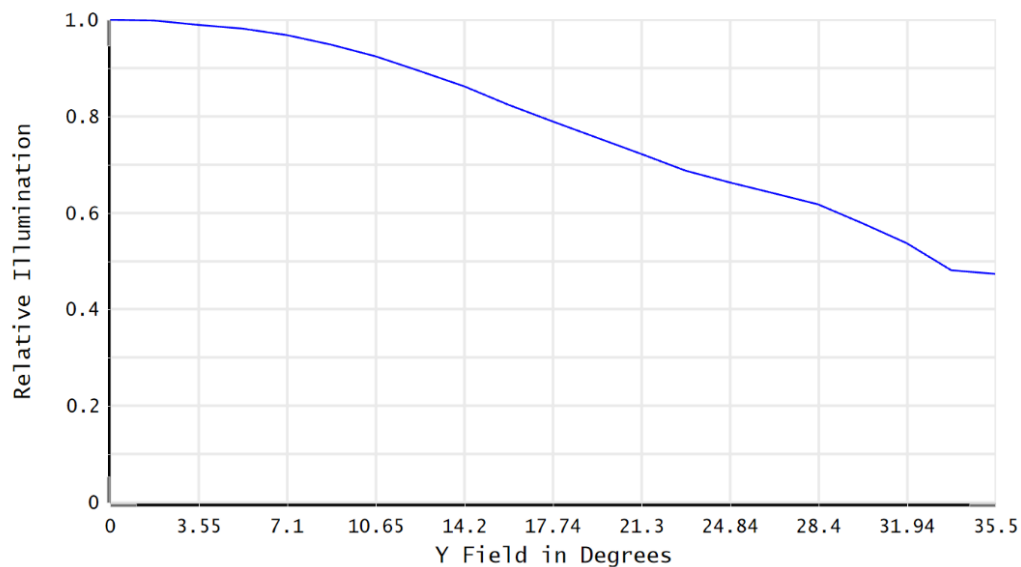
4th Order Term	6th Order Term	8th Order Term	10th Order Term	12th Order Term	14th Order Term	16th Order Term
4.975E-03 V	7.793E-04 V	8.108E-03 V	-0.010 V	6.319E-03 V	-1.252E-03 V	0.000
0.062 V	-0.038 V	9.876E-03 V	9.845E-03 V	-8.495E-03 V	1.874E-03 V	0.000
0.020 V	-0.061 V	0.023 V	6.278E-04 V	-7.692E-03 V	6.706E-03 V	-2.761E-03 V
0.045 V	-0.032 V	-7.483E-03 V	6.009E-03 V	0.012 V	-0.012 V	2.591E-03 V
0.036 V	8.013E-03 V	-0.015 V	-5.759E-03 V	0.012 V	-6.703E-03 V	3.564E-03 V
-0.326 V	0.354 V	-0.313 V	0.142 V	0.043 V	-0.082 V	0.031 V
-0.327 V	0.127 V	-0.015 V	0.039 V	-0.044 V	0.013 V	1.812E-03 V
-0.029 V	-0.069 V	0.062 V	-2.633E-04 V	-0.025 V	6.504E-03 V	9.458E-04 V
0.346 V	-0.234 V	0.151 V	-0.060 V	-0.026 V	0.039 V	-0.013 V
0.152 V	-0.036 V	-0.023 V	0.024 V	-8.458E-03 V	-5.361E-04 V	6.097E-04 V
0.015 V	-0.043 V	-1.422E-03 V	1.190E-03 V	1.175E-03 V	-1.153E-04 V	-7.045E-05 V
0.110 V	-0.092 V	0.024 V	-1.459E-03 V	-6.177E-04 V	1.222E-04 V	-7.431E-06 V
-0.095 V	0.041 V	-6.547E-03 V	2.639E-05 V	6.205E-05 V	1.057E-06 V	-5.026E-07 V
-0.070 V	0.018 V	-1.728E-03 V	-5.423E-05 V	1.591E-05 V	-6.351E-07 V	-1.420E-08 V

The following graphs depict the performance of the optimized Fukaya lens system:



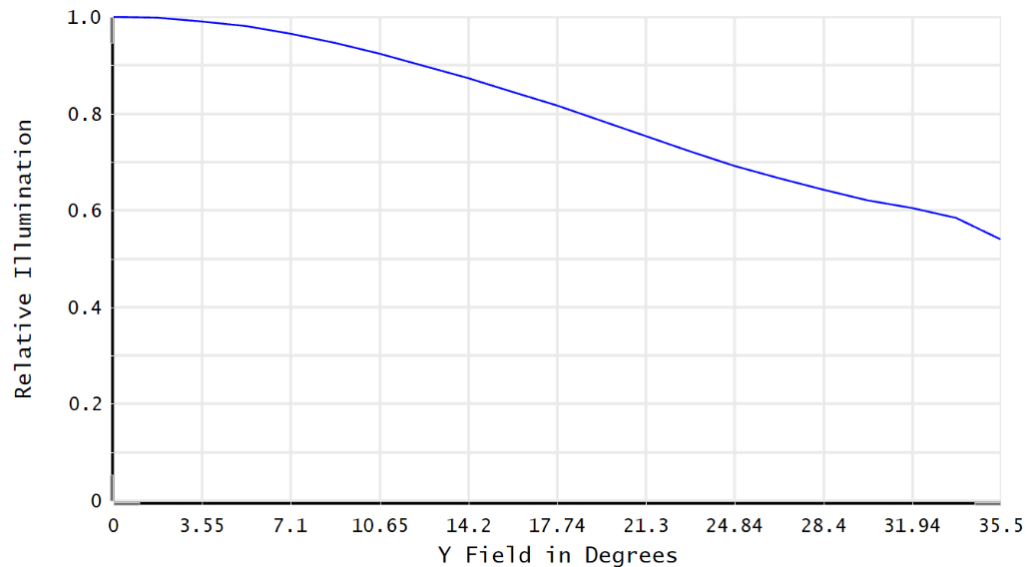
Compared to Fukaya FIG. 2, the optimized Fukaya lens system with a meniscus-gullwing lens pair achieves better aberration control, including for the field curvature, distortion, and longitudinal aberration. As discussed *infra* Section X.C, the optimized Fukaya imaging lens satisfies the challenged claims.

86. Fukaya also expresses a desire to “ensure high brightness to cope with the increase in the number of pixels and provide a wide angle of view to capture an image of an object in a wider perspective.” EX1004, [0006]. However, a POSITA would have recognized that the relative illumination of Fukaya’s imaging lens is below 50% at the edge of the image:



A POSITA would have known that lens specifications require a relative illumination “greater than 50% at the edge of the field.” EX1013, 7; *id.*, 6 (explaining that “relative illumination is the level of light energy incident at the image plane for a given field point relative to that at the center of the image”). A POSITA understood that improved control over chief ray angle across the image plane would ensure that relative illumination would be above 50%, even at the edge. EX1006, [0038] (explaining how the gullwing shape for the seventh lens “makes control of the chief ray angle easy, preventing a decline in relative illumination in the peripheral

[region]”); EX1005, [0128] (same, for the sixth lens). The modified Fukaya imaging lens, with a concave image-side surface of the sixth lens and convex object-side surface of the seventh lens such that both lenses are meniscus on-axis and gullwing-shaped, achieves relative illumination above 50% across the image plane:



The improved relative illumination arises from the increased control over the chief ray angle enabled by implementing the image-side surface of the sixth lens with a gullwing shape, as discussed above.

87. Thus, a POSITA would have found it obvious to use the known technique of double-gullwing lens pairs in a seven-lens system to predictably improve the Fukaya imaging lens.

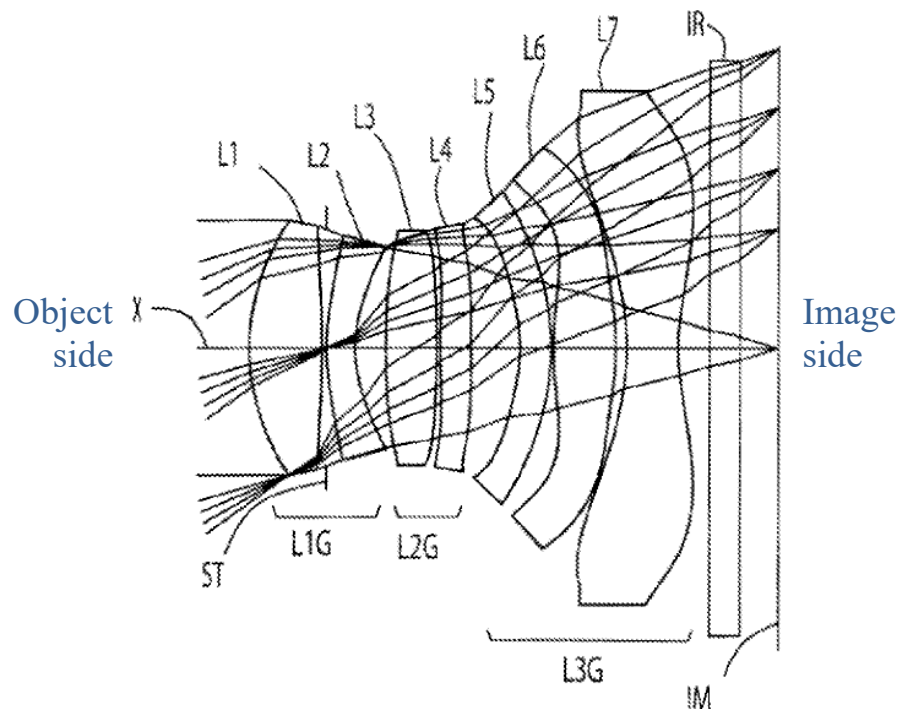
C. Claim Mapping**1. Claim 1****a) Element 1.1**

[1.1]¹⁴ A photographing optical lens assembly comprising, in order from an object side to an image side:

88. To the extent the preamble is limiting, Fukaya discloses it. For example, Fukaya discloses “imaging lenses which form an image of an object on a solid-state image sensor such as a CCD sensor or C-MOS sensor used in a compact image pickup device,” which a POSITA would have understood is a photographing optical lens assembly. EX1004, [0003]. The “lenses are arranged in ... order from an object side to an image side.” *Id.*, [0014]. FIG. 1 confirms this:

¹⁴ Reference numbers in the format of [claim#.element#] are added throughout for ease of reference.

FIG. 1



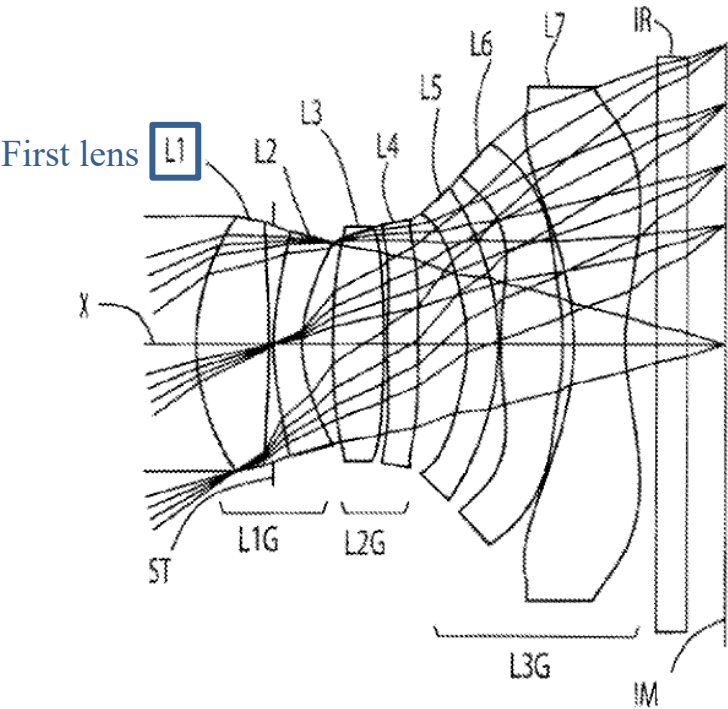
EX1004, FIG. 1 (annotations added); *id.*, [0095].

b) Element 1.2

[1.2] a first lens element having positive refractive power;

89. Fukaya discloses a “positive first lens L1,” which a POSITA would have understood is a first lens element having positive refractive power. EX1004, [0102]; *id.*, [0094]-[0097] (explaining the first lens group L1G including the first lens L1 with positive refractive power). FIG. 1 depicts the first lens L1 in Embodiment 1:

FIG. 1



EX1004, FIG. 1 (annotations added). Table 1 discloses a positive focal length, and thus confirms a positive refractive power, for the first lens L1 of Embodiment 1:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.913
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

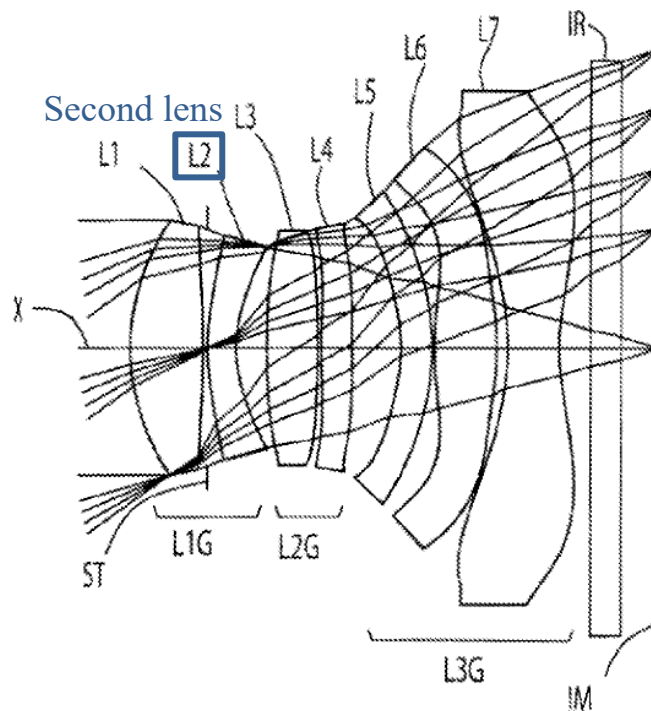
EX1004, [0125] (Table 1) (excerpted) (annotations added).

c) **Element 1.3**

[1.3] a second lens element having negative refractive power;

90. Fukaya discloses a “second lens L2 with negative refractive power.” EX1004, [0096]; *id.*, [0102] (explaining how “the negative second lens L2 effectively ... correct[s] chromatic aberration generated in the positive first lens L1”). FIG. 1 depicts the second lens L2 in Embodiment 1:

FIG. 1



EX1004, FIG. 1 (annotations added). Table 1 discloses a negative focal length, thus confirming a negative refractive power, for the second lens L2 of Embodiment 1:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

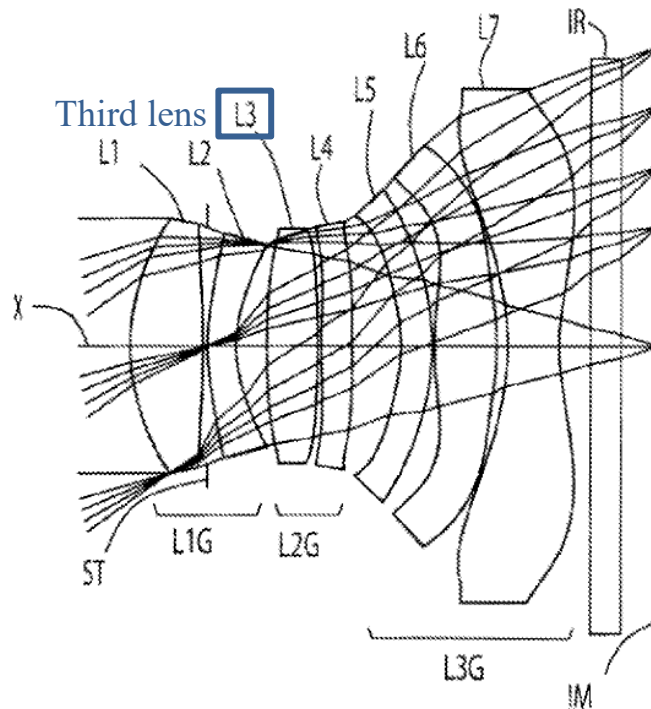
EX1004, [0125] (Table 1) (excerpted) (annotations added).

d) Element 1.4

[1.4] a third lens element;

91. Fukaya discloses a “third lens L3.” EX1004, [0099]; *id.*, [0102] (explaining how “the negative second lens L2 effectively ... correct[s] chromatic aberration generated in the positive first lens L1”). FIG. 1 depicts the third lens L3 in Embodiment 1:

FIG. 1



EX1004, FIG. 1 (annotations added).

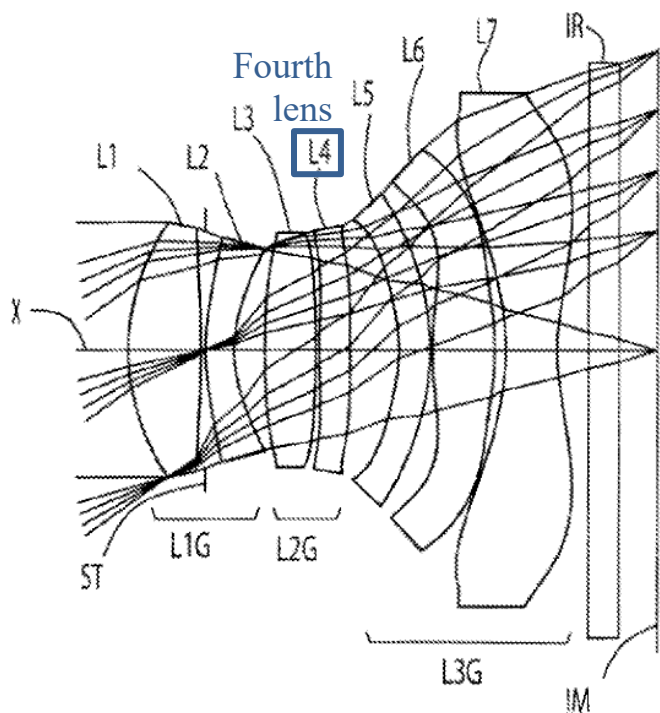
e) **Element 1.5**

[1.5] a fourth lens element having positive refractive power;

92. Fukaya discloses a “fourth lens L4 with positive refractive power.”

EX1004, [0099]. FIG. 1 depicts the fourth lens L4 in Embodiment 1:

FIG. 1



EX1004, FIG. 1 (annotations added). Table 1 discloses a positive focal length, thus confirming a positive refractive power, for the fourth lens L4 of Embodiment 1:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

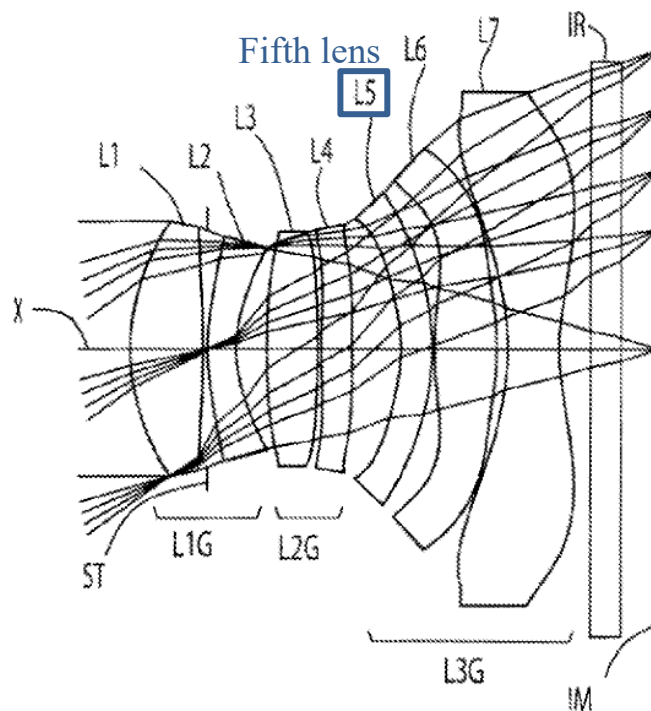
EX1004, [0125] (Table 1) (excerpted) (annotations added).

f) **Element 1.6**

[1.6] a fifth lens element with negative refractive power having an object-side surface being concave in a paraxial region thereof and an image-side surface being convex in a paraxial region thereof;

93. Fukaya discloses a “fifth lens L5 with negative refractive power having a concave object-side surface and a convex image-side surface near the optical axis X,” which a POSITA would have understood as a paraxial region. EX1004, [0100]. FIG. 1 depicts the fifth lens L5 in Embodiment 1 with this meniscus shape:

FIG. 1



EX1004, FIG. 1 (annotations added). Table 1 discloses a negative curvature radius for the object-side surface (surface number 9) and a negative curvature radius for the image-side surface (surface number 10) of the fifth lens L5 of Embodiment 1,

confirming a concave object-side surface and a convex image-side surface for the fifth lens:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added).

94. Table 1 further discloses a negative focal length for the fifth lens L5 of Embodiment 1, confirming the fifth lens L5 having a negative refractive power:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

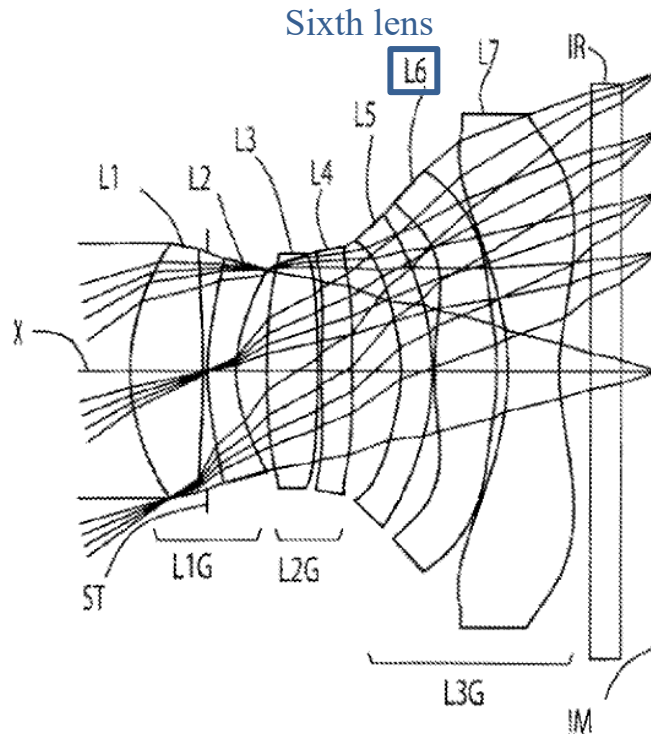
EX1004, [0125] (Table 1) (excerpted) (annotations added).

g) Element 1.7

[1.7] a sixth lens element having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the sixth lens element are aspheric, and the image-side surface of the sixth lens element has at least one inflection point; and

95. Fukaya discloses a “sixth lens L6.” EX1004, [0100]. Fukaya discloses both the object-side and the image-side surface of the sixth lens are aspheric, and explains that when “both the surfaces of the sixth lens are aspheric with their peripheral areas inclined toward the object, it is easy to suppress various aberrations and control the angle of principal light rays incident on the image sensor properly.” *Id.*, [0022]; *id.*, [0123] (“all the lens surfaces are aspheric”), [0125] (providing aspheric coefficients for both surfaces). FIG. 1 depicts the sixth lens L6 in Embodiment 1:

FIG. 1



EX1004, FIG. 1 (annotations added).

96. Regarding an inflection point on the image-side surface of the sixth lens, Fukaya discloses the aspheric equation providing “the aspheric shapes of these lens surfaces,” as well as the radius of curvature, conic constant, and aspheric surface coefficients of the image-side surface of the sixth lens L6. EX1004, [0123], [0125] (Table 1).

Surface Data							
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd			
(Objective Plane)	Infinity	Infinity					
1*	2.120	0.706	1.535	56.16			
2*	-8.388	0.045					
Stop	Infinity	0.000					
3*	2.328	0.280	1.635	23.91			
4*	1.271	0.304					
5*	11.499	0.488	1.535	56.16			
5*	-14.778	0.040					
7*	7.147	0.300	1.535	56.16			
8*	279.233	0.479					
9*	-1.724	0.308	1.635	23.91			
10*	-2.451	0.025					
11*	3.281	0.603	1.535	56.16			
12*	-2.276	0.106					
13*	-2.768	0.500	1.535	56.16			
14*	1.939	0.150					
15	Infinity	0.300	1.517	64.20			
Image Plane	Infinity	0.517					
Aspheric Surface Data							
	1st Surface	2nd Surface	3rd Surface	4th Surface	5th Surface	6th Surface	7th Surface
k	-2.613E-01	0.000E+00	-1.337E+01	-3.683E+00	4.183E+01	0.000E+00	0.000E+00
A4	3.254E-03	4.130E-02	-9.523E-03	8.580E-04	6.036E-02	-1.033E-02	-9.734E-02
A6	-5.108E-04	-1.584E-02	-1.837E-02	1.710E-03	-2.284E-02	-1.354E-02	-2.892E-02
A8	-3.395E-03	-3.810E-03	2.118E-02	2.506E-02	2.337E-02	1.724E-02	3.955E-03
A10	-1.192E-03	4.403E-03	-2.901E-03	-2.479E-02	-3.673E-02	-8.876E-03	3.914E-02
A12	2.923E-03	7.487E-04	-3.172E-03	8.752E-03	2.799E-02	-7.400E-03	-1.458E-02
A14	-1.263E-03	-1.296E-03	4.167E-04	3.157E-04	-1.073E-02	-8.861E-12	1.587E-11
A16	0.000E+00	0.000E+00	5.039E-07	-5.850E-08	-8.096E-06	-6.139E-13	9.787E-13
	8th Surface	9th Surface	10th Surface	11th Surface	12th Surface	13th Surface	14th Surface
k	0.000E+00	7.240E-01	-1.804E+00	-1.321E+01	-2.578E+01	-3.711E+00	-1.822E+01
A4	-4.140E-02	2.245E-01	-1.129E-02	-9.798E-02	5.301E-02	-2.617E-03	-3.214E-02
A6	-4.822E-02	-1.627E-01	1.408E-02	2.567E-02	-4.127E-02	1.485E-03	5.137E-03
A8	-3.177E-03	8.516E-02	-7.161E-03	-1.845E-02	3.896E-03	1.225E-04	-7.897E-04
A10	4.302E-02	-1.878E-02	-2.788E-04	1.269E-03	1.419E-03	3.748E-05	-1.132E-05
A12	-1.925E-02	-3.120E-03	4.709E-04	8.921E-04	-2.734E-04	-2.633E-08	4.631E-06
A14	5.573E-03	2.388E-03	0.000E+00	0.000E+00	0.000E+00	-1.777E-06	6.436E-07
A16	2.179E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.876E-07	-4.667E-09

EX1004, [0125] (Table 1) (annotations added). These values confirm at least one inflection point on the image-side surface of the sixth lens L6.

97. Regarding the image-side surface being concave in a paraxial region thereof, Fukaya discloses the sixth lens L6 with a convex image-side surface in the

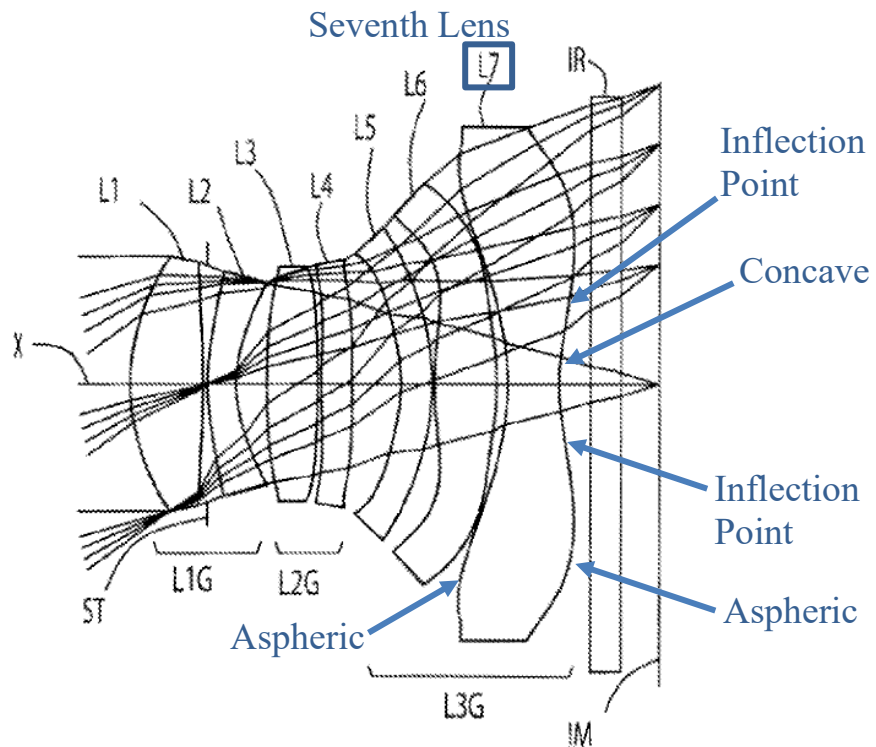
paraxial region. EX1004, [0022], [0100], [0125] (negative curvature radius for surface number 12). As explained *supra* Section X.B, a POSITA would have been motivated, with a reasonable expectation of success, to implement the sixth lens L6 with an image-side surface that is concave in the paraxial region thereof because doing so would naturally provide a gullwing shape for the image-side surface, thereby improving aberration correction and control over chief ray angle.

h) Element 1.8

[1.8] a seventh lens element having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the seventh lens element are aspheric, and the image-side surface of the seventh lens element has at least one inflection point;

98. Fukaya discloses a “seventh lens L7 in which ... the image-side surface [is] concave.” EX1004, [0100]. Both the object-side surface and the image-side surface of the seventh lens L7 are aspheric. *Id.*, [0123] (“all the lens surfaces are aspheric”), [0125] (indicating both surfaces are aspheric). Further, “[t]he image-side surface of the seventh lens L7 has an aspheric shape whose shape changes from concave to convex in the direction toward the periphery,” which a POSITA would understand describes an inflection point. EX1004, [0100]. FIG. 1 depicts the seventh lens L7 in Embodiment 1:

FIG. 1



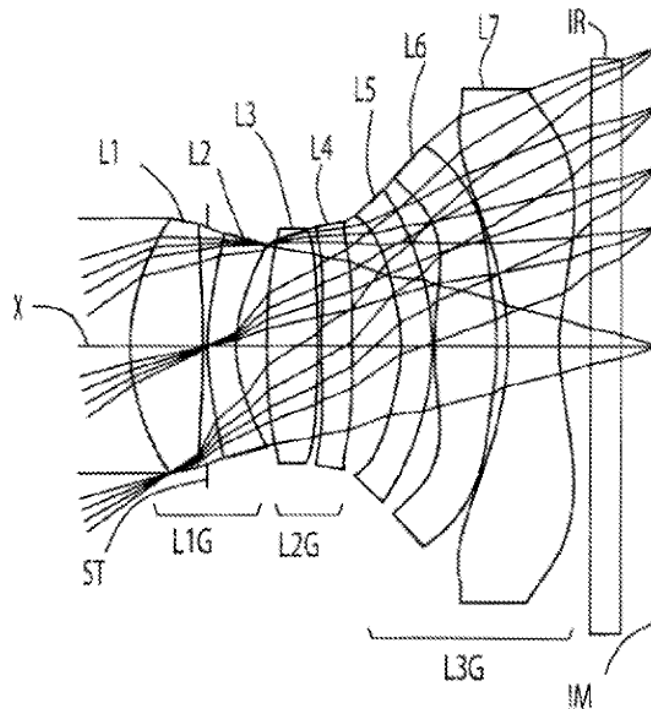
EX1004, FIG. 1 (annotations added).

i) **Element 1.9**

[1.9] wherein the photographing optical lens assembly has a total of seven lens elements,

99. Fukaya discloses imaging lenses composed of “seven lenses.” EX1004, [0069], [0096], [0158], [0160]. FIG. 1 depicts the seven lens elements of Fukaya’s Embodiment 1:

FIG. 1



EX1004, FIG. 1.

j) **Element 1.10**

[1.10] there is a non-axial critical point on the image-side surface of the sixth lens element at which a tangent to the image-side surface of the sixth lens element is perpendicular to an optical axis, there is a non-axial critical point on the image-side surface of the seventh lens element at which a tangent to the image-side surface of the seventh lens element is perpendicular to the optical axis, a vertical distance between the nonaxial critical point on the image-side surface of the sixth lens element and the optical axis is $Yc62$, a vertical distance between the non-axial critical point on the image-side surface of the seventh lens element and the optical axis is $Yc72$, a focal length of the photographing optical lens assembly is f , a focal length of the first lens element is $f1$, a focal length of the seventh lens element is $f7$, and the following conditions are satisfied:

$$0.5 < Yc62/Yc72 < 1.5;$$

$$0.1 < Yc72/f < 0.9; \text{ and}$$

$$|f1/f7| < 3.0.$$

100. **Regarding the $|f1/f7|$ condition,** Fukaya discloses focal lengths of the first lens L1 and the seventh lens L7 satisfying this condition, because the focal length $f1$ of the first lens L1 is 3.241mm, the focal length $f7$ of the seventh lens L7 is -2.057mm, and the ratio $|f1/f7|$ is 1.576, within the claimed range:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

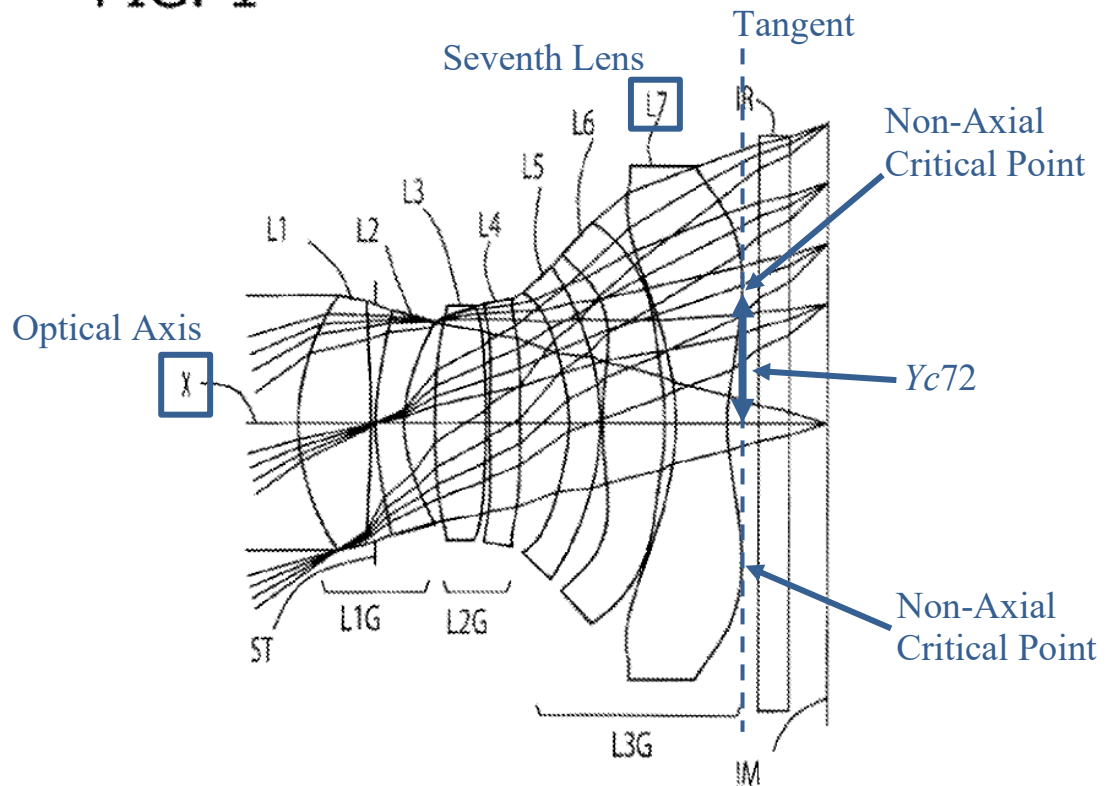
EX1004, [0125] (Table 1) (excerpted) (annotations added).

101. **Regarding the $Yc72/f$ condition,** Fukaya discloses a focal length f of the system of 4.06mm:

Numerical Example 1 in mm
$f = 4.06$ $Fno = 1.64$ $\omega(deg) = 35.49$ $ih = 2.934$

EX1004, [0125] (Table 1) (excerpted) (annotations added). Fukaya further discloses the image-side surface of the seventh lens L7 including a non-axial critical point at which a tangent to the surface is perpendicular to the optical axis, where the non-axial critical point is a vertical distance $Yc72$ from the optical axis X, as depicted in FIG. 1:

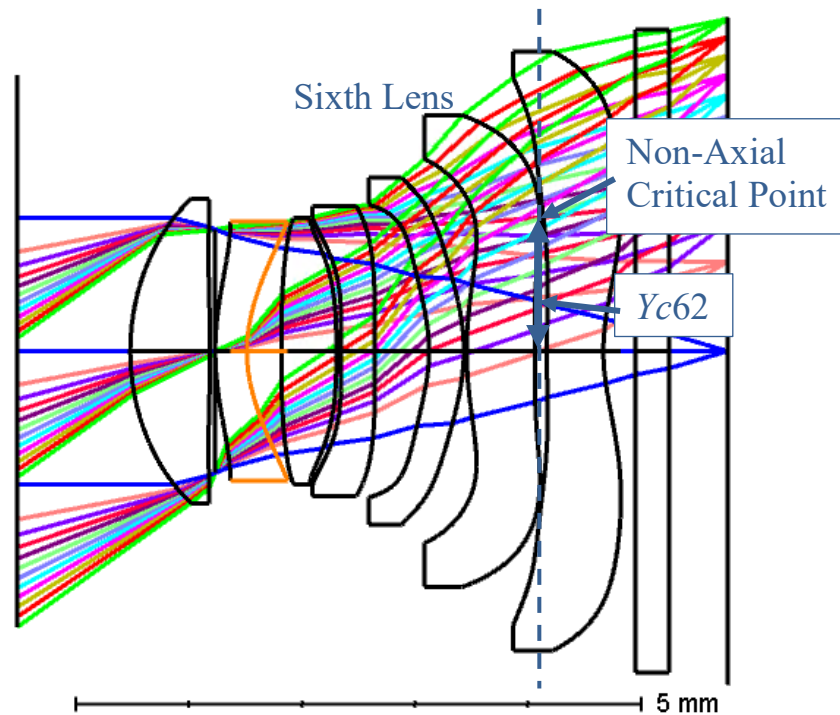
FIG. 1



EX1004, FIG. 1 (annotations added). The vertical distance $Yc72$, which can be accurately measured using lens design software and the aspheric surface values for the surface, is 1.35mm. EX1004, [0125] (disclosing aspheric surface values). Fukaya therefore discloses $Yc72/f=0.33$, which is within the claimed range $0.1 < Yc72/f < 0.9$.

102. **Regarding the $Yc62/Yc72$ condition**, Fukaya does not disclose non-axial critical points on the image-side surface of the sixth lens L6. However, as discussed *supra* Section X.B, a POSITA would have been motivated to implement the sixth lens L6 of Fukaya with the image-side surface concave in the paraxial region in order to achieve a gullwing shape, which enables better off-axis performance and a reduced burden on the seventh lens L7. When so implemented,

the modified Fukaya imaging lens includes a non-axial critical point on the image-side surface of the sixth lens L6 at which a tangent to the image-side surface of the sixth lens L6 is perpendicular to the optical axis, where a vertical distance between the non-axial critical point on the image-side surface of the sixth lens L6 and the optical axis is $Y_{c62}=1.173\text{mm}$.



The vertical distance Y_{c72} in the modified Fukaya imaging lens is 1.303mm. The ratio Y_{c62}/Y_{c72} is therefore 0.900, within the claimed range.

2. Claim 2

2. The photographing optical lens assembly of claim 1, wherein the object-side surface of the sixth lens element is convex in a paraxial region thereof.

103. Fukaya discloses the object-side surface of the sixth lens L6 is “convex near the optical axis X” (in a paraxial region thereof). EX1004, [0100]; *id.*, [0022], [0104]. Table 1 confirms the object-side surface (Surface No. 11) is convex because the curvature radius is positive:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). The object-side surface of the sixth lens L6 remains convex after modification.

3. Claim 3

3. The photographing optical lens assembly of claim 1, wherein the object-side surface of the seventh lens element is convex in a paraxial region thereof.

104. Fukaya discloses the seventh lens L7 with an object-side surface that is concave in a paraxial region thereof. EX1004, [0100], [0104] (“biconcave shape near the optical axis”), [0125] (Surface No. 13 with negative curvature radius). As

discussed *supra* Section X.B, however, a POSITA would have been motivated to implement the seventh lens L7 with an object-side surface that is convex in the paraxial region, in order to achieve a double meniscus-gullwing arrangement for the last two lenses, as doing so would have eased and complemented the implementation of the concave (and thus gullwing shape of) image-side surface of the sixth lens L6, and furthered the advantages of a double-gullwing lens pair. The curvature radius of the object-side surface of the seventh lens in the modified Fukaya imaging lens is positive, confirming a convex object-side surface of the seventh lens L7 in the paraxial region:

	Radius	Thickness	Material	Clear Semi-Dia	Conic
0	Infinity	Infinity		Infinity	0.000
1	Infinity	1.000		2.442	0.000
2	2.057 V	0.706	1.53,56.2 M	1.346	-0.152 V
3	-10.071 V	0.045		1.212	0.000
4	Infinity	0.000		1.076	0.000
5	2.419 V	0.280	1.64,23.9 M	1.097	-13.857 V
6	1.307 V	0.304		1.145	-4.197 V
7	18.231 V	0.488	1.53,56.2 P	1.168	60.863 V
8	-10.103 V	0.040		1.181	-640.164 V
9	14.354 V	0.300	1.53,56.2 P	1.185	74.169 V
10	-15.024 V	0.479		1.282	-5.090E+35
11	-1.477 V	0.308	1.64,23.9 P	1.294	0.168 V
12	-1.699 V	0.025		1.534	-0.260 V
13	3.067 V	0.603	1.53,56.2 P	1.698	-23.389 V
14	10.000 V	0.106		2.085	-7.557E+25
15	10.000 V	0.500	1.53,56.2 P	2.426	-3.711 V
16	1.738 V	0.282 V		2.647	-9.713 V
17	Infinity	0.300	1.52,64.2 M	2.801	0.000
18	Infinity	0.517		2.842	0.000
19	Infinity	-		2.950	0.000

4. Claim 4

4. The photographing optical lens assembly of claim 1, wherein the third lens element has positive refractive power.

105. Fukaya discloses the third lens L3 with positive focal length, and thus positive refractive power:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added). The positive refractive power of the third lens L3 remains after modification.

5. Claim 5

a) Element 5.1

[5.1] The photographing optical lens assembly of claim 1, wherein at least three lens elements have positive refractive power among the first lens element, the second lens element, the third lens element, the fourth lens element, the fifth lens element, the sixth lens element and the seventh lens element,

106. Fukaya discloses four (at least three) lens elements with positive focal lengths and thus positive refractive power:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added).

b) Element 5.2

[5.2] the focal length of the photographing optical lens assembly is f , a curvature radius of the image-side surface of the seventh lens element is $R14$, and the following condition is satisfied:
 $0 < R14/f < 0.7$.

107. Fukaya discloses a focal length f of 4.06mm, and a curvature radius $R14$ of the image-side surface (Surface No. 14) of the seventh lens L7 of 1.939mm, so $R14/f=0.478$, within the claimed range:

Numerical Example 1 in mm				
$f = 4.06$ $Fno = 1.04$ $\omega(deg) = 35.49$ $ih = 2.934$				
Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). The ratio of $R14/f$ remains within the claimed range after modification, because $R14/f = 1.738/4.098 = 0.424$.

6. Claim 6

6. The photographing optical lens assembly of claim 1, wherein the focal length of the photographing optical lens assembly is f , a curvature radius of the image-side surface of the sixth lens element is $R12$, and the following condition is satisfied:
 $0 < f/R12 < 5.0$.

108. Fukaya discloses a focal length f of 4.06mm, but the curvature radius $R12$ of the image-side surface (Surface No. 12) of the sixth lens L6 is -2.276mm, so $f/R12$ is negative and outside the claimed range.

Numerical Example 1 in mm				
$f = 4.06$ $n_{no} = 1.04$ $\omega(\text{deg}) = 35.49$ $i_h = 2.934$				
Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added).

109. However, as discussed *supra* Section X.B, a POSITA would have found it obvious to implement the sixth lens L6 with a concave image-side surface near the optical axis in order to achieve a gullwing shape and its corresponding benefits. So implemented, the curvature radius R12 is 10.000mm, the focal length f is 4.098mm, and $f/R12=0.410$, within the claimed range.

	Radius	Thickness	Material	Clear Semi-Dia	Conic
0	Infinity	Infinity		Infinity	0.000
1	Infinity	1.000		2.442	0.000
2	2.057 V	0.706	1.53,56.2 M	1.346	-0.152 V
3	-10.071 V	0.045		1.212	0.000
4	Infinity	0.000		1.076	0.000
5	2.419 V	0.280	1.64,23.9 M	1.097	-13.857 V
6	1.307 V	0.304		1.145	-4.197 V
7	18.231 V	0.488	1.53,56.2 P	1.168	60.863 V
8	-10.103 V	0.040		1.181	-640.164 V
9	14.354 V	0.300	1.53,56.2 P	1.185	74.169 V
10	-15.024 V	0.479		1.282	-5.090E+35
11	-1.477 V	0.308	1.64,23.9 P	1.294	0.168 V
12	-1.699 V	0.025		1.534	-0.260 V
13	3.067 V	0.603	1.53,56.2 P	1.698	-23.389 V
14	10.000 V	0.106		2.085	-7.557E+25
15	10.000 V	0.500	1.53,56.2 P	2.426	-3.711
16	1.738 V	0.282 V		2.647	-9.713 V
17	Infinity	0.300	1.52,64.2 M	2.801	0.000
18	Infinity	0.517		2.842	0.000
19	Infinity	-		2.950	0.000

7. Claim 7

7. The photographing optical lens assembly of claim 1, wherein the seventh lens element has negative refractive power.

110. Fukaya discloses the seventh lens L7 with negative refractive power. EX1004, [0014], [0021], [0104]. Table 1 confirms that the seventh lens L7 has negative focal length and thus negative refractive power:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added). The negative refractive power of the seventh lens L7 remains after modification.

8. Claim 8

8. The photographing optical lens assembly of claim 1, wherein a curvature radius of the object-side surface of the seventh lens element is R13, a curvature radius of the image-side surface of the seventh lens element is R14, and the following condition is satisfied:
 $0 < (R13 - R14) / (R13 + R14) < 1.5$.

111. This claim is obvious in view of Fukaya. Fukaya discloses a curvature radius R13 of the object-side surface (Surface No. 13) of the seventh lens L7 of -2.768mm, and a curvature radius R14 of the image-side surface (Surface No. 14) of the seventh lens L7 of 1.939mm:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). These curvature radii do not satisfy the claimed condition due to the negative curvature radius R13 corresponding to the concave object-side surface. Since both surfaces are concave, $(R13-R14)/(R13+R14)$ as disclosed equals 5.678.

112. However, as discussed *supra* Sections X.B and X.C.3, a POSITA would have been motivated to implement the seventh lens L7 with a convex object-side surface in order to achieve a double-gullwing pair for the sixth and seventh lenses. So implemented, the curvature radius R13 of the object-side surface is 10.000mm and the curvature radius R14 of the image-side surface is 1.738mm, so $(R13-R14)/(R13+R14)=0.704$, satisfying the condition.

9. Claim 9

9. The photographing optical lens assembly of claim 1, wherein a sum of axial distances between any two lens elements adjacent to each other is $\sum AT$, a maximum image height of the photographing optical lens assembly is $ImgH$, and the following condition is satisfied:
 $0.20 < \sum AT / ImgH < 0.60$.

113. Fukaya discloses a “maximum image height” ih ($ImgH$) of 2.934mm, and axial distances between any two lens elements adjacent to each other that sum to $\sum AT = 0.999$ mm:

Numerical Example 1 in mm				
$f = 4.06$ $Fno = 1.64$ $\omega(deg) = 35.49$ $ih = 2.934$				
Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added), [0061]. Fukaya thus discloses $\sum AT / ImgH = 0.340$, within the claimed range. This ratio remains unchanged after modification.

10. Claim 10

10. The photographing optical lens assembly of claim 1, wherein both of an object-side surface and an image-side surface of the first lens element are aspheric, both of an object-side surface and an image-side surface of the second lens element are aspheric, both of an object-side surface and an image-side surface of the third lens element are aspheric, both of an object-side surface and an image-side surface of the fourth lens element are aspheric, both of an object-side surface and an image-side surface of the fifth lens element are aspheric, an axial distance between the object-side surface of the first lens element and an image surface is TL , the focal length of the photographing optical lens assembly is f , and the following condition is satisfied:
 $0.80 < TL/f < 1.80$.

114. **Regarding aspheric surfaces**, Fukaya discloses that “all the lens surfaces are aspheric.” EX1004, [0123]. This includes both surfaces of the first, second, third, fourth, and fifth lenses. *Id.*, [0069], [0097], [0099], [0103], [0125].

115. **Regarding the TL/f condition**, Fukaya discloses a focal length f of 4.06mm and axial distances from the object-side surface of the first lens element (Surface No. 1) to the image surface (Image Plane) that sum to $TL=5.151$ mm, so $TL/f=1.269$, within the claimed condition:

Numerical Example 1 in mm				
$f = 4.06$ $FNO = 1.64$ $\omega(deg) = 35.49$ $ih = 2.934$				
Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). The condition remains satisfied after modification, with $TL/f=5.283/4.098=1.289$.

11. Claim 11

11. The photographing optical lens assembly of claim 1, wherein a maximum refractive index of one single lens element among the first lens element, the second lens element, the third lens element, the fourth lens element, the fifth lens element, the sixth lens element and the seventh lens element is N_{max} , and the following condition is satisfied:
 $1.640 \leq N_{max} < 1.750$.

116. Fukaya discloses a maximum refractive index N_{max} of 1.635 for two of the lens elements of Embodiment 1, which is just outside the claimed range. EX1004, [0125]. Fukaya discloses a maximum refractive index of 1.635 (or 1.6355)

in its other embodiments, again just outside the claimed range. EX1004, [0128], [0131], [0134], [0137], [0140], [0143], [0146], [0149] ($N_{\max}=1.6355$), [0152], [0155] ($N_{\max}=1.6355$).

117. However, lens materials with a higher refractive index within the claimed range were known to a POSITA and used in similar devices. *E.g.*, EX1005, [0176] (disclosing $N_{\max}=1.640$), [0292] (disclosing $N_{\max}=1.650$); EX1009, 15-16 (showing “commonly available optical plastics” with refractive indices in the claimed range). A POSITA would have found it obvious to simply substitute the higher-index materials with $N=1.635$ of Fukaya with a similar material having $N=1.640$ to yield predictable results, as such materials are effectively interchangeable once the lens is optimized. *E.g.*, EX1010, 31 (explaining that refractive index can be varied during lens optimization, and that a “real [material] nearest the optimized values can be substituted for the optimized [material] to achieve nearly the same resultant design after another cycle or two of optimization with the real [material]”). Zemax modeling confirms that the Fukaya lenses with $N=1.635$, when substituted with material having $N=1.640$, perform nearly identically.

12. Claim 12

12. The photographing optical lens assembly of claim 1, wherein an Abbe number of the second lens element is V_2 , and the following condition is satisfied: $V_2 < 26.0$.

118. Fukaya discloses an Abbe number $V_2=23.91$ of the second lens element, satisfying the condition:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added).

13. Claim 13

13. The photographing optical lens assembly of claim 1, wherein the focal length of the photographing optical lens assembly is f , and the following condition is satisfied:
 $3.0[\text{mm}] < f < 6.5[\text{mm}]$.

119. Fukaya discloses a focal length f of 4.06mm, within the claimed range:

$f = 4.06$
$\Gamma_{HO} = 1.04$
$\omega(\text{deg}) = 35.49$
$i_h = 2.934$

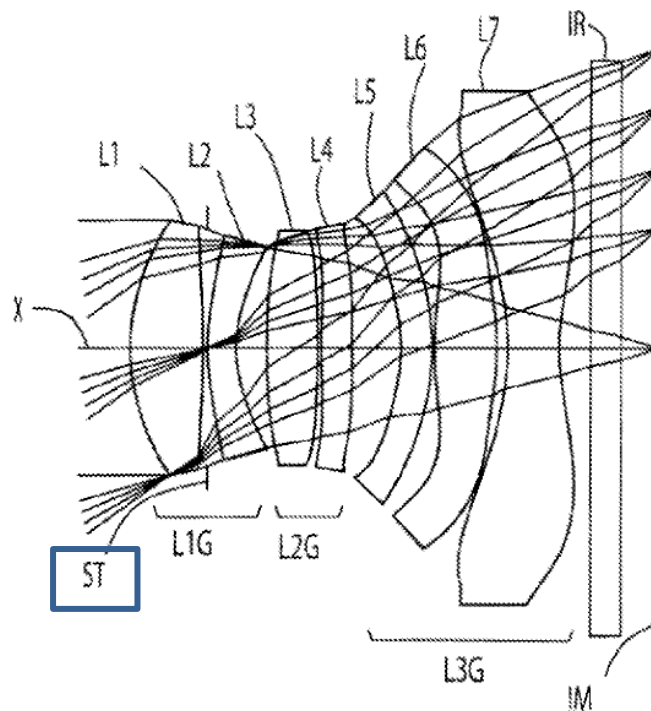
EX1004, [0125] (Table 1) (excerpted) (annotations added). The focal length f remains within the claimed range after the modification.

14. Claim 14

14. The photographing optical lens assembly of claim 1, further comprising an aperture stop, wherein an axial distance between the aperture stop and the image-side surface of the seventh lens element is SD, an axial distance between an object-side surface of the first lens element and the image-side surface of the seventh lens element is TD, and the following condition is satisfied:
 $0.75 < SD/TD < 1.1$.

120. Fukaya discloses an aperture stop in the imaging lens. EX1004, [0067], [0098], [0106], [0125]. FIG. 1 depicts the aperture stop (ST):

FIG. 1



EX1004, FIG. 1 (annotations added). Fukaya discloses the axial distances (Surface Distance) between each surface:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). The darker blue box indicates the axial surface distances from the object-side surface of the first lens (Surface No. 1) to the image-side surface of the seventh lens (Surface No. 13), while the lighter blue box indicates the axial surface distances from the stop (Surface No. Stop) to the image-side surface of the seventh lens (Surface No. 13). These surface distances / axial distances can be summed to determine the axial distance between any two surfaces, including from the aperture stop to the image-side surface of the seventh lens (SD) and from the object-side surface of the first lens to the image-side surface of the seventh lens (TD). Fukaya thus discloses $SD=3.433\text{mm}$ and $TD=4.184\text{mm}$, so $SD/TD=0.821$, within the claimed range. The stop remains in the same position after modification, so the ratio SD/TD continues to satisfy the claimed range after modification.

15. Claim 16

16. The photographing optical lens assembly of claim 1, wherein the focal length of the photographing optical lens assembly is f , an entrance pupil diameter of the photographing optical lens assembly is EPD, half of a maximal field of view of the photographing optical lens assembly is HFOV, and the following conditions are satisfied:

$1.2 < f/EPD < 2.6$; and
 $15[\text{deg.}] < \text{HFOV} < 45[\text{deg.}]$.

121. The recited ratio of focal length f to entrance pupil diameter EPD was well understood as the f-number (“Fno”) of the lens system. EX1009, 71. Fukaya discloses an f-number of 1.64, within the claimed range, and a “half angle of view” (HFOV) of 35.49 degrees, within the claimed range:

Numerical Example 1 in mm	
$f = 4.06$	
Fno = 1.64	
$\omega(\text{deg}) = 35.49$	
$m = 2.934$	

EX1004, [0125] (Table 1) (excerpted) (annotations added); *id.*, [0068] (imaging lens “provides brightness with an F-number of 2.0 or less and ...it provides very high brightness ($1.6 < \text{Fno} < 1.8$)”), [0124] (“Fno represents F-number, ω represents half angle of view”). The f-number and HFOV of the modified Fukaya system also satisfy the claimed ranges.

16. Claim 17

17. The photographing optical lens assembly of claim 1, wherein a central thickness of the first lens element is CT1, a central thickness of the second lens element is CT2, an axial distance between the second lens element and the third

lens element is T23, an axial distance between the third lens element and the fourth lens element is T34, and the following conditions are satisfied:
 $1.0 < CT1/CT2 < 5.5$; and
 $0.5 < T23/T34 < 4.5$.

122. Fukaya discloses a central thickness $CT1=0.706\text{mm}$ of the first lens L1, a central thickness $CT2=0.280\text{mm}$ of the second lens L2, an axial distance $T23=0.304\text{mm}$ between the second and third lenses, and an axial distance $T34=0.040\text{mm}$ between the third and fourth lenses:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706 CT1	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280 CT2	1.635	23.91
4*	1.271	0.304 T23		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040 T34		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). Fukaya thus discloses $CT1/CT2=2.521$, within the claimed range.

123. The ratio $T23/T34=7.6$ is outside the claimed range, but a POSITA would have found it obvious to vary the axial distances between the second, third, and fourth lenses in Fukaya's Embodiment 1, because nearly every other

embodiment of Fukaya discloses air spaces between these lenses satisfying the T_{23}/T_{34} condition while also achieving the objectives of Fukaya, such as a positive composite focal length of the third and fourth lenses. EX1004, [0128] (disclosing $T_{23}/T_{34}=1.9$ but a similar positive composite focal length for second lens group), [0134] ($T_{23}/T_{34}=0.93$), [0137] ($T_{23}/T_{34}=2.97$), [0140] ($T_{23}/T_{34}=2.88$), [0143] ($T_{23}/T_{34}=1.59$), [0146] ($T_{23}/T_{34}=2.75$), [0149] ($T_{23}/T_{34}=3.97$), [0152] ($T_{23}/T_{34}=4.38$), [0155] ($T_{23}/T_{34}=2.08$). These other embodiments also satisfy all 14 conditional expressions set forth by Fukaya in paragraphs [0025]-[0066]. EX1004, [0129], [0135], [0138], [0141], [0144], [0147], [0150], [0153], [0156]. A POSITA thus would have simply substituted the known elements with predictable results.

17. Claim 18

a) Element 18.1

[18.1] An image capturing unit, comprising:

124. Fukaya discloses “imaging lenses which form an image of an object on a solid-state image sensor such as a CCD sensor or C-MOS sensor used in a compact image pickup device.” EX1004, [0003]. A “compact image pickup device” is an “image capturing unit” because it uses the image sensor to capture the image of the object formed on the sensor by the imaging lenses.

b) Element 18.2

[18.2] the photographing optical lens assembly of claim 1;

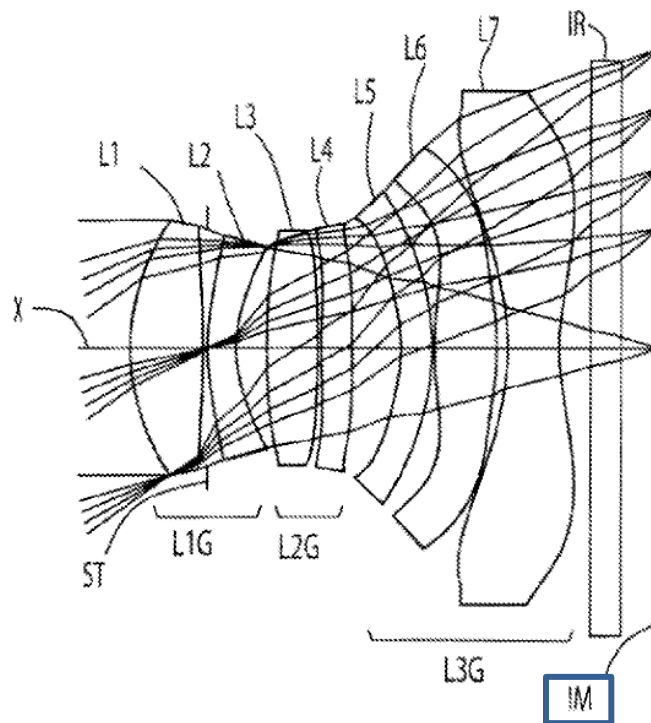
125. As discussed *supra* Section X.C.1, Fukaya renders the photographing optical lens assembly of claim 1 obvious.

c) Element 18.3

[18.3] and an image sensor, wherein the image sensor is disposed on the image side of the photographing optical lens assembly.

126. Fukaya discloses a “solid-state image sensor such as a CCD sensor or C-MOS sensor” that is disposed on the image side of the seventh lens L7 of the imaging lens, and thus on the image side of the imaging lens (photographing optical lens assembly) taught by Fukaya. EX1004, [0003], [0013]-[0015], [0023], [0067], [0104], [0106], [0119], [0122], [0125] (showing “Image Plane” as the last surface at the image side). FIG. 1 depicts the image plane (IM) where the image sensor is disposed:

FIG. 1



EX1004, FIG. 1 (annotations added).

18. Claim 19

a) Element 19.1

[19.1] An electronic device, comprising:

127. Fukaya discloses “imaging lenses which are built in image pickup devices mounted in mobile terminals such as smart phones and mobile phones, which are becoming increasingly compact and thin, and PDAs (Personal Digital Assistants), game consoles and information terminals such as PCs.” EX1004, [0003], *id.*, [0005], [0160]. Such mobile terminals, game consoles, and information terminals are electronic devices.

b) Element 19.2

[19.2] the image capturing unit of claim 18.

128. As discussed *supra* Section X.C.17, Fukaya renders obvious the image capturing unit of claim 18.

19. Claim 20

a) Elements 20.1-20.6

[20.1] A photographing optical lens assembly comprising, in order from an object side to an image side:

[20.2] a first lens element having positive refractive power;

[20.3] a second lens element;

[20.4] a third lens element having positive refractive power;

[20.5] a fourth lens element having positive refractive power;

[20.6] a fifth lens element;

129. As explained *supra* Sections X.C.1.a)-X.C.1.f) (elements 1.1-1.6) and X.C.4 (claim 4), Fukaya discloses these elements.

b) Element 20.7

[20.7] a sixth lens element with positive refractive power having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the sixth lens element are aspheric, and the image-side surface of the sixth lens element has at least one inflection point; and

130. As discussed *supra* Sections X.B and X.C.1.g), Fukaya renders this obvious. Fukaya discloses a sixth lens L6 with aspheric surfaces and at least one inflection point on the image-side surface. *Supra* Section X.C.1.g). Fukaya also

discloses that the sixth lens L6 has “positive refractive power.” EX1004, [0014], [0021]-[0022], [0104]. Table 1 confirms that the sixth lens L6 has positive focal length and thus positive refractive power:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added). As discussed *supra* Sections X.B, a POSITA would have been motivated to implement the sixth lens L6 with a concave image-side surface so that the image-side surface has a gullwing shape, thereby improving off-axis aberration control and reducing the burden on the seventh lens for field corrections. So implemented, the sixth lens L6 of the modified Fukaya imaging lens maintains positive refractive power.

c) Elements 20.8-20.9

[20.8] a seventh lens element having an image-side surface being concave in a paraxial region thereof, wherein both of an object-side surface and the image-side surface of the seventh lens element are aspheric, and the image-side surface of the seventh lens element has at least one inflection point;

[20.9] wherein the photographing optical lens assembly has a total of seven lens elements,

131. As discussed *supra* Sections X.C.1.h) and X.C.1.i), Fukaya discloses these elements.

d) **Element 20.10**

[20.10] there is a non-axial critical point on the image-side surface of the seventh lens element at which a tangent to the image-side surface of the seventh lens element is perpendicular to an optical axis, a focal length of the photographing optical lens assembly is f , a vertical distance between the non-axial critical point on the image-side surface of the seventh lens element and the optical axis is Y_{c72} , a focal length of the first lens element is f_1 , a focal length of the second lens element is f_2 , an axial distance between an object-side surface of the first lens element and an image surface is TL , a maximum image height of the photographing optical lens assembly is $ImgH$, and the following conditions are satisfied:

$$0.1 < Y_{c72}/f < 0.9;$$

$$|f_1/f_2| < 2.0; \text{ and}$$

$$TL/ImgH < 2.20.$$

132. As discussed *supra* Section X.C.1.j), Fukaya discloses a non-axial critical point on the image-side surface of the seventh lens L7 satisfying the Y_{c72}/f condition. As discussed *supra* Sections X.C.9 and X.C.10 (claims 9, 10), Fukaya discloses a maximum image height i_h ($ImgH$) of 2.934mm, and a track length (TL) of 5.151mm. Fukaya thus discloses $TL/ImgH=1.756$, within the claimed range.

133. Fukaya further discloses a focal length $f_1=3.241$ mm for the first lens L1 and a focal length $f_2=-4.915$ mm for the second lens L2, so $|f_1/f_2|=0.659$, within the claimed range:

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added). These conditions remain satisfied after implementing Fukaya with a double-gullwing lens pair.

20. Claim 21

21. The photographing optical lens assembly of claim 20, wherein the object-side surface of the first lens element is convex in a paraxial region thereof, and the second lens element has an image-side surface being concave in a paraxial region thereof.

134. Fukaya discloses the “first lens ... having a convex object-side surface” and the “second lens ... having a concave image-side surface near the optical axis.” EX1004, [0014], [0016]-[0017], [0096]. Table 1 confirms a positive curvature radius and thus convex curvature for the object-side surface (Surface No. 1) of the first lens L1 and a positive curvature radius and thus concave curvature for the image-side surface (Surface No. 4) of the second lens L2:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.228	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). These characteristics remain after implementing Fukaya with a double-gullwing lens pair.

21. Claim 22

22. The photographing optical lens assembly of claim 20, wherein the third lens element has an object-side surface being convex in a paraxial region thereof.

135. Fukaya discloses the third lens L3 with a convex object-side surface.

EX1004, [0020], [0099], [0105]. Table 1 discloses a positive curvature radius and thus convex curvature for the object-side surface (Surface No. 5) of the third lens L3:

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). This surface remains convex after modification.

22. Claim 23

23. The photographing optical lens assembly of claim 20, wherein the fifth lens element has negative refractive power.

136. Fukaya discloses this. *Supra* Section X.C.1.f) (element 1.6).

23. Claim 24

24. The photographing optical lens assembly of claim 20, wherein the fifth lens element has an image-side surface being convex in a paraxial region thereof.

137. Fukaya discloses this. *Supra* Section X.C.1.f) (element 1.6).

24. Claim 25

25. The photographing optical lens assembly of claim 20, wherein the focal length of the photographing optical lens assembly is f, a curvature radius of the

image-side surface of the sixth lens element is R12, and the following condition is satisfied:
 $0 < f/R12 < 3.0$.

138. For the same reasons discussed *supra* Section X.C.6 (claim 6), Fukaya renders this claim obvious.

25. Claim 26

26. The photographing optical lens assembly of claim 20, wherein the focal length of the first lens element is f1, the focal length of the second lens element is f2, a focal length of the third lens element is f3, a focal length of the fourth lens element is f4, a focal length of the fifth lens element is f5, a focal length of the sixth lens element is f6, a focal length of the seventh lens element is f7, and the following condition is satisfied:
 $|f1| < |fi|$, wherein $i=2, 3, 4, 5, 6, 7$.

139. Fukaya discloses a focal length f1 of the first lens L1 with a magnitude less than the magnitude of the focal lengths for the remaining lenses, except for the sixth and seventh lenses. EX1004, [0125] (Table 1). However, a POSITA would have been motivated, with a reasonable expectation of success, to increase the focal lengths of the sixth and seventh lenses when implementing them as a double-gullwing lens pair, because increasing their focal lengths decreases their refractive power accordingly, thereby allowing the sixth and seventh lenses to primarily affect off-axis performance. Implementing the sixth and seventh lenses as a double-gullwing lens pair, while varying the curvature radii and optimizing off-axis performance, naturally results in the focal lengths of the sixth and seventh lenses increasing:

Lens	Focal Length (mm)
1	3.245
2	-4.915
3	12.172
4	13.712
5	-38.543
6	7.991
7	-4.001

So implemented, the focal lengths of the modified Fukaya imaging lens satisfy the claimed condition.

26. Claim 27

27. The photographing optical lens assembly of claim 20, wherein a curvature radius of the object-side surface of the sixth lens element is $R11$, a curvature radius of the image-side surface of the sixth lens element is $R12$, and the following condition is satisfied:
 $-2.0 < (R11 - R12) / (R11 + R12) < 0.2$.

140. Fukaya discloses curvature radii for the sixth lens L6 that do not satisfy this condition. EX1004, [0125] (Table 1). However, a POSITA would have found it obvious to implement the sixth lens L6 with a concave image-side surface, as discussed *supra* Sections X.B and X.C.1.g), and specifically would have found it obvious to implement the sixth lens with curvature radii satisfying this condition because such condition was known for “optimizing a shape of the sixth lens” for “correcting aberration.” EX1007, [0070]-[0072]. So implemented, the curvature radii for the sixth lens satisfy this condition, as $R11=3.067\text{mm}$, $R12=10.000\text{mm}$, and $(R11-R12)/(R11+R12)=-0.531$, within the claimed range.

	Radius	Thickness	Material	Clear Semi-Dia	Conic
0	Infinity	Infinity		Infinity	0.000
1	Infinity	1.000		2.442	0.000
2	2.057 V	0.706	1.53,56.2 M	1.346	-0.152 V
3	-10.071 V	0.045		1.212	0.000
4	Infinity	0.000		1.076	0.000
5	2.419 V	0.280	1.64,23.9 M	1.097	-13.857 V
6	1.307 V	0.304		1.145	-4.197 V
7	18.231 V	0.488	1.53,56.2 P	1.168	60.863 V
8	-10.103 V	0.040		1.181	-640.164 V
9	14.354 V	0.300	1.53,56.2 P	1.185	74.169 V
10	-15.024 V	0.479		1.282	-5.090E+35
11	-1.477 V	0.308	1.64,23.9 P	1.294	0.168 V
12	-1.699 V	0.025		1.534	-0.260 V
13	3.067 V	0.603	1.53,56.2 P	1.698	-23.389 V
14	10.000 V	0.106		2.085	-7.557E+25
15	10.000 V	0.500	1.53,56.2 P	2.426	-3.711
16	1.738 V	0.282 V		2.647	-9.713 V
17	Infinity	0.300	1.52,64.2 M	2.801	0.000
18	Infinity	0.517		2.842	0.000
19	Infinity	-		2.950	0.000

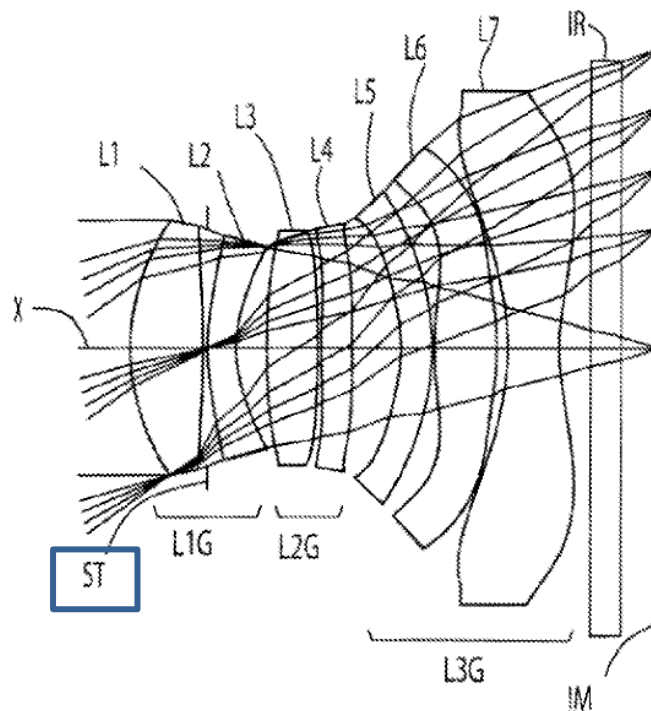
Fukaya thus renders this claim obvious in view of the knowledge of a POSITA.

27. Claim 30

30. The photographing optical lens assembly of claim 20, further comprising an aperture stop, wherein the first lens element, the second lens element, the third lens element, the fourth lens element, the fifth lens element, the sixth lens element and the seventh lens element are all non-cemented lens elements, and the aperture stop is located between an imaged object and the second lens element.

141. Fukaya discloses “an aperture stop ... located between the first and second lenses or on the object side of the first lens.” EX1004, [0067]; *id.*, [0098], [0106], [0125]. FIG. 1 depicts the aperture stop (ST) between the first lens L1 and the second lens L2 (between an imaged object and the second lens element), and also depicts the first through seventh lenses as non-cemented lenses:

FIG. 1



EX1004, FIG. 1 (annotations added).

28. Claim 32

32. The photographing optical lens assembly of claim 20, wherein the focal length of the photographing optical lens assembly is f , a focal length of the third lens element is f_3 , and the following condition is satisfied:
 $-0.5 < f/f_3 < 0.6$.

142. Fukaya discloses a focal length $f=4.06\text{mm}$ for the imaging lens and a focal length $f_3=12.175\text{mm}$ for the third lens L3, so $f/f_3=0.333$, within the claimed range.

Constituent Lens Data		
Lens	Start Surface	Focal Length
1	1	3.241
2	3	-4.915
3	5	12.175
4	7	13.714
5	9	-10.937
6	11	2.612
7	13	-2.057

EX1004, [0125] (Table 1) (excerpted) (annotations added). This condition remains satisfied after modification.

29. Claim 33

33. The photographing optical lens assembly of claim 20, wherein an axial distance between the first lens element and the second lens element is T_{12} , an axial distance between the second lens element and the third lens element is T_{23} , an axial distance between the third lens element and the fourth lens element is T_{34} , an axial distance between the fourth lens element and the fifth lens element is T_{45} , an axial distance between the fifth lens element and the sixth lens element is T_{56} , an axial distance between the sixth lens element and the seventh lens element is T_{67} , and the following condition is satisfied:
 $0 < (T_{12}/T_{23}) + (T_{34}/T_{45}) + (T_{56}/T_{67}) < 3.8$.

143. Fukaya discloses axial distances between the lenses of $T_{12}=0.045\text{mm}$, $T_{23}=0.304\text{mm}$, $T_{34}=0.040\text{mm}$, $T_{45}=0.479\text{mm}$, $T_{56}=0.025\text{mm}$, and $T_{67}=0.106\text{mm}$, so $(T_{12}/T_{23}) + (T_{34}/T_{45}) + (T_{56}/T_{67}) = 1.219$, within the claimed range.

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). This condition remains satisfied after modification.

30. Claim 34

34. The photographing optical lens assembly of claim 20, further comprising aperture stop, wherein the aperture stop is located between an imaged object and the first lens element, an axial distance between the second lens element and the third lens element is T23, a central thickness of the second lens element is CT2, the focal length of the photographing optical lens assembly is f, a curvature radius of an image-side surface of the third lens element is R6, and the following conditions are satisfied:

$0.3 < T23/CT2 < 3.0$; and
 $-1.0 < f/R6 < 2.5$.

144. Fukaya discloses a focal length $f=4.06\text{mm}$, axial distance $T23=0.304\text{mm}$, central thickness $CT2=0.280\text{mm}$, and curvature radius $R6=-14.778\text{mm}$, so $T23/CT2=1.086$, within the claimed range, and $f/R6=-0.275$, within the claimed range.

Surface Data				
Surface No. i	Curvature Radius r	Surface Distance d	Refractive Index Nd	Abbe Number vd
(Objective Plane)	Infinity	Infinity		
1*	2.120	0.706	1.535	56.16
2*	-8.388	0.045		
Stop	Infinity	0.000		
3*	2.328	0.280	1.635	23.91
4*	1.271	0.304		
5*	11.499	0.488	1.535	56.16
5*	-14.778	0.040		
7*	7.147	0.300	1.535	56.16
8*	279.233	0.479		
9*	-1.724	0.308	1.635	23.91
10*	-2.451	0.025		
11*	3.281	0.603	1.535	56.16
12*	-2.276	0.106		
13*	-2.768	0.500	1.535	56.16
14*	1.939	0.150		
15	Infinity	0.300	1.517	64.20
Image Plane	Infinity	0.517		

EX1004, [0125] (Table 1) (excerpted) (annotations added). These conditions remain satisfied after modification.

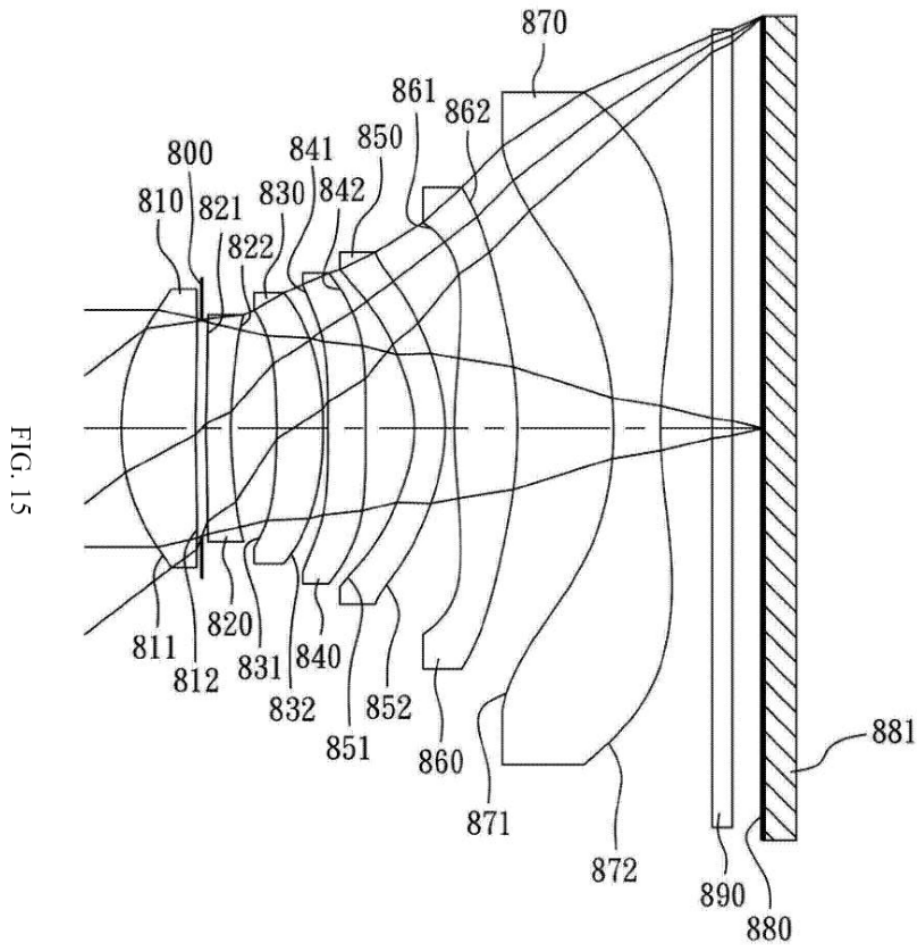
XI. GROUND 2: CLAIMS 1-4, 7, 9-13, 15-16, 18-21, 23-24, AND 28-31 ARE OBVIOUS OVER CAI AND THE KNOWLEDGE OF A POSITA

145. As explained below, claims 1-4, 7, 9-13, 15-16, 18-21, 23-24, and 28-31 are obvious over Cai in view of the knowledge of a POSITA.

A. Cai (EX1005)

146. Chinese Patent Grant No. CN 202886720 U (EX1005, “Cai”) was filed October 16, 2012, and granted April 17, 2013. EX1005, Cover. Cai thus qualifies as prior art under at least Sections 102(a)(1-2). Cai is analogous art to the ’845 patent because both are within the same field of endeavor of lens assemblies with seven lens elements. EX1005, [0001], [0005]-[0006]; EX1001, 1:14-18, 1:52-56.

147. Cai discloses various embodiments of a seven-lens-element “optical image capturing system set” that uses “aspherical surfaces and inflection points to facilitate correcting the high order aberration and the off-axis aberrations,” “to reduce the angle at which the incident light projects onto the image sensing element under a limited total length,” and to achieve “a better image quality and a compact size.” EX1005, [0005]. Cai discloses a gullwing shape for the image-side surface of the seventh lens, which includes a “tangent point ... formed between the tangent plane and the image-side surface” with vertical distance Y_{c72} from the optical axis satisfying “ $0.1 < Y_{c72}/f < 0.9$,” the same condition recited in claim 1 of the ’845 patent. EX1005, [0031], [0033].



EX1005, FIG. 15.

148. Cai satisfies all elements of claim 1, aside from those pertaining to a gullwing sixth lens ([1.7], “a sixth lens element having an image-side surface being concave in a paraxial region thereof”; [1.10], “ $0.5 < Y_{c62}/Y_{c72} < 1.5$ ”). Nevertheless, as explained in the following sub-sections, Cai in view of the knowledge of a POSITA renders the challenged claims obvious.

B. Implementing Cai With A Gullwing Sixth Lens

149. As discussed below and herein, a POSITA would have been motivated, with a reasonable expectation of success, to implement the optical image capturing system set of Cai with a gullwing sixth lens. Specifically, a POSITA would have found it obvious to implement Cai with a gullwing sixth lens that works together with the gullwing seventh lens because the use of two gullwing lenses near the image plane was a well-known solution for compact, high-resolution image systems that improves aberration correction and control of the chief ray angle. So implemented, Cai discloses all elements of the challenged claims. *Infra* Section XI.C.

150. Cai discloses “the use of aspherical surfaces and inflection points to facilitate correcting the high order aberration and the off-axis aberrations ... and to reduce the angle at which the incident light projects onto the image sensing element ...” EX1005, [0005]. Cai discloses using such inflection points on the seventh lens to improve off-axis performance and control the chief ray angle (CRA), as well as to achieve a compact size of the imaging system. EX1005, [0005], [0052], [0129]. Cai similarly discloses “the object-side surface of the sixth lens chang[ing] from convex at a paraxial region to concave at a peripheral region so as to maintain a relative illumination of the periphery of [the] images.” EX1005, [0128]. Cai therefore already recognized the benefits of the gullwing shape for the last two lenses of the system.

151. As discussed *supra* Sections VII.B.2-VII.B.3, through developments in compact lens design between the filing of Cai and the alleged priority date of the '845 patent, POSITAs recognized that using gullwing shapes for both image-side surfaces of the sixth and seventh lenses would further achieve these same goals of off-axis aberration correction, compact length, and improved control of the chief ray angle. Additionally, POSITAs recognized that using meniscus shapes on-axis for both the sixth and seventh lenses, with both object-side surfaces convex and both image-side surfaces concave at the optical axis, also furthered these goals while ensuring correction of axial (on-axis) aberrations.

152. A POSITA thus would have been motivated to implement Cai with a sixth lens with a gullwing image-side surface in order to achieve a double-gullwing lens pair that enables improved off-axis aberration correction, compact length, and improved control of chief ray angle. To do so, a POSITA would have used the 8th embodiment of Cai because the sixth lens has a weaker refractive power (longer focal length) compared to other Cai embodiments with the same refractive power configuration, and thus the modification to the image-side surface would have been

easiest to implement.¹⁵ Compare EX1005, [0292] ($f_6=4.50\text{mm}$), with *id.*, [0176], [0242]. With this starting point, the POSITA would have incrementally, iteratively optimized the Cai design while varying the image-side curvature radius of the sixth lens from convex to concave, and targeting improved relative illumination and aberration correction. A POSITA could have used other approaches to implementing the image-side surface with a gullwing lens, such as manually setting the curvature radius to positive and then optimizing, or manually targeting critical points on the surface in the merit function while optimizing; any approach would have been reasonable and easy for a POSITA to pursue.

153. The POSITA would have similarly varied the object-side curvature of the seventh lens from concave to convex while incrementally optimizing the Cai design, to balance the change to the image-side surface of the sixth lens and so that both the sixth and seventh lenses would be meniscus on axis. During this optimization, a POSITA would have expected the image-side surface of the sixth lens to naturally become a gullwing shape with non-axial critical points because of its highly aspheric starting point. As mentioned above, the POSITA would have been

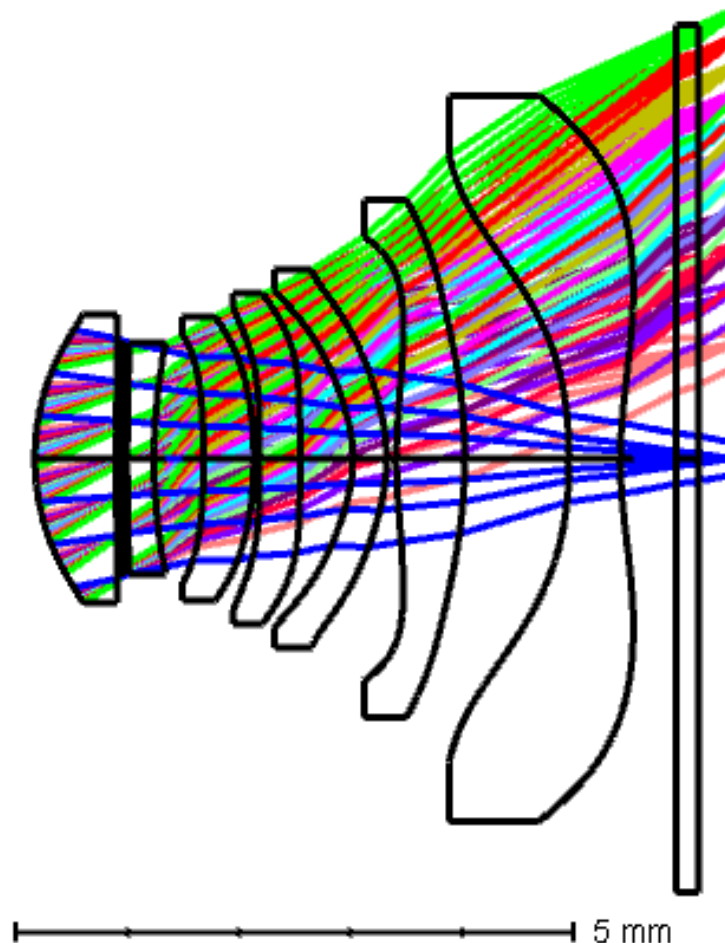
¹⁵ While it would have been obvious to implement other Cai embodiments with a gullwing sixth lens for the same reason, the 8th embodiment on its face appears the most suitable for this improvement.

motivated to make this change because the POSITA knew that such gullwing shape is optimal for off-axis correction and improved control of chief ray angle (and thus improved relative illumination).

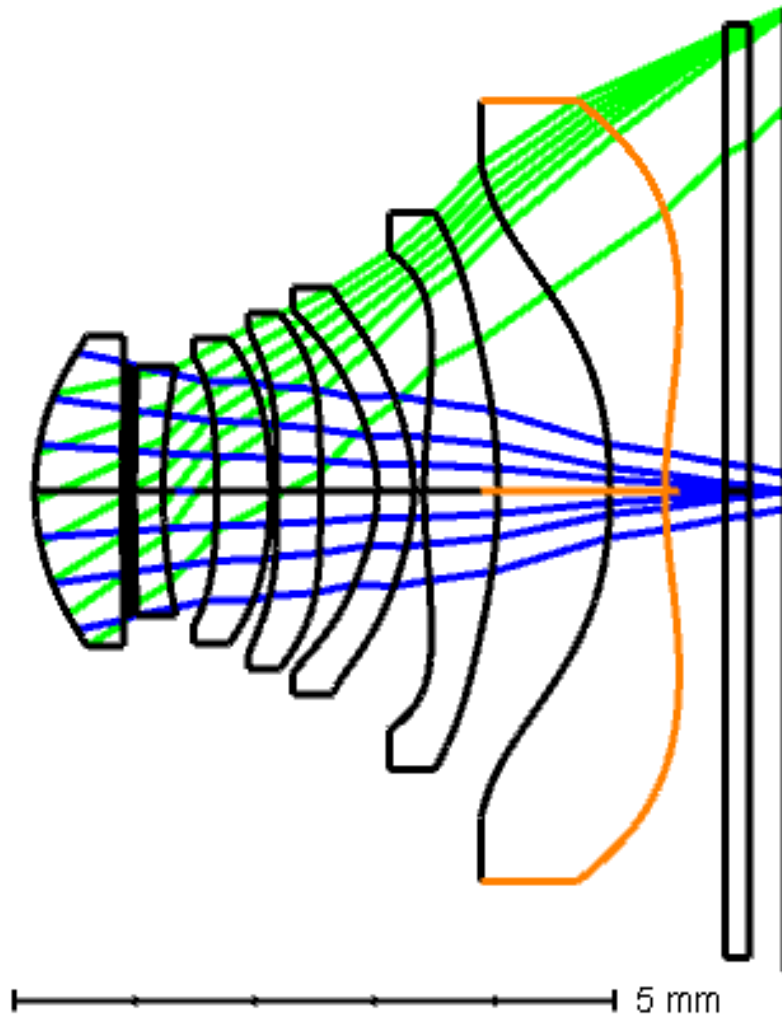
154. A POSITA would have had a reasonable expectation of success implementing Cai with a concave image-side surface on the sixth lens and a convex object-side surface on the seventh lens, because implementing these changes would be a straightforward application of the incremental, iterative lens design process to improve a known starting point, and doing so was well within the skill of a POSITA. *Supra* Section VII.A. A POSITA further would have had a reasonable expectation of success because the resulting configuration (a meniscus-gullwing lens pair with meniscus shapes on-axis) was well understood as reflected by prior art designs with this configuration. *Supra* Section VII.B.3.

155. Zemax modeling confirms that a POSITA would have easily implemented Cai with a concave image-side surface of the sixth lens and a convex object-side surface of the seventh lens. In the following paragraphs, I explain the iterative and incremental approach I used to implement Cai with a gullwing sixth lens, which is consistent with how a POSITA at the time would have approached improving Cai. It is also the same approach that I used to implement Fukaya with a gullwing sixth lens, though slightly adapted for the particular Cai lens system. *Supra* Section X.B. As noted *supra* paragraph 152, a POSITA would have started by

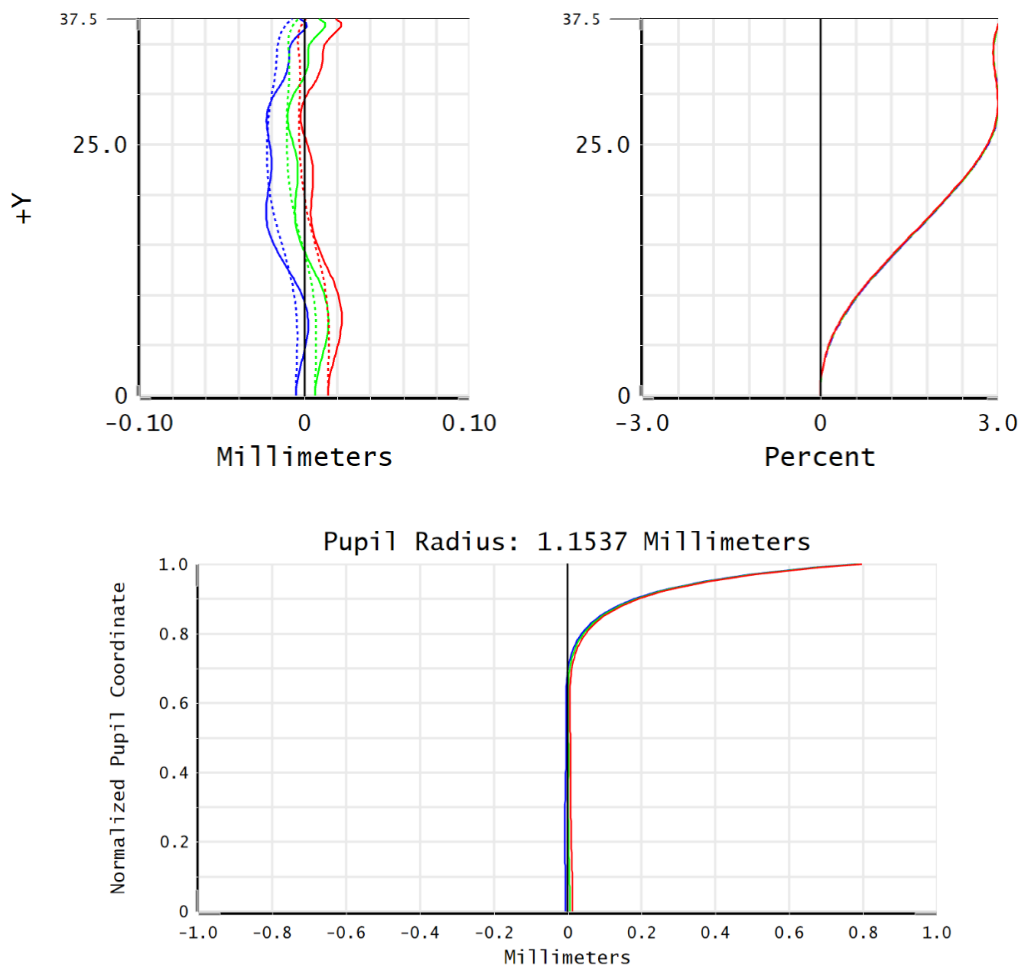
inputting the lens data for Cai's 8th embodiment provided in Tables 15 and 16 into lens design software such as Zemax. *See* EX1005, [0292]-[0293] (Tables 15 and 16). The 8th embodiment is a logical choice to optimize because it has desirable focal length, field angle, and FOV. The following ray-trace diagram depicts the unoptimized Cai 8th embodiment starting point:



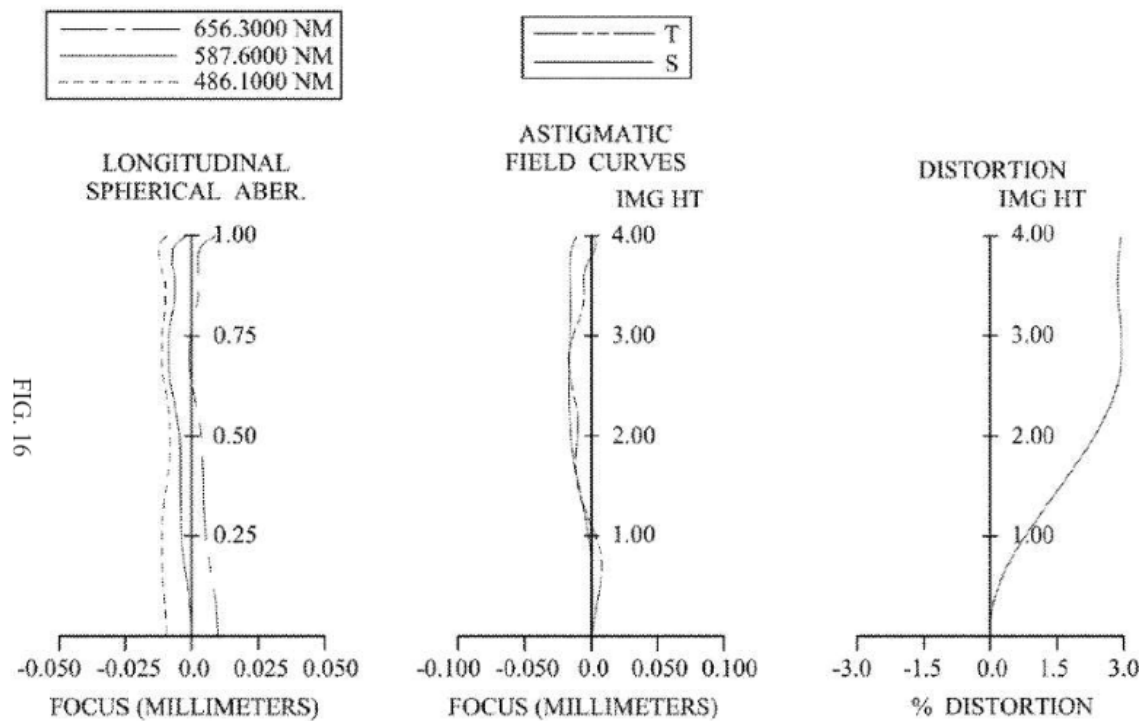
The following ray-trace diagram depicts the same unoptimized Cai 8th embodiment starting point, with only the axial ray bundle and the ray bundle for the largest field angle:



The rays do not appear to focus well at the image plane for any of the field angles. This initial design does not show good performance, as confirmed by the following Zemax performance graphs that indicate how the Cai 8th embodiment system performs without any optimization:



Compare these graphs to the performance graphs shown in FIG. 16 of Cai:



EX1005, FIG. 16. It is clear from the Zemax performance graphs that the Cai lens system should be improved, especially for off-axis performance. The following Zemax lens data is the starting point obtained from the lens tables of Cai:

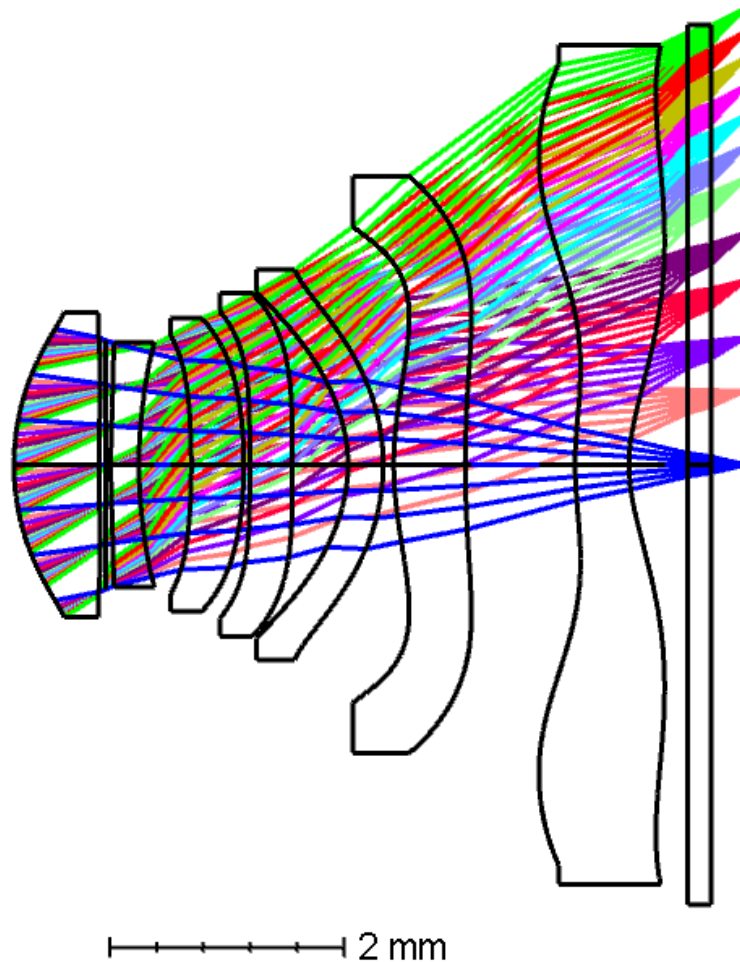
	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia	Conic
0	OBJECT	Standard ▾	Infinity	Infinity		Infinity	Infinity	0.000000
1	Even Asphere ▾	Lens 1	2.106050 V	0.727000	1.53,55.9 M	1.296079	1.296079	0.890178 V
2	Even Asphere ▾		16.377300 V	0.058000		1.098971	1.296079	-0.361096 V
3	STOP	Standard ▾	Infinity	0.042000		1.058370	1.058370	0.000000
4	Even Asphere ▾	Lens 2	9.396400 V	0.240000	1.65,21.4 M	1.041639	1.041639	-38.321800 V
5	Even Asphere ▾		4.171200 V	0.447000		1.032499	1.041639	-9.147380 V
6	Even Asphere ▾	Lens 3	-6.904700 V	0.449000	1.53,55.9 P	1.105119	1.272758	-19.816400 V
7	Even Asphere ▾		-3.745600 V	0.050000		1.272758	1.272758	-2.565550
8	Even Asphere ▾	Lens 4	-237.531700 V	0.364000	1.53,55.9 P	1.356754	1.479297	3.000000 V
9	Even Asphere ▾		-91.271700 V	0.476000		1.479297	1.479297	-1.031830 V
10	Even Asphere ▾	Lens 5	-1.264930 V	0.300000	1.65,21.4 P	1.515342	1.689963	-1.768520 V
11	Even Asphere ▾		-1.687700 V	0.090000		1.689963	1.689963	-3.425950 V
12	Even Asphere ▾	Lens 6	4.716500 V	0.612000	1.53,55.9 P	1.990436	2.318695	-6.588200 V
13	Even Asphere ▾		-4.604000 V	0.936000		2.318695	2.318695	-16.145100
14	Even Asphere ▾	Lens 7	-4.091400 V	0.460000	1.53,55.9 P	2.715802	3.253819	-2.621150
15	Even Asphere ▾		3.720800 V	0.500000		3.253819	3.253819	-21.164300 V
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.822744	3.880360	0.000000
17	Standard ▾		Infinity	0.294000		3.880360	3.880360	0.000000
18	IMAGE	Standard ▾	Infinity	-		4.016130	4.016130	0.000000

4th Order Term	6th Order Term	8th Order Term	10th Order Term	12th Order Term	14th Order Term
-4.952720E-03 V	-0.014455 V	0.024994 V	-0.029334 V	0.016170 V	-4.708100E-03 V
-0.045736 V	0.052977 V	-0.031547 V	2.417460E-03 V	4.397500E-03 V	-1.466930E-03 V
-0.098337 V	0.111966 V	-0.063164 V	7.642090E-03 V	0.012425 V	-4.159650E-03 V
-0.053183 V	0.069794 V	-0.037562 V	0.010309 V	5.482840E-04 V	1.098660E-03 V
-0.039500 V	-0.019545 V	3.725840E-04 V	-8.464460E-03 V	2.586650E-03 V	-1.179260E-08 V
-0.061896 V	0.018750 V	-0.015334 V	2.170520E-03 V	1.958780E-03 V	-4.051290E-04 V
-0.104186 V	4.153420E-03 V	8.387580E-03 V	8.771930E-04 V	-4.854660E-04 V	1.228230E-05 V
-0.051001 V	-0.029851 V	9.543880E-03 V	1.306230E-03 V	-4.865550E-04 V	8.104090E-06 V
0.155550 V	-0.166325 V	0.091204 V	-0.042429 V	0.013720 V	-1.815670E-03 V
0.033280 V	-0.050006 V	0.027015 V	-0.011485 V	2.893030E-03 V	-2.383890E-04 V
-0.062539 V	0.025714 V	-7.557470E-03 V	9.906230E-04 V	-1.458050E-04 V	1.308500E-05 V
-8.144100E-03 V	-7.655520E-03 V	9.579820E-03 V	-3.647170E-03 V	5.802790E-04 V	-3.366110E-05 V
-0.044231 V	7.715170E-03 V	-2.574840E-04 V	-1.439740E-05 V	7.506060E-07 V	-2.465400E-08 V
-0.021926 V	3.608280E-03 V	-5.485950E-04 V	5.095810E-05 V	-3.193150E-06 V	1.000410E-07 V

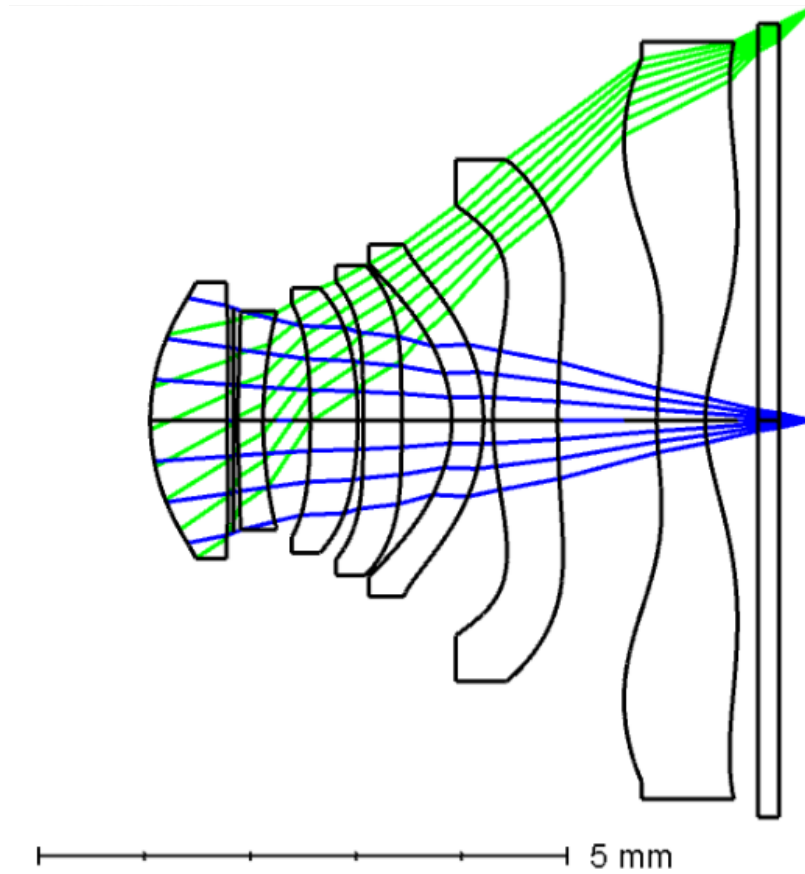
156. The poor performance of the unoptimized Cai system would have further motivated a POSITA to implement Cai with a gullwing sixth lens, so that the off-axis performance can be improved. To optimize the Cai system, I followed a similar design path as I described for Fukaya, and used the same merit function developed for Fukaya while monitoring the conic constants during optimization cycles. *Supra* Section X.B. I also recognized that better performance could be obtained by modifying lens 6 to a gullwing shape. I used standard LONA, FCGT, FCGS, DIMX, FTGT, and RELI operands to control aberrations and lens thicknesses/spacings. Similar to my approach to implementing Fukaya, I set target curvatures on the image-side surface of the sixth lens and the object-side surface of the seventh lens to positive values. During the optimization process, the image-side surface shape of lens 6 naturally changed into a gullwing shape. The positive curvature on the object side of lens 7 changed to be complementary to the positive

curvature on the image side of lens 6. The optimization process produced good results with only a few iteration cycles.

157. The modified Cai system maintains the overall design of the original Cai system, but with improved off-axis performance, as expected, from the meniscus-gullwing lens pair:



The following ray-trace diagram depicts the optimized Cai lens system with only the blue and green ray bundles:



As shown, the optimized Cai lens system exhibits significantly better focusing of the ray bundles on the image plane, compared to the original Cai lens system. The following Zemax table provides lens data for the optimized Cai lens system:

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

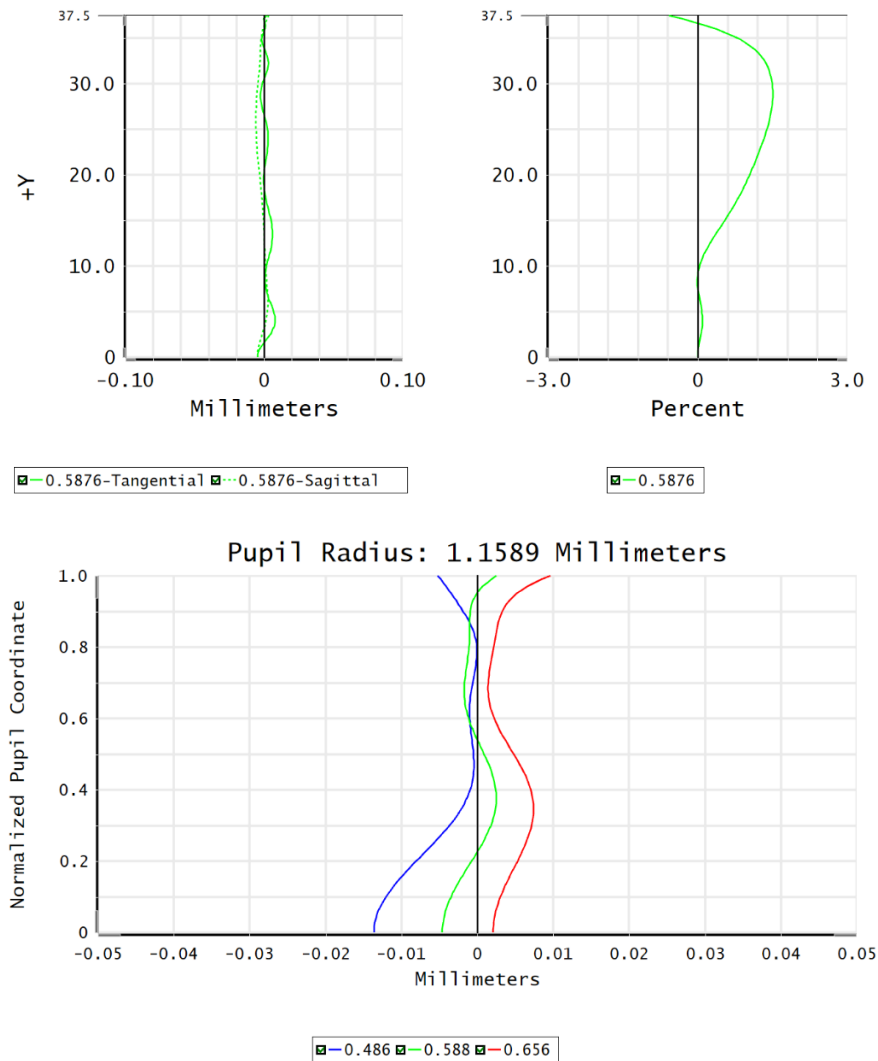
Conic	4th Order Term	6th Order Term	8th Order Term	10th Order Term	12th Order Term	14th Order Term
0.000000						
0.881767 V	-0.011607 V	-4.159321E-03 V	-9.598567E-04 V	-5.453822E-03 V	4.029858E-03 V	-2.022330E-03 V
-63.813001 V	-0.056342 V	0.047983 V	-0.030956 V	7.903928E-03 V	-5.160935E-04 V	-2.351640E-04 V
0.000000						
-16.456834 V	-0.104747 V	0.092714 V	-0.031876 V	-2.533093E-03 V	9.159729E-03 V	-1.895994E-03 V
-2.544687 V	-0.058307 V	0.053047 V	-6.761464E-03 V	-7.594774E-03 V	5.067236E-03 V	1.519315E-03 V
-93.988170 V	-0.055776 V	-6.482485E-04 V	-0.036720 V	0.036407 V	-0.024490 V	8.024854E-03 V
6.727762 V	-0.020701 V	0.015285 V	-0.052429 V	0.042654 V	-0.015663 V	3.053616E-03 V
3.000000	-0.094292 V	0.046294 V	-0.057096 V	0.031134 V	-8.174665E-03 V	7.115026E-04 V
-7.008953E+04	-0.084658 V	0.018418 V	-8.365685E-03 V	-8.733212E-04 V	2.017126E-03 V	-5.329690E-04 V
-0.742918 V	0.113717 V	-0.159928 V	0.133479 V	-0.062159 V	0.016294 V	-1.870309E-03 V
-0.567180 V	0.011450 V	-0.037850 V	0.033904 V	-0.011371 V	1.421393E-03 V	4.204509E-05 V
-8.648853 V	-0.046161 V	0.020121 V	-0.014965 V	5.799144E-03 V	-1.336326E-03 V	1.257488E-04 V
-33.593386 V	0.010489 V	-0.018895 V	6.869531E-03 V	-1.620310E-03 V	2.108881E-04 V	-1.115303E-05 V
-42.827368 V	-0.079310 V	0.019801 V	-2.269742E-03 V	1.410631E-04 V	-4.510008E-06 V	5.701163E-08 V
-8.411531 V	-0.034357 V	6.976996E-03 V	-9.097251E-04 V	7.742197E-05 V	-3.688160E-06 V	7.396367E-08 V
0.000000						
0.000000						
0.000000						

The focal length of the system is $f=5.099\text{mm}$, and the focal lengths of the individual lenses are:

Lens	Focal Length (mm)
1	4.48
2	-11.76
3	14.72
4	279.46
5	-9.61
6	6.76

7	-5.68
---	-------

The following graphs depict the performance of the optimized Cai lens system:



Compared to Cai FIG. 16, the optimized Cai lens system with a meniscus-gullwing lens pair achieves better aberration control, including for the field curvature, distortion, and longitudinal aberration. This modified Cai design satisfies the challenged claims. *Infra* Section XI.C.

158. Thus, a POSITA would have found it obvious to use the known technique of double-gullwing lens pairs in a seven-lens system to predictably improve the Cai lens system.

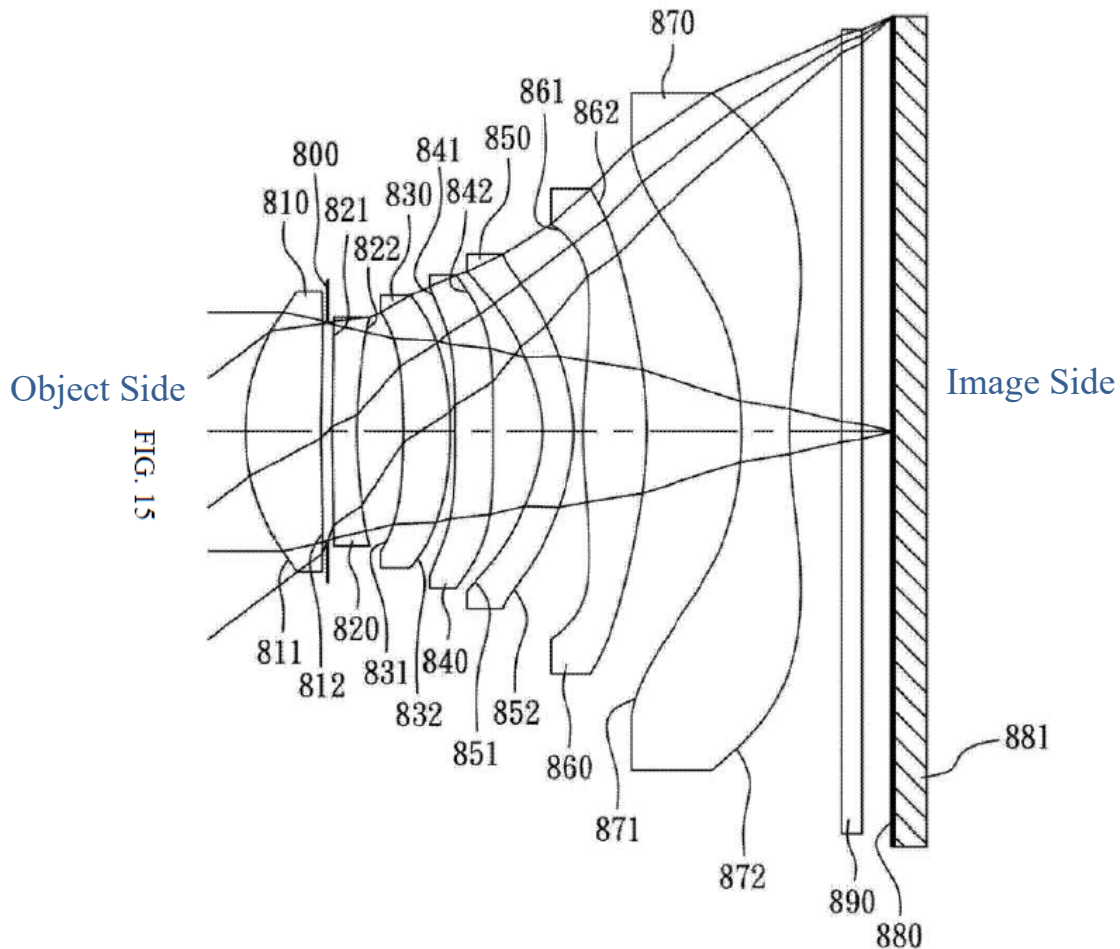
C. Claim Mapping

1. Claim 1

159. Cai discloses or renders obvious each element of the claim.

a) **Element 1.1**

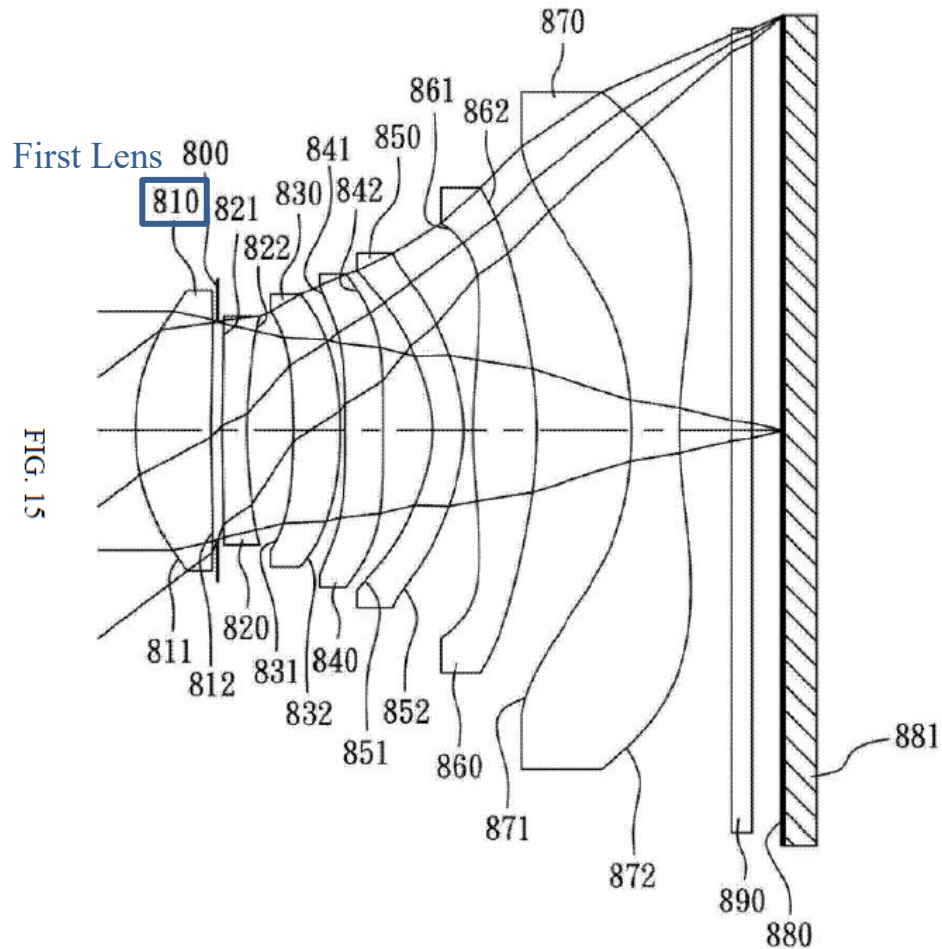
160. To extent the preamble is limiting, Cai discloses it. Cai discloses “[a]n optical image capturing system set in order from an object side to an image side.” EX1005, [0124]; *id.*, [0149], [0006], [0031], [0282].



EX1005, FIG. 15 (annotations added). A POSITA would understand an “optical image capturing system” is a “photographing optical lens assembly.”

b) Element 1.2

161. Cai discloses a “first lens 810 with positive refractive power.” EX1005, [0283]; *id.*, [0125]. FIG. 1 depicts the first lens 810 in the 8th Embodiment:



EX1005, FIG. 15 (annotations added). Table 15 discloses a positive focal length, and thus positive refractive power, for the first lens 810:

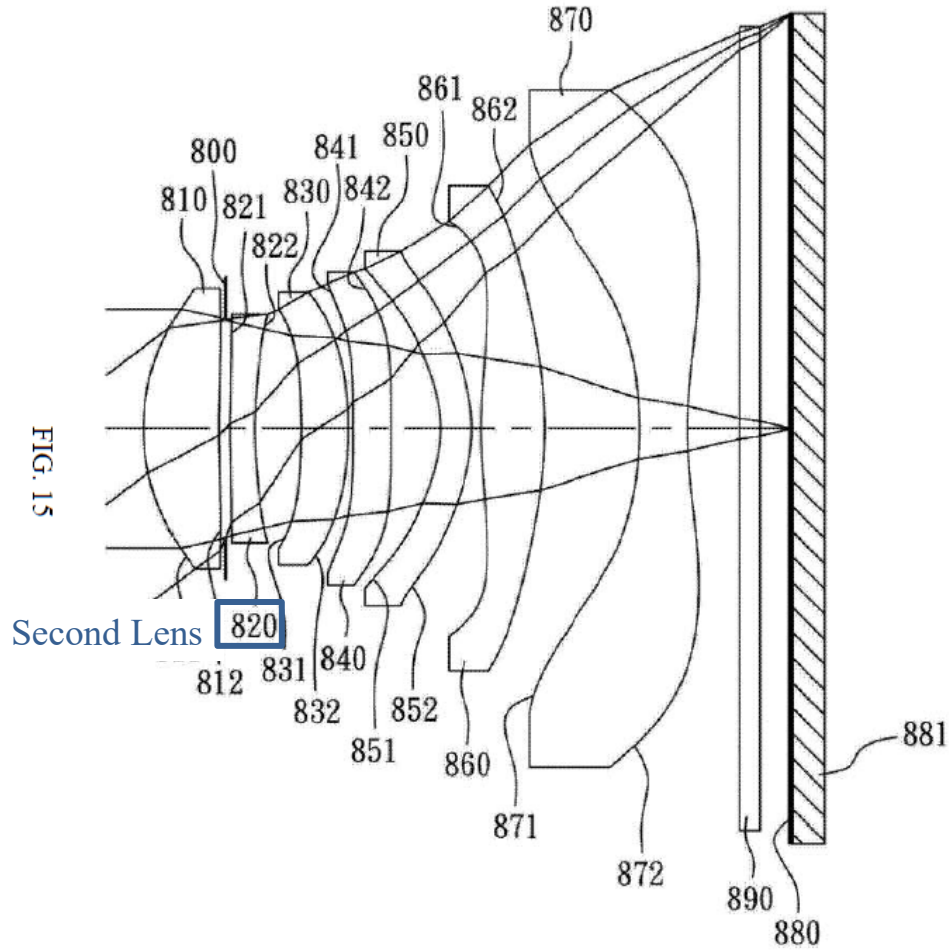
TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface		Curvature Radius	Thickness	Material	index	Abbe #	Focal length
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

c) Element 1.3

162. Cai discloses a “second lens 820 with negative refractive power.”

EX1005, [0284]. FIG. 15 depicts the second lens 820:



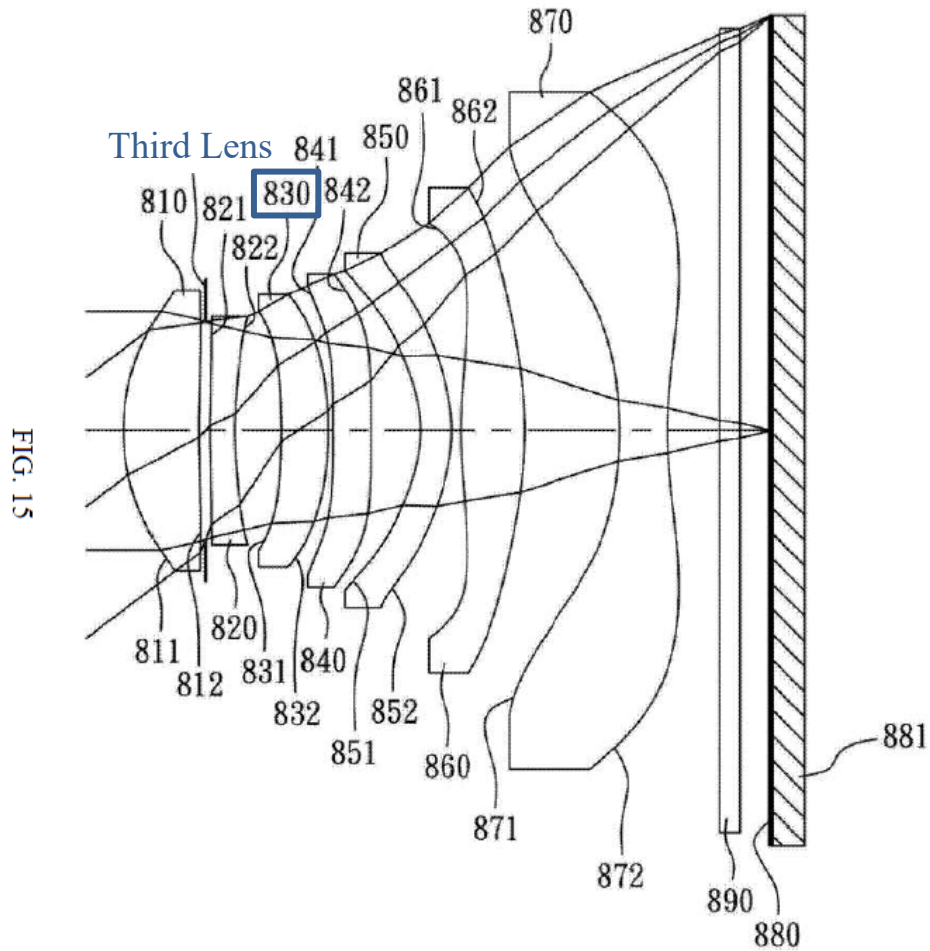
EX1005, FIG. 15 (annotations added). Table 15 discloses a negative focal length, and thus negative refractive power, for the second lens 820:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface		Curvature Radius	Thickness	Material	index	Abbe #	Focal length
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

d) Element 1.4

163. Cai discloses a “third lens 830.” EX1005, [0285]. FIG. 15 depicts the third lens 830:

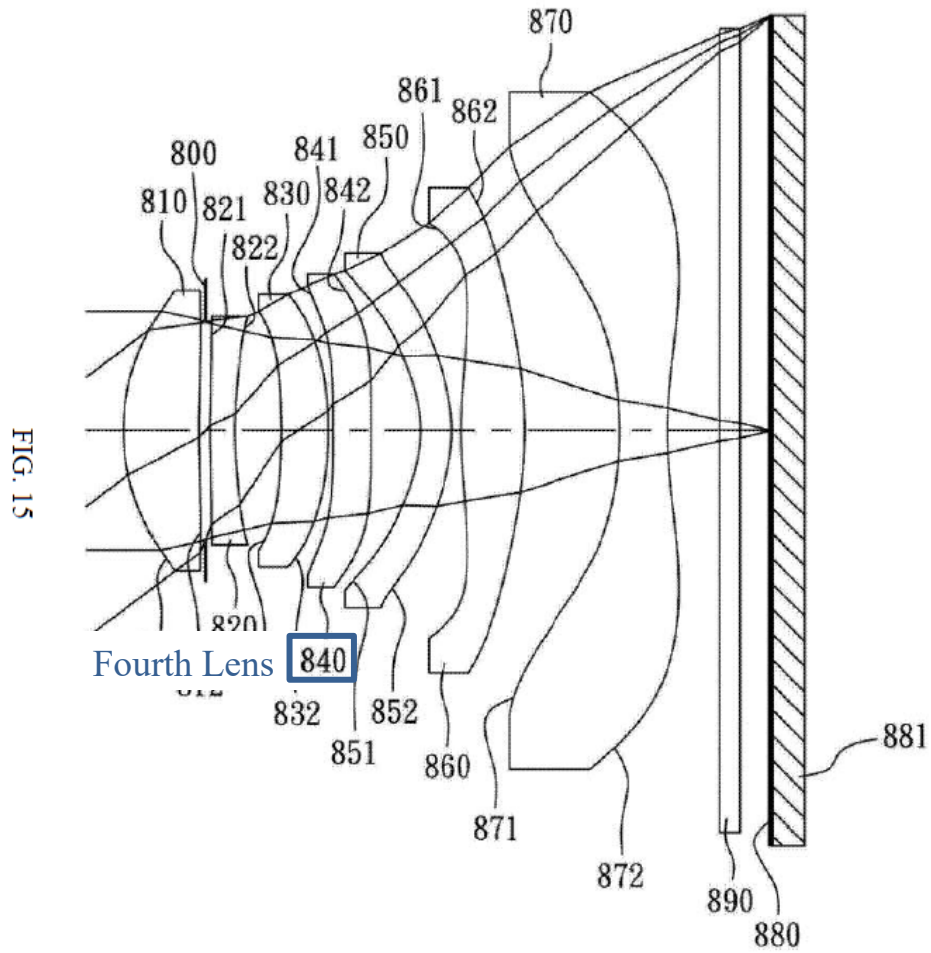


EX1005, FIG. 15 (annotations added).

e) Element 1.5

164. Cai discloses a “fourth lens 840 with positive refractive power.”

EX1005, [0286]. FIG. 15 depicts the fourth lens 840:



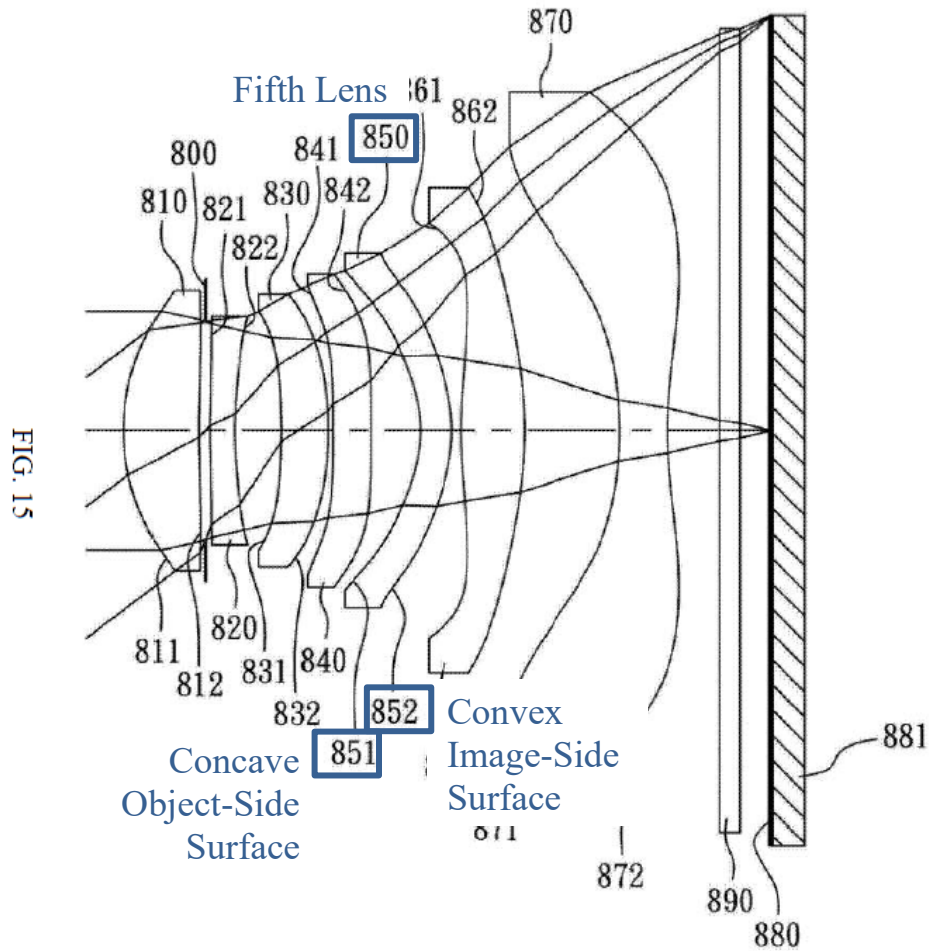
EX1005, FIG. 15 (annotations added). Table 15 discloses a positive focal length, and thus positive refractive power, for the fourth lens 840:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface		Curvature Radius	Thickness	Material	index	Abbe #	Focal length
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

f) Element 1.6

165. Cai discloses a “fifth lens 850 with negative refractive power [that] has a concave object-side surface 851 and a convex image-side surface 852.” EX1005, [0287]. FIG. 15 depicts the fifth lens 850 with this meniscus shape:



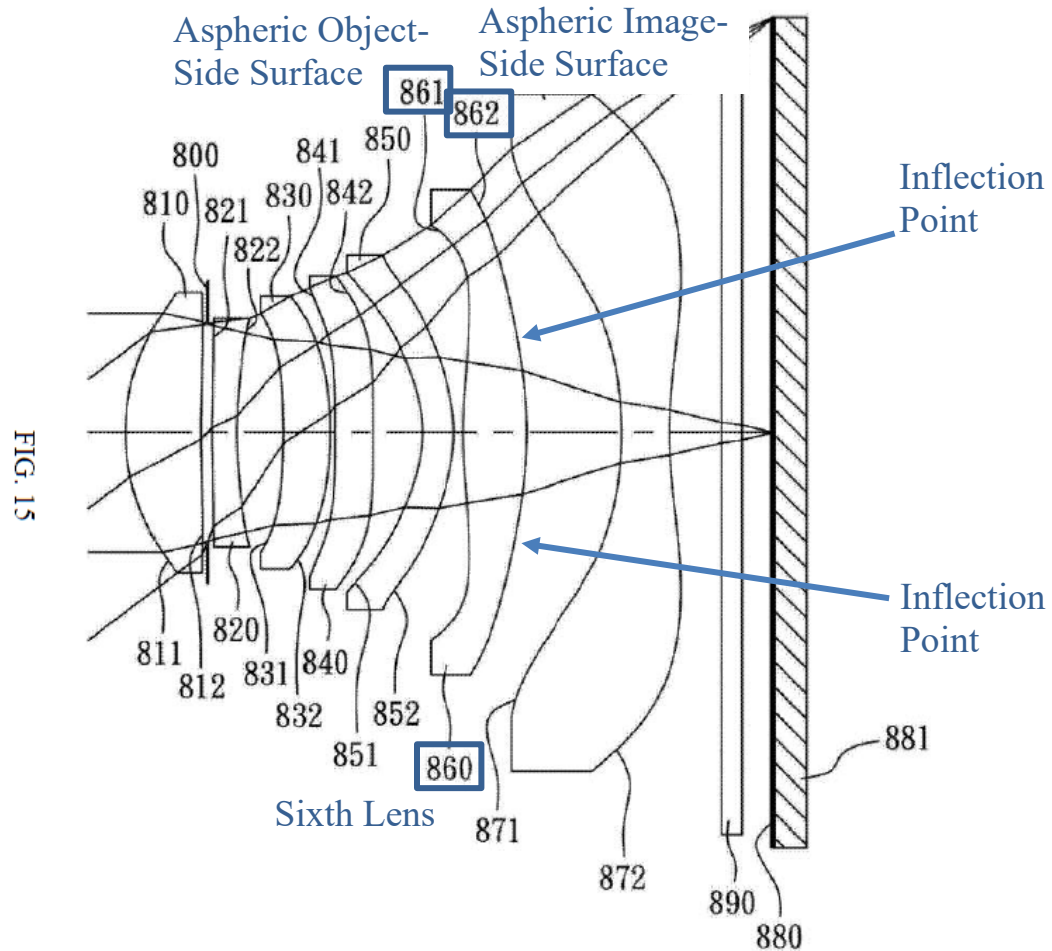
EX1005, FIG. 15 (annotations added). Table 15 discloses a negative focal length for the fifth lens 150, confirming a negative refractive power, as well as negative curvature radius for the object-side surface (Surface 10) and negative curvature radius for the image-side surface (Surface 11), confirming a concave object-side surface and convex image-side surface:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

g) Element 1.7

166. Cai discloses a “sixth lens 860” where the object-side and image-side surfaces “both are aspheric.” EX1005, [0288], [0292] (depicting “ASP” by both lens surfaces to indicate aspherics). FIG. 15 depicts the sixth lens 860 with aspheric surfaces and inflection points:



EX1005, FIG. 15 (annotations added). Regarding inflection points, a POSITA would have recognized from FIG. 15 that the image-side surface of the sixth lens has at least one inflection point, as depicted above. Further, Cai discloses the “equation of the aspheric surface profiles” along with the curvature radius, conic constant, and aspheric surface coefficients, which confirm at least one inflection point on the image-side surface of the sixth lens 860:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added); [0158]-[0165] (aspheric equation).

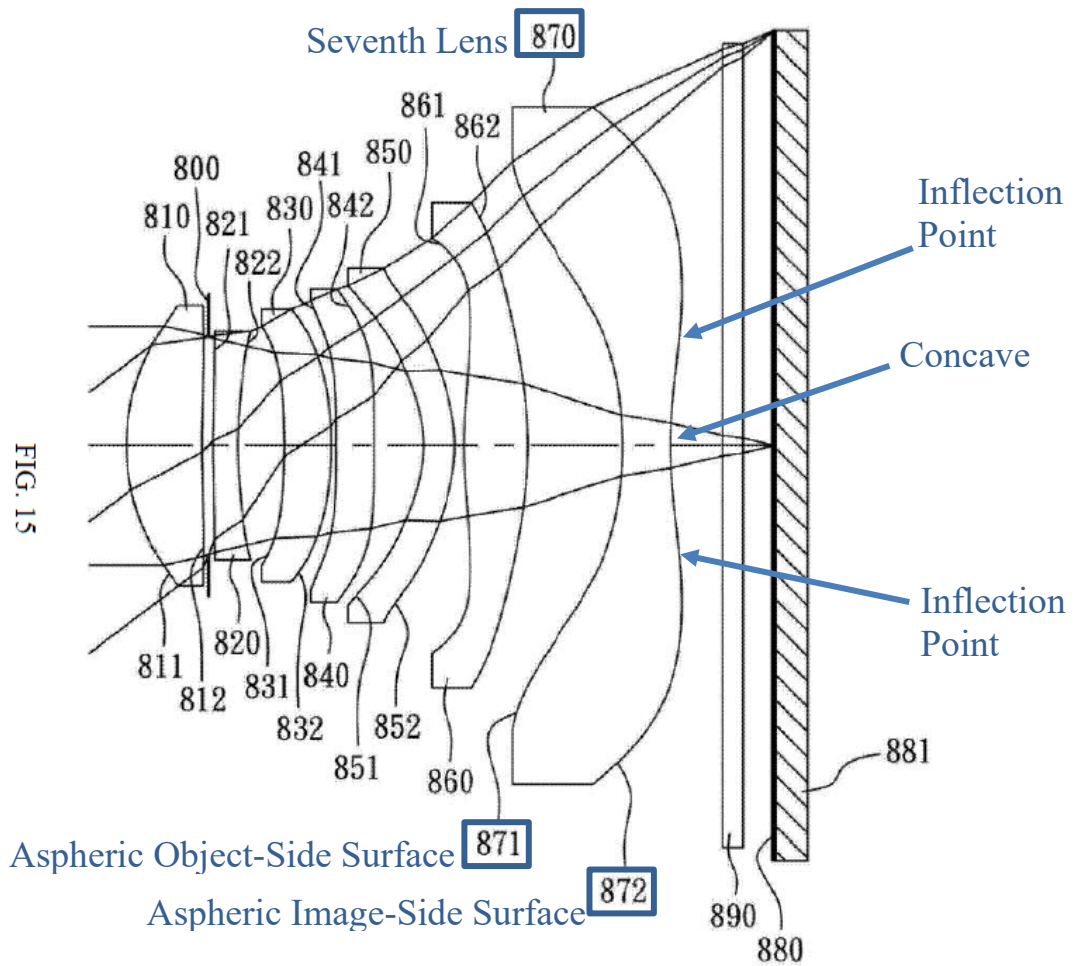
Surface	12	13	14	15
k=	-6.58821E+00	-1.61451E+01	-2.62115E+00	-2.11643E+01
A4 =	-6.25392E-02	-8.14410E-03	-4.42315E-02	-2.19259E-02
A6 =	2.57139E-02	-7.65552E-03	7.71517E-03	3.60828E-03
A8 =	-7.55747E-03	9.57982E-03	-2.57484E-04	-5.48595E-04
A10 =	9.90623E-04	-3.64717E-03	-1.43974E-05	5.09581E-05
A12 =	-1.45805E-04	5.80279E-04	7.50606E-07	-3.19315E-06
A14 =	1.30850E-05	-3.36611E-05	-2.46540E-08	1.00041E-07

Id., [0293] (Table 16) (excerpted) (annotations added).

167. Regarding the image-side surface being concave in a paraxial region thereof, Cai discloses the sixth lens 860 with a convex image-side surface. EX1005, [0288], [0292] (negative curvature radius for surface 13), FIG. 15. As explained *supra* Section XI.B, a POSITA would have been motivated, with a reasonable expectation of success, to implement the sixth lens 860 with an image-side surface that is concave in the paraxial region thereof because doing so would naturally provide a gullwing shape for the image-side surface, thereby improving aberration correction and control of the chief ray angle. Thus, Cai in view of the knowledge of a POSITA renders this element obvious.

h) Element 1.8

168. Cai discloses a “seventh lens 870” with “a concave image-side surface 872 that changes from concave at a paraxial region to convex at a peripheral region” and “includes inflection points.” EX1005, [0289]. The object- and image-side surfaces “both are aspheric.” *Id.* FIG. 1 depicts the seventh lens 870 with aspheric surfaces and inflection points:



EX1005, FIG. 15 (annotations added). Table 15 discloses a positive curvature radius for the image-side surface 872 (Surface 15), confirming a concave shape in the paraxial region:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

i) Element 1.9

169. Cai discloses an optical image capturing system with seven lenses, where “the first lens to the seventh lens are seven single and non-cemented lenses.” EX1005, [0124]; *id.*, [0031], [0281]-[0297] (describing 8th Embodiment with seven lenses), FIG. 1.

j) **Element 1.10**

170. **Regarding the Y_{c72}/f condition**, Cai expressly discloses the same condition: “ $0.1 < Y_{c72}/f < 0.9$.” EX1005, [0138]. For the 8th Embodiment, Cai discloses $Y_{c72}/f = 0.30$, within the claimed range. EX1005, [0296]. Cai defines Y_{c72} as “a vertical distance from the tangent point to the optical axis” where “a tangent plane of the image-side surface 172 is perpendicular to the optical axis” and “a tangent point is formed between the tangent plane and the image-side surface 172,” depicted in FIG. 22:

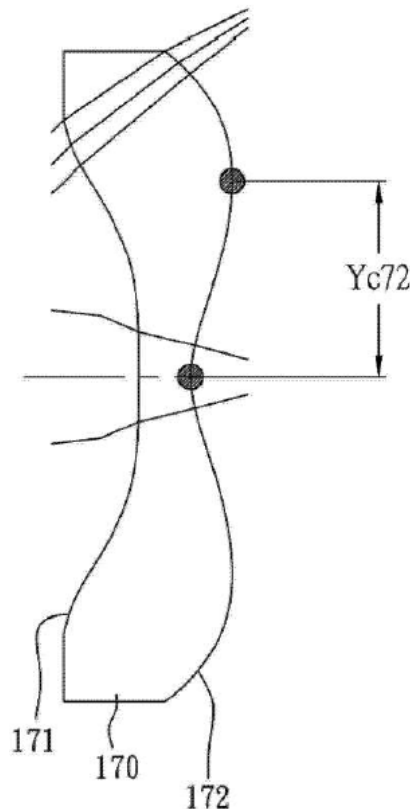
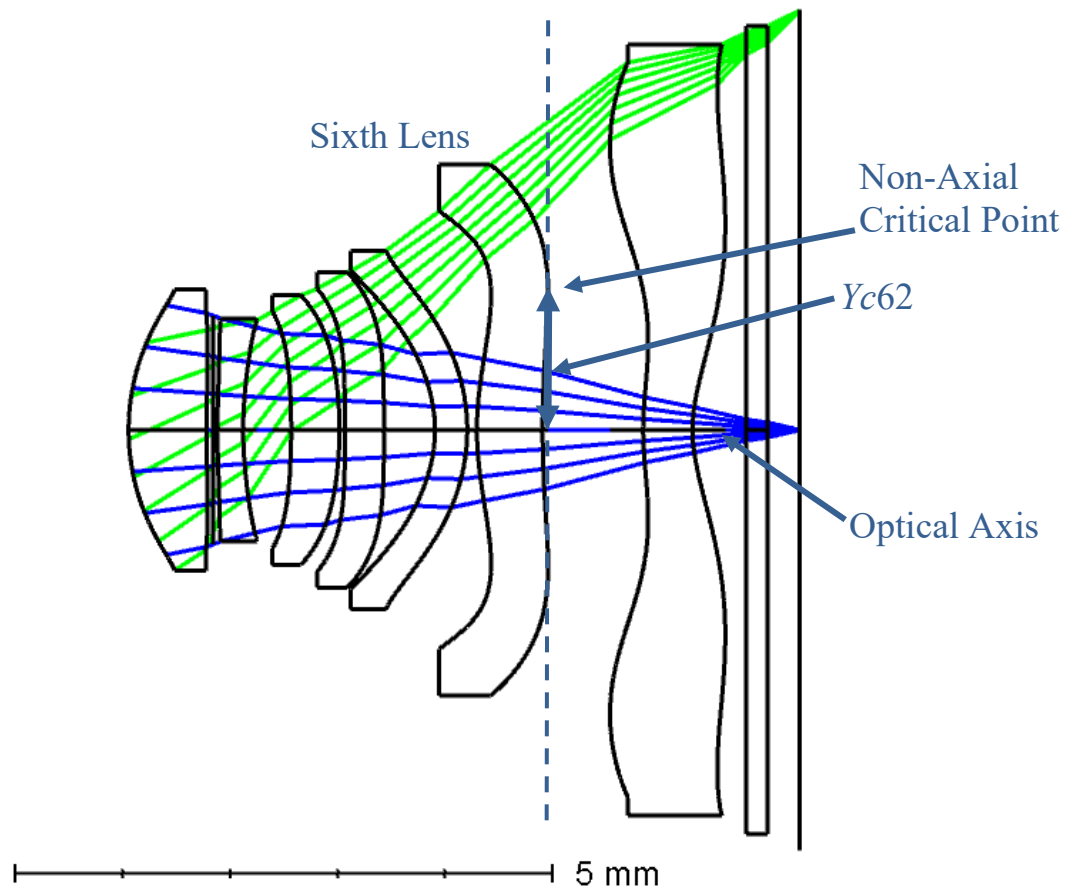


FIG. 22

EX1005, FIG. 22, [0172]; *id.*, [0294] (definition of Yc72 for the 8th embodiment identical to the 1st embodiment). The “tangent point” of Cai for Yc72 is the same as the “non-axial critical point” of the ’845 patent for Yc72. *Compare* EX1001, FIG. 27 (illustrating Yc72), *with* EX1005, FIG. 22 (same).

171. **Regarding the Yc62/Yc72 condition**, Cai does not disclose non-axial critical points on the image-side surface of the sixth lens 860, and thus no vertical distance Yc62. However, as discussed *supra* Section XI.B, a POSITA would have been motivated to implement the sixth lens 860 of Cai with the image-side surface concave in the paraxial region in order to achieve a gullwing shape, which enables better off-axis performance and a reduced burden on the seventh lens 870. When so implemented, the modified Cai lens system includes non-axial critical points on the image-side surface of the sixth lens 860 at which a tangent to the image-side surface of the sixth lens is perpendicular to the optical axis, where a vertical distance between the non-axial critical points on the image-side surface of the sixth lens and the optical axis is $Yc62=1.233\text{mm}$.



The vertical distance Y_{c72} in the modified Cai lens system is 1.903mm. The ratio Y_{c62}/Y_{c72} is therefore 0.648, within the claimed range.

172. **Regarding the $|f_1/f_7|$ condition,** Cai discloses a focal length $f_1=4.48\text{mm}$ for the first lens element, and a focal length $f_7=-3.60\text{ mm}$ for the seventh lens element, so $|f_1/f_7|=1.24$ for the 8th embodiment, within the claimed range. EX1005, [0292]. This condition remains satisfied in the modified Cai lens system, because $|f_1/f_7|=0.790$.

2. Claim 2

173. Cai discloses the sixth lens 860 with “a convex object-side surface 861 that changes from convex at a paraxial region to concave at a peripheral region.” EX1005, [0288]. Table 15 confirms the object-side surface (Surface 12) of the sixth lens is convex because the curvature radius is positive:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). The object-side surface of the sixth lens remains convex after modification:

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

3. Claim 3

174. Cai discloses the seventh lens 870 with “a concave object-side surface 871.” EX1005, [0289]. As discussed *supra* Section XI.B, a POSITA would have been motivated to implement the seventh lens 870 with an object-side surface that is convex in the paraxial region, in order to achieve a double meniscus-gullwing arrangement for the last two lenses, as doing so would have eased and complemented the implementation of the concave (and thus gullwing shape of) image-side surface of the sixth lens 860. The curvature radius of the object-side surface of the seventh lens in the modified Cai lens system is positive, confirming a convex object-side surface of the seventh lens.

	Surface Type	Comment	Radius	Thickness	Material
0	OBJECT Standard ▼		Infinity	Infinity	
1	Even Asphere ▼	Lens 1	2.051819 V	0.727000	1.53,55.9 M
2	Even Asphere ▼		13.228088 V	0.058000	
3	STOP Standard ▼		Infinity	0.042000	
4	Even Asphere ▼	Lens 2	6.998585 V	0.240000	1.65,21.4 M
5	Even Asphere ▼		3.604169 V	0.447000	
6	Even Asphere ▼	Lens 3	-7.140128 V	0.449000	1.53,55.9 P
7	Even Asphere ▼		-3.809330 V	0.050000	
8	Even Asphere ▼	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P
9	Even Asphere ▼		-130.264408 V	0.476000	
10	Even Asphere ▼	Lens 5	-1.289939 V	0.300000	1.65,21.4 P
11	Even Asphere ▼		-1.774469 V	0.090000	
12	Even Asphere ▼	Lens 6	2.713429 V	0.612000	1.53,55.9 P
13	Even Asphere ▼		10.289202 V	0.936000	
14	Even Asphere ▼	Lens 7	2.757915 V	0.460000	1.53,55.9 P
15	Even Asphere ▼		1.356564 V	0.500000	
16	Standard ▼	Filter	Infinity	0.200000	1.52,64.2 M
17	Standard ▼		Infinity	0.294000	
18	IMAGE Standard ▼		Infinity	-	

4. Claim 4

175. Cai discloses “[t]he third lens 830 with positive refractive power.” EX1005, [0285]. Table 15 discloses a positive focal length for the third lens, thus confirming positive refractive power:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). The positive refractive power of the third lens remains after modification. *Supra* ¶155.

5. Claim 7

176. Cai discloses “[t]he seventh lens 870 with negative refractive power.” EX1005, [0289]. Table 15 confirms the seventh lens 870 has negative focal length and thus negative refractive power:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). The negative refractive power of the seventh lens 870 remains after modification. *Supra* ¶155.

6. Claim 9

177. Cai discloses “a half of the diagonal length of the effective sensing area of the image sensing element is ImgH , and a distance between the object-side surface of the first lens and the image plane is TTL .” EX1005, [0141]. For the 8th embodiment, “ $\text{TTL}/\text{ImgH}=1.54$.” EX1005, [0296]. Table 15 discloses, by summing the appropriate thicknesses, $\text{TTL}=6.245\text{mm}$ and $\sum \text{AT}=2.099\text{mm}$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). Cai thus discloses $\text{ImgH}=4.055\text{mm}$ and $\sum \text{AT}/\text{ImgH}=0.517$, satisfying the claimed condition. This condition remains satisfied after modification because the axial distances are unchanged:

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

7. Claim 10

178. **Regarding aspheric surfaces**, Cai discloses “surfaces of the lenses can be arranged to be aspheric, because the aspheric surface of the lens is easy to form a shape other than spherical surface so as to have more controllable variables for eliminating the aberration thereof.” EX1005, [0142]. All lens surfaces in Cai, including those of the first through fifth lenses, are aspheric. *Id.*, [0283]-[0293].

179. **Regarding the TL/f condition**, Cai discloses a focal length $f=5.08\text{mm}$ and axial distances from the object-side surface of the first lens element (Surface 2) to the image surface (Surface 18) that sum to $TL=6.245\text{mm}$, so $TL/f=1.23$, satisfying the condition:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). This condition remains satisfied after modification because the axial distances or thicknesses remain unchanged:

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

8. Claim 11

180. Cai discloses a maximum refractive index $N_{\max}$ of 1.650 for two of the lens elements of the 8th embodiment, satisfying the condition $1.640 \leq N_{\max} < 1.750$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

9. Claim 12

181. Cai discloses an Abbe number $V_2=21.4$ for the second lens, satisfying the condition $V_2 < 26.0$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface		Curvature Radius	Thickness	Material	index	Abbe #	Focal length
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

10. Claim 13

182. Cai discloses a focal length $f=5.08\text{mm}$, within the range $3.0[\text{mm}]<f<6.5[\text{mm}]$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

11. Claim 15

15. The photographing optical lens assembly of claim 1, wherein a curvature radius of an object-side surface of the first lens element is R1, a curvature radius of an image-side surface of the first lens element is R2, and the following condition is satisfied:
 $-0.2 < R1/R2 < 0.2$.

183. Cai discloses a curvature radius R1=2.106050mm for the object-side surface of the first lens and a curvature radius R2=16.377300mm for the image-side

surface of the first lens, so Cai discloses $R1/R2=0.128596$, within the claimed range $-0.2 < R1/R2 < 0.2$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). This condition remains satisfied after modification because $R1=2.051819\text{mm}$, $R2=13.228088\text{mm}$, and $R1/R2=0.15$.

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

12. Claim 16

184. Cai discloses an f-number (i.e., f/EPD) of 2.20, within the claimed range $1.2 < f/EPD < 2.6$, and HFOV=37.5 degrees, within the claimed range $15[\text{deg.}] < \text{HFOV} < 45[\text{deg.}]$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added), [0296]. These values remain unchanged after modification.

13. Claim 18

a) Element 18.1

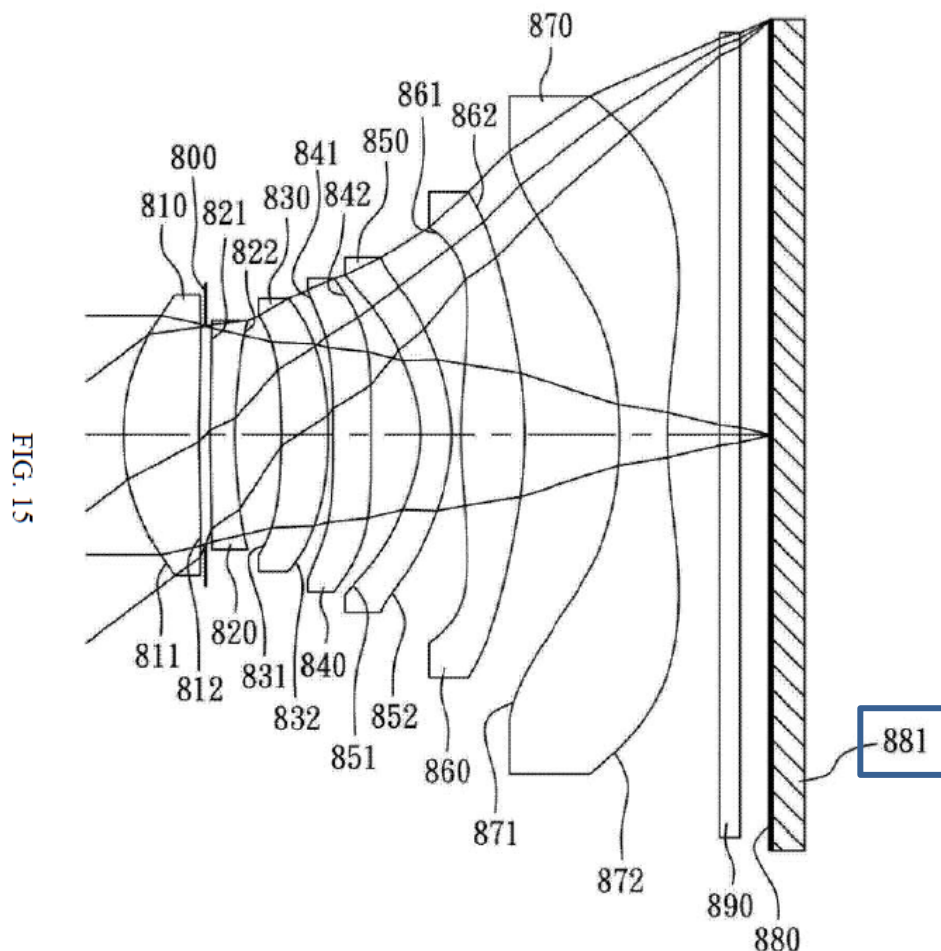
185. Cai discloses an “optical image capturing system” which is an image capturing unit. EX1005, [0124], [0282].

b) Element 18.2

186. As discussed *supra* Section XI.C.1, Cai renders the photographing optical lens assembly of claim 1 obvious.

c) Element 18.3

187. Cai discloses an “image sensing element 881” that is “disposed on an image plane,” thus on the image side of the lens assembly. EX1005, [0282], [0124]; *id.*, [0145] (image sensing element is “CCD or CMOS”), [0002]. FIG. 15 depicts the image sensing element 881 at the image side:



EX1005, FIG. 15 (annotations added).

14. Claim 19

a) Element 19.1

188. Cai discloses “a miniaturized optical image capturing system set applicable to electronic products,” and explains that “mobile electronic products with camera functionalities” include “smart phones and PDAs (Personal Digital Assistants).” EX1005, [0001]-[0003]. Such electronic products are electronic devices.

b) Element 19.2

189. As discussed *supra* Section XI.C.13, Cai renders obvious the image capturing unit of claim 18.

15. Claim 20

a) Elements 20.1-20.6

190. As discussed *supra* Sections XI.C.1.a)-XI.C.1.f) (elements 1.1-1.6) and XI.C.4 (claim 4), Cai discloses these elements.

b) Element 20.7

191. As discussed *supra* Section XI.C.1.g), Cai renders this obvious. Cai discloses a “sixth lens 860 with positive refractive power” where “both [surfaces] are aspheric” and the image-side surface has at least one inflection point. EX1005, [0288]; *id.*, [0292] (Table 15 disclosing positive focal length); *supra* Section

XI.C.1.g) (element 1.7). As discussed *supra* Sections XI.B and XI.C.1.g), a POSITA would have been motivated to implement the sixth lens 860 with a concave image-side surface in the paraxial region thereof so that the image-side surface has a gullwing shape, thereby improving off-axis aberration control and reducing the burden on the seventh lens. So implemented, the sixth lens 860 of the modified Cai system maintains positive refractive power.

c) Elements 20.8-20.9

192. As discussed *supra* Sections XI.C.1.h) and XI.C.1.i), Cai discloses these elements.

d) Element 20.10

193. Cai discloses a non-axial critical point on the image-side surface of the seventh lens 870 satisfying the $Yc72/f$ condition. EX1005, [0031], [0033], [0054], [0119], [0138], [0296]; *supra* Section XI.C.1.j).

194. As discussed *supra* Sections XI.C.6 (claim 9) and XI.C.7 (claim 10), Cai discloses a maximum image height $ImgH=4.055mm$ and a track length $TL=6.245mm$; Cai thus discloses $TL/ImgH=1.540$, satisfying the condition $TL/ImgH<2.20$.

195. Cai also discloses focal length $f1=4.48mm$ for the first lens and focal length $f2=-11.76mm$ for the second lens, so $|f1/f2|=0.38$, satisfying the condition $|f1/f2|<2.0$:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface		Curvature Radius	Thickness	Material	index	Abbe #	Focal length
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added).

16. Claim 21

196. Cai discloses the “first lens 810 ... has a convex object-side surface” and the “second lens 820 [has a] concave image-side surface.” EX1005, [0283]-[0284]. Table 15 confirms positive curvature radii for Surface 1 and Surface 5, corresponding respectively to a convex object-side surface of the first lens and a concave image-side surface of the second lens:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). These characteristics remain after modification:

	Surface Type	Comment	Radius	Thickness	Material	Clear Semi-Dia	Mech Semi-Dia
0	OBJECT Standard ▾		Infinity	Infinity		Infinity	Infinity
1	Even Asphere ▾	Lens 1	2.051819 V	0.727000	1.53,55.9 M	1.302885	1.302885
2	Even Asphere ▾		13.228088 V	0.058000		1.113610	1.302885
3	STOP Standard ▾		Infinity	0.042000		1.062865	1.062865
4	Even Asphere ▾	Lens 2	6.998585 V	0.240000	1.65,21.4 M	1.036519	1.036519
5	Even Asphere ▾		3.604169 V	0.447000		1.018948	1.036519
6	Even Asphere ▾	Lens 3	-7.140128 V	0.449000	1.53,55.9 P	1.101350	1.251535
7	Even Asphere ▾		-3.809330 V	0.050000		1.251535	1.251535
8	Even Asphere ▾	Lens 4	-1079.856435 V	0.364000	1.53,55.9 P	1.313689	1.465341
9	Even Asphere ▾		-130.264408 V	0.476000		1.465341	1.465341
10	Even Asphere ▾	Lens 5	-1.289939 V	0.300000	1.65,21.4 P	1.478021	1.666257
11	Even Asphere ▾		-1.774469 V	0.090000		1.666257	1.666257
12	Even Asphere ▾	Lens 6	2.713429 V	0.612000	1.53,55.9 P	2.034098	2.465426
13	Even Asphere ▾		10.289202 V	0.936000		2.465426	2.465426
14	Even Asphere ▾	Lens 7	2.757915 V	0.460000	1.53,55.9 P	3.415910	3.581989
15	Even Asphere ▾		1.356564 V	0.500000		3.581989	3.581989
16	Standard ▾	Filter	Infinity	0.200000	1.52,64.2 M	3.693200	3.753789
17	Standard ▾		Infinity	0.294000		3.753789	3.753789
18	IMAGE Standard ▾		Infinity	-		3.901954	3.901954

17. Claim 23

197. Cai discloses this. EX1005, [0287] (“fifth lens 850 with negative refractive power”); *id.*, [0292] (Table 15 disclosing negative focal length); *supra* Section XI.C.1.f) (element 1.6).

18. Claim 24

198. Cai discloses this. EX1005, [0287] (fifth lens with “convex image-side surface”), [0292] (Table 15 disclosing negative curvature radius); *supra* Section XI.C.1.f) (element 1.6).

19. Claim 28

28. The photographing optical lens assembly of claim 20, wherein the focal length of the photographing optical lens assembly is f , the focal length of the first lens element is f_1 , the focal length of the second lens element is f_2 , a focal length of the third lens element is f_3 , a focal length of the fourth lens element is f_4 , a

focal length of the fifth lens element is f_5 , a focal length of the sixth lens element is f_6 , a focal length of the seventh lens element is f_7 , and the following condition is satisfied:

$|f/f_j|_{\max} < 1.8$, wherein $j=1, 2, 3, 4, 5, 6, 7$.

199. Cai discloses focal lengths that satisfy the condition $|f/f_j|_{\max} < 1.8$, because the focal length $f=5.08\text{mm}$ divided by any of the individual lens focal lengths (i.e., $f_1, f_2, f_3, f_4, f_5, f_6, f_7$) is less than 1.8:

TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). This condition remains satisfied after modification.

20. Claim 29

29. The photographing optical lens assembly of claim 20, wherein an Abbe number of the first lens element is V_1 , an Abbe number of the second lens element is V_2 , an Abbe number of the third lens element is V_3 , an Abbe number of the fourth lens element is V_4 , an Abbe number of the fifth lens element is V_5 , an Abbe number of the sixth lens element is V_6 , an Abbe number of the seventh lens element is V_7 , and at least three lens elements among the first lens element to the seventh lens element satisfy the following condition:

$V_i < 26.0$, wherein $i=1, 2, 3, 4, 5, 6, 7$.

200. Cai discloses Abbe numbers for each lens, but only two lens elements satisfy the claimed condition:

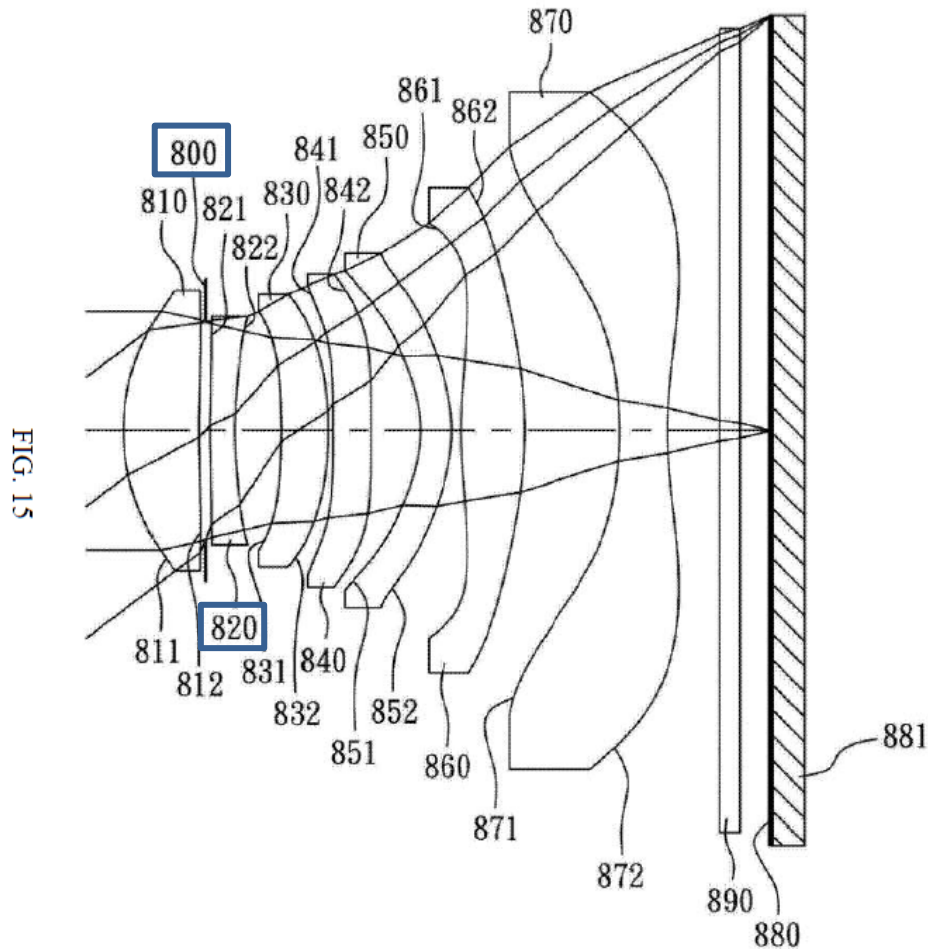
TABLE 15: 8th Embodiment							
f (focal length)= 5.08 mm. Fno (F-number)= 2.20. HFOV (half of field of view) = 37.5 deg.							
Surface	Curvature Radius	Thickness	Material	index	Abbe #	Focal length	
0	Object	Plano	Infinity				
1	Lens 1	2.106050 (ASP)	0.727	Plastic	1.530	55.8	4.48
2		16.377300 (ASP)	0.058				
3	Ape.	Plano	0.042				
4	Lens 2	9.396400 (ASP)	0.240	Plastic	1.650	21.4	-11.76
5		4.171200 (ASP)	0.447				
6	Lens 3	-6.904700 (ASP)	0.449	Plastic	1.530	55.8	14.72
7		-3.745600 (ASP)	0.050				
8	Lens 4	-237.531700 (ASP)	0.364	Plastic	1.530	55.8	279.46
9		-91.271700 (ASP)	0.476				
10	Lens 5	-1.264930 (ASP)	0.300	Plastic	1.650	21.4	-10.79
11		-1.687700 (ASP)	0.090				
12	Lens 6	4.716500 (ASP)	0.612	Plastic	1.530	55.8	4.50
13		-4.604000 (ASP)	0.936				
14	Lens 7	-4.091400 (ASP)	0.460	Plastic	1.530	55.8	-3.60
15		3.720800 (ASP)	0.500				
16	IR filter	Plano	0.200	Glass	1.517	64.2	—
17		Plano	0.294				
18	Image plane	Plano	—				
Reference wavelength (d-line) is 587.6 nm.							

EX1005, [0292] (annotations added). A POSITA would have found it obvious, however, to implement Cai with at least three lenses having Abbe numbers satisfying the claimed condition because doing so was a known technique for seven-lens imaging systems with double-gullwing lens pairs, with predictable results. *E.g.*, EX1006, [0132], [0136], [0141], [0145], [0149], [0153], [0157], [0161]; EX1007, [0099], [0104], [0109], [0114], [0119], [0124], [0129]. Alternating high and low dispersion materials (i.e., materials with low and high Abbe numbers) was a well-known practice since the beginning of photographic lenses. *E.g.*, EX1017, 7 (“Photography was invented ... in 1839, and the first lens to be used on a camera was the achromatic landscape lens”); EX1010, 52. As Sekine explained, for compact seven-lens imaging systems with a double-gullwing lens pair, “the lenses made of low-dispersion material and high-dispersion material are arranged alternately and consequently axial chromatic aberrations and chromatic aberrations of magnification occurred on the image plane side in the lens system can be corrected more properly.” EX1006, [0081]. A POSITA therefore would have found it obvious, when implementing Cai with a meniscus-gullwing lens pair (*see supra* Section XI.B), to simply substitute the lower-dispersion (high Abbe number) material for one of the lenses with a higher-dispersion (lower Abbe number) material, such as the other lens material used in the imaging lens, in order to predictably control chromatic aberrations occurring in the image side of the imaging lens. Further, Cai

discloses an embodiment with at least three lenses satisfying the claimed condition, confirming that a POSITA would have been motivated, with a reasonable expectation of success, to implement Cai with three lenses with Abbe numbers less than 26.0. EX1005, [0224] (three lens elements with Abbe numbers less than 26.0). Cai thus renders this claim obvious.

21. Claim 30

201. Cai discloses “an aperture 800” between the first lens 810 and the second lens 820, and thus between an imaged object and the second lens element. EX1005, [0282]. FIG. 15 depicts the aperture 800 on the object side of the second lens 820, and also depicts the first through seventh lenses as non-cemented lenses:

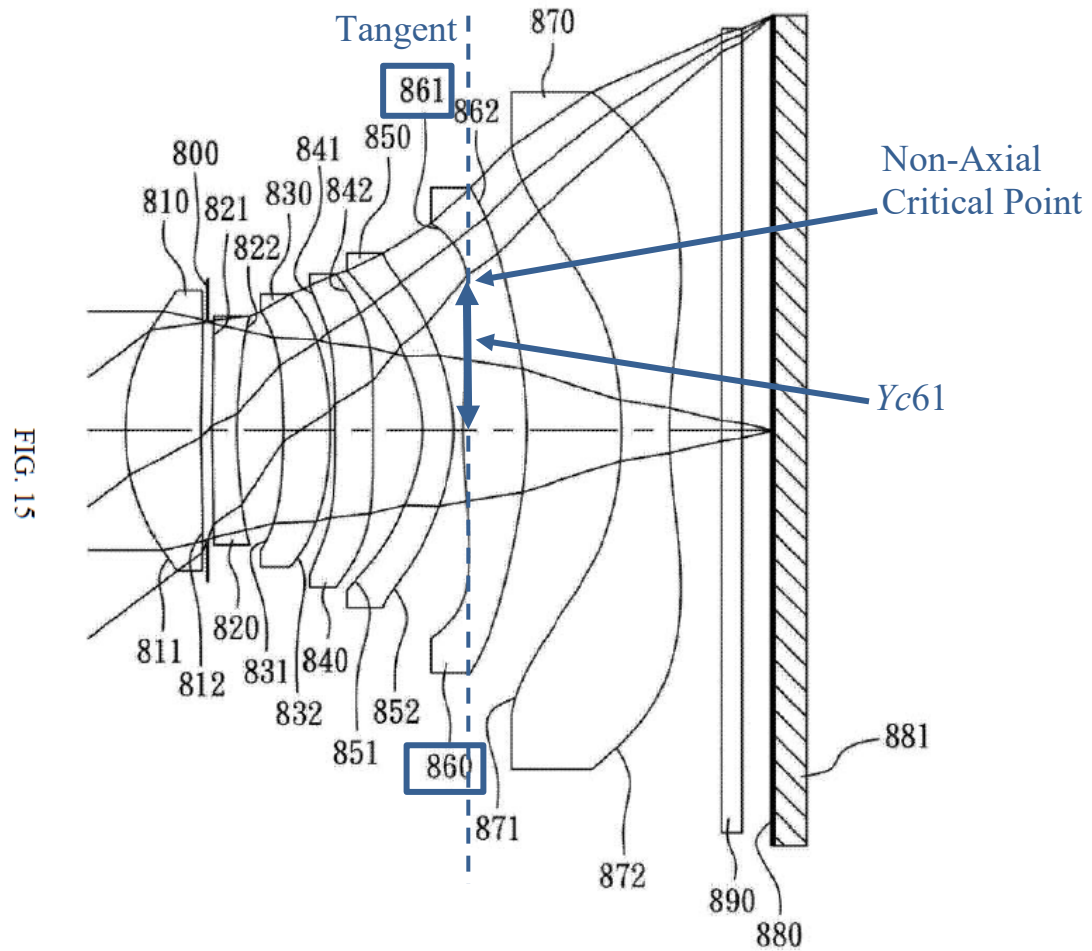


EX1005, FIG. 15 (annotations added).

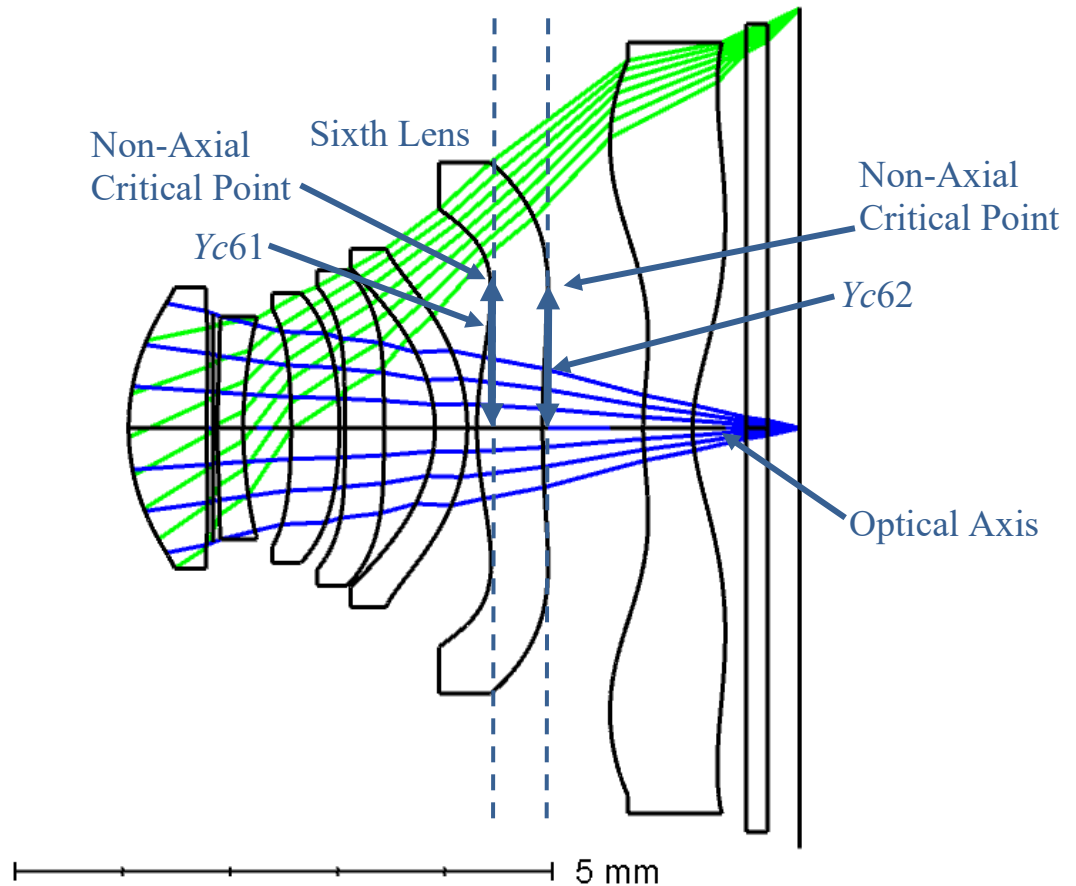
22. Claim 31

31. The photographing optical lens assembly of claim 20, wherein there is a non-axial critical point on the object-side surface of the sixth lens element at which a tangent to the object-side surface of the sixth lens element is perpendicular to the optical axis, there is a non-axial critical point on the image-side surface of the sixth lens element at which a tangent to the image-side surface of the sixth lens element is perpendicular to the optical axis, a vertical distance between the non-axial critical point on the object-side surface of the sixth lens element and the optical axis is Y_{c61} , a vertical distance between the non-axial critical point on the image-side surface of the sixth lens element and the optical axis is Y_{c62} , and the following condition is satisfied:
 $0.30 < Y_{c62}/Y_{c61} < 1.80$.

202. Cai discloses a non-axial critical point on the object-side surface of the sixth lens 860, as depicted in FIG. 15:



EX1005, FIG. 15 (annotations added); *id.*, [0288] (“convex object-side surface 861 that changes from convex at a paraxial region to concave at a peripheral region”). As discussed *supra* Section XI.B, a POSITA would have found it obvious to implement the image-side surface of the sixth lens 860 with a concave curvature on-axis, thereby providing a gullwing shape to improve off-axis performance and reduce the burden on the seventh lens 870:



So implemented, the vertical distance $Y_{c61}=1.271\text{mm}$, the vertical distance $Y_{c62}=1.233\text{mm}$, and $Y_{c62}/Y_{c61}=0.970$, within the claimed range. A POSITA would have expected the critical points to satisfy this condition, because otherwise one of the critical points would need to be in an atypical position (e.g., close to the optical axis or close to the edge of the lens) for a gullwing lens that would not be beneficial for correcting aberrations and maintaining a compact length for the lens system. *E.g.*, EX1006, [0036].

I, Tom D. Milster, Ph.D., do hereby declare and state, that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: June 27, 2024

Tom D Milster
Signature