

UNITED STATES PATENT AND TRADEMARK OFFICE

---

BEFORE THE PATENT TRIAL AND APPEAL BOARD

---

MOTOROLA MOBILITY LLC,  
Petitioner,

v.

LARGAN PRECISION CO., LTD.,  
Patent Owner.

Case IPR2024-00689  
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

---

**PETITION FOR**  
**INTER PARTES REVIEW OF U.S. PATENT NO. 9,366,845**

**TABLE OF CONTENTS**

|                                                                                                                                                                          | Page(s) |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| LIST OF EXHIBITS .....                                                                                                                                                   | ix      |
| MANDATORY NOTICES UNDER 37 C.F.R. § 42.8 .....                                                                                                                           | xi      |
| 1. Real Party-In-Interest .....                                                                                                                                          | xi      |
| 2. Related Matters .....                                                                                                                                                 | xi      |
| 3. Lead And Back-Up Counsel, And Service Information .....                                                                                                               | xi      |
| I. INTRODUCTION .....                                                                                                                                                    | 1       |
| II. GROUNDS FOR STANDING PER 37 C.F.R. § 42.104(a) .....                                                                                                                 | 2       |
| III. IDENTIFICATION OF CHALLENGE .....                                                                                                                                   | 2       |
| A. Statement Of The Precise Relief Requested / Statutory Grounds.....                                                                                                    | 2       |
| B. The Board Should Not Discretionarily Deny Under Section 325(d)....                                                                                                    | 3       |
| C. No Parallel Litigation Involving Petitioner.....                                                                                                                      | 5       |
| IV. STATE OF THE ART .....                                                                                                                                               | 5       |
| A. The Lens Design Process Typically Involves Use Of<br>Highly Sophisticated Software to Optimize Older Designs.....                                                     | 5       |
| B. Gullwing Lenses Were Often Used To Perform<br>Field Corrections And Control Chief Ray Angles .....                                                                    | 8       |
| 1. Compact Lens Designs In The 2000s Included<br>At Least One Gullwing Lens As The Last Lens.....                                                                        | 9       |
| 2. By 2013, Demands For Higher<br>Performance Led To Designs With<br>Seven Or More Lenses And Two Gullwing Lenses .....                                                  | 10      |
| 3. By 2014, Lens Designers Knew That Gullwing<br>Lens Pairs With Meniscus On-Axis Curvature Would Achieve<br>Better Aberration Correction And Chief Ray Angle Control... | 10      |

|       |                                                                                                               |    |
|-------|---------------------------------------------------------------------------------------------------------------|----|
| V.    | THE ‘845 PATENT .....                                                                                         | 12 |
| A.    | The ‘845 Specification .....                                                                                  | 13 |
| B.    | The Prosecution History .....                                                                                 | 15 |
| C.    | Claims Listing .....                                                                                          | 16 |
| VI.   | LEVEL OF SKILL IN THE ART .....                                                                               | 17 |
| VII.  | CLAIM CONSTRUCTION .....                                                                                      | 18 |
| VIII. | GROUND 1: CLAIMS 1-14, 16-27, 30,<br>AND 32-34 ARE OBVIOUS OVER<br>FUKAYA AND THE KNOWLEDGE OF A POSITA ..... | 18 |
| A.    | Fukaya (EX1004) .....                                                                                         | 18 |
| B.    | A POSITA Would Have<br>Implemented Fukaya With A Gullwing Sixth Lens.....                                     | 20 |
| C.    | Claim Mapping.....                                                                                            | 27 |
| 1.    | Claim 1 .....                                                                                                 | 27 |
| a)    | Element 1.1 .....                                                                                             | 27 |
| b)    | Element 1.2 .....                                                                                             | 28 |
| c)    | Element 1.3 .....                                                                                             | 29 |
| d)    | Element 1.4 .....                                                                                             | 31 |
| e)    | Element 1.5 .....                                                                                             | 31 |
| f)    | Element 1.6 .....                                                                                             | 33 |
| g)    | Element 1.7 .....                                                                                             | 35 |
| h)    | Element 1.8 .....                                                                                             | 38 |
| i)    | Element 1.9 .....                                                                                             | 39 |
| j)    | Element 1.10 .....                                                                                            | 40 |

|     |                       |    |
|-----|-----------------------|----|
| 2.  | Claim 2 .....         | 43 |
| 3.  | Claim 3 .....         | 44 |
| 4.  | Claim 4 .....         | 45 |
| 5.  | Claim 5 .....         | 46 |
|     | a) Element 5.1 .....  | 46 |
|     | b) Element 5.2 .....  | 47 |
| 6.  | Claim 6 .....         | 48 |
| 7.  | Claim 7 .....         | 49 |
| 8.  | Claim 8 .....         | 50 |
| 9.  | Claim 9 .....         | 52 |
| 10. | Claim 10 .....        | 53 |
| 11. | Claim 11 .....        | 54 |
| 12. | Claim 12 .....        | 55 |
| 13. | Claim 13 .....        | 56 |
| 14. | Claim 14 .....        | 57 |
| 15. | Claim 16 .....        | 58 |
| 16. | Claim 17 .....        | 59 |
| 17. | Claim 18 .....        | 61 |
|     | a) Element 18.1 ..... | 61 |
|     | b) Element 18.2 ..... | 61 |
|     | c) Element 18.3 ..... | 61 |
| 18. | Claim 19 .....        | 62 |
|     | a) Element 19.1 ..... | 62 |

|     |                                                                                                                              |    |
|-----|------------------------------------------------------------------------------------------------------------------------------|----|
| b)  | Element 19.2 .....                                                                                                           | 63 |
| 19. | Claim 20 .....                                                                                                               | 63 |
| a)  | Elements 20.1-20.6 .....                                                                                                     | 63 |
| b)  | Element 20.7 .....                                                                                                           | 63 |
| c)  | Elements 20.8-20.9 .....                                                                                                     | 64 |
| d)  | Element 20.10 .....                                                                                                          | 65 |
| 20. | Claim 21 .....                                                                                                               | 66 |
| 21. | Claim 22 .....                                                                                                               | 67 |
| 22. | Claim 23 .....                                                                                                               | 68 |
| 23. | Claim 24 .....                                                                                                               | 68 |
| 24. | Claim 25 .....                                                                                                               | 69 |
| 25. | Claim 26 .....                                                                                                               | 69 |
| 26. | Claim 27 .....                                                                                                               | 70 |
| 27. | Claim 30 .....                                                                                                               | 71 |
| 28. | Claim 32 .....                                                                                                               | 72 |
| 29. | Claim 33 .....                                                                                                               | 73 |
| 30. | Claim 34 .....                                                                                                               | 74 |
| IX. | GROUND 2: CLAIMS 1-4, 7, 9-13, 15-16,<br>18-21, 23-24, AND 28-31 ARE OBVIOUS<br>OVER CAI AND THE KNOWLEDGE OF A POSITA ..... | 75 |
| A.  | Cai (EX1005) .....                                                                                                           | 75 |
| B.  | A POSITA Would Have<br>Implemented Cai With A Gullwing Sixth Lens .....                                                      | 78 |
| C.  | Claim Mapping .....                                                                                                          | 82 |

|     |                       |     |
|-----|-----------------------|-----|
| 1.  | Claim 1 .....         | 82  |
|     | a) Element 1.1 .....  | 82  |
|     | b) Element 1.2 .....  | 83  |
|     | c) Element 1.3 .....  | 84  |
|     | d) Element 1.4 .....  | 86  |
|     | e) Element 1.5 .....  | 87  |
|     | f) Element 1.6 .....  | 89  |
|     | g) Element 1.7 .....  | 91  |
|     | h) Element 1.8 .....  | 93  |
|     | i) Element 1.9 .....  | 95  |
|     | j) Element 1.10 ..... | 96  |
| 2.  | Claim 2 .....         | 98  |
| 3.  | Claim 3 .....         | 99  |
| 4.  | Claim 4 .....         | 101 |
| 5.  | Claim 7 .....         | 102 |
| 6.  | Claim 9 .....         | 103 |
| 7.  | Claim 10 .....        | 104 |
| 8.  | Claim 11 .....        | 105 |
| 9.  | Claim 12 .....        | 106 |
| 10. | Claim 13 .....        | 107 |
| 11. | Claim 15 .....        | 108 |
| 12. | Claim 16 .....        | 110 |
| 13. | Claim 18 .....        | 111 |

|     |                                               |     |
|-----|-----------------------------------------------|-----|
| a)  | Element 18.1 .....                            | 111 |
| b)  | Element 18.2 .....                            | 111 |
| c)  | Element 18.3 .....                            | 111 |
| 14. | Claim 19 .....                                | 112 |
| a)  | Element 19.1 .....                            | 112 |
| b)  | Element 19.2 .....                            | 113 |
| 15. | Claim 20 .....                                | 113 |
| a)  | Elements 20.1-20.6 .....                      | 113 |
| b)  | Element 20.7 .....                            | 113 |
| c)  | Elements 20.8-20.9 .....                      | 114 |
| d)  | Element 20.10 .....                           | 114 |
| 16. | Claim 21 .....                                | 115 |
| 17. | Claim 23 .....                                | 116 |
| 18. | Claim 24 .....                                | 117 |
| 19. | Claim 28 .....                                | 117 |
| 20. | Claim 29 .....                                | 118 |
| 21. | Claim 30 .....                                | 121 |
| 22. | Claim 31 .....                                | 122 |
| X.  | NO OBJECTIVE INDICIA OF NON-OBVIOUSNESS ..... | 124 |
| XI. | CONCLUSION .....                              | 125 |
|     | CERTIFICATE OF COMPLIANCE .....               | 126 |



**TABLE OF AUTHORITIES**

Page(s)

**Cases**

|                                                                                               |   |
|-----------------------------------------------------------------------------------------------|---|
| <i>Corephotonics, Ltd. v. Apple Inc.</i> ,<br>2021 WL 4944467 (Fed. Cir. Oct. 25, 2021) ..... | 6 |
|-----------------------------------------------------------------------------------------------|---|

**Board Decisions**

|                                                                                                                                |   |
|--------------------------------------------------------------------------------------------------------------------------------|---|
| <i>Advanced Bionics, LLC v. Med-El Elektromedizinische Geräte GMBH</i> ,<br>IPR 2019-01469, Paper 6 (PTAB Feb. 13, 2020) ..... | 5 |
|--------------------------------------------------------------------------------------------------------------------------------|---|

**Statutes**

|                       |   |
|-----------------------|---|
| 35 U.S.C. § 325 ..... | 5 |
| 35 U.S.C. § 103 ..... | 2 |
| 35 U.S.C. § 314 ..... | 5 |

**Rules**

|                          |   |
|--------------------------|---|
| 37 C.F.R. § 42.104 ..... | 2 |
| 37 C.F.R. § 42.15 .....  | 3 |

**LIST OF EXHIBITS**

| <b>No.</b> | <b>Description</b>                                                                                                                                                   |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1001       | U.S. Patent No. 9,366,845 (“ <b>845 patent</b> ”)                                                                                                                    |
| 1002       | File History of U.S. Patent No. 9,366,845 ( <b>’845 FH</b> )                                                                                                         |
| 1003       | Declaration of Professor Tom D. Milster, signed and dated June 27, 2024 (“ <b>Milster</b> ”)                                                                         |
| 1004       | U.S. Patent Application Publ. No. 2014/0139719 (“ <b>Fukaya</b> ”)                                                                                                   |
| 1005       | Certified Translation and Original Copy of Chinese Patent Grant No. CN 202886720 U (“ <b>Cai</b> ”)                                                                  |
| 1006       | U.S. Patent Application Publ. No. 2014/0376105 (“ <b>Sekine</b> ”)                                                                                                   |
| 1007       | U.S. Patent Application Publ. No. 2015/0103414 (“ <b>Baik</b> ”)                                                                                                     |
| 1008       | U.S. Patent Application Publ. No. 2014/0211324 (“ <b>Ishizaka</b> ”)                                                                                                 |
| 1009       | Michael P. Schaub, <i>The Design of Plastic Optical Systems</i> (SPIE Press 2009) (excerpts) (“ <b>Schaub</b> ”)                                                     |
| 1010       | Warren J. Smith, <i>Modern Lens Design</i> (2d ed. 2005) (excerpts) (“ <b>Smith</b> ”)                                                                               |
| 1011       | Robert E. Fischer et al., <i>Optical System Design</i> (2d ed. 2008) (excerpts) (“ <b>Fischer</b> ”)                                                                 |
| 1012       | Joseph M. Geary, <i>Introduction to Lens Design With Practical ZEMAX® Examples</i> (2002) (excerpts) (“ <b>Geary</b> ”)                                              |
| 1013       | Jane Bareau & Peter P. Clark, <i>The Optics of Miniature Digital Camera Modules</i> (2006) (“ <b>Bareau</b> ”)                                                       |
| 1014       | Rob Bates, <i>Performance and Tolerance Sensitivity Optimization of Highly Aspheric Miniature Camera Lenses</i> , Proc. SPIE 7793 (Aug. 23, 2010) (“ <b>Bates</b> ”) |
| 1015       | Stefan Bäumer, <i>Handbook of Plastic Optics</i> (2d ed. 2010) (excerpts) (“ <b>Bäumer</b> ”)                                                                        |
| 1016       | Julie Bentley & Craig Olson, <i>Field Guide to Lens Design</i> (2012) (“ <b>Bentley Guide</b> ”)                                                                     |

| No.  | Description                                                                                                                       |
|------|-----------------------------------------------------------------------------------------------------------------------------------|
| 1017 | Rudolf Kingslake, <i>A History of the Photographic Lens</i> (1989) (“ <b>Kingslake</b> ”)                                         |
| 1018 | Deposition Transcript of Julie L. Bentley, Ph.D. dated May 18, 2023 (“ <b>Bentley Transcript</b> ”)                               |
| 1019 | U.S. Patent No. 8,094,231 (“ <b>Tsai-231</b> ”)                                                                                   |
| 1020 | U.S. Patent No. 7,394,602 (“ <b>Chen-602</b> ”)                                                                                   |
| 1021 | U.S. Patent No. 7,738,186 (“ <b>Chen-186</b> ”)                                                                                   |
| 1022 | U.S. Patent No. 8,023,203 (“ <b>Shyu</b> ”)                                                                                       |
| 1023 | Thomas Steinich & Vladan Blahnik, <i>Optical Design of Camera Optics for Mobile Phones</i> (2012) (“ <b>Steinich</b> ”)           |
| 1024 | U.S. Patent Application Publ. No. 2015/0212298 (“ <b>Shinohara-298</b> ”)                                                         |
| 1025 | U.S. Patent No. 9,507,125 (“ <b>Hashimoto</b> ”)                                                                                  |
| 1026 | U.S. Patent No. 9,383,553 (“ <b>Shinohara-553</b> ”)                                                                              |
| 1027 | U.S. Patent No. 9,448,386 (“ <b>Kubota-386</b> ”)                                                                                 |
| 1028 | U.S. Patent No. 8,780,464 (“ <b>Huang-464</b> ”)                                                                                  |
| 1029 | U.S. Patent No. 9,146,380 (“ <b>Kubota-380</b> ”)                                                                                 |
| 1030 | Rudolf Kingslake & R. Barry Johnson, <i>Lens Design Fundamentals</i> (2d ed. 2010) (excerpts) (“ <b>Kingslake Fundamentals</b> ”) |
| 1031 | List of Challenged Claims                                                                                                         |
| 1032 | U.S. Patent No. 8,599,495 (“ <b>Tsai</b> ”)                                                                                       |

**MANDATORY NOTICES UNDER 37 C.F.R. § 42.8**

**1. Real Party-In-Interest**

Motorola Mobility LLC is the sole real party-in-interest.

**2. Related Matters**

The following pending patent applications alleged priority to the '845 patent or its alleged priority application: 18/107,400.

The following issued patents allege priority to the '845 patent or its alleged priority applications: 11,624,896; 9,798,112; 10,394,002; and 11,036,033.

**3. Lead And Back-Up Counsel, And Service Information**

| <b>Lead Counsel</b>                                                                                                                  | <b>Back-up Counsel</b>                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Andrew M. Mason (Reg. No. 64,034)<br>andrew.mason@klarquist.com                                                                      | Frank Morton-Park (Reg. No. 80,750)<br>frank.morton-park@klarquist.com |
| KLARQUIST SPARKMAN, LLP<br>121 SW Salmon Street, Suite 1600<br>Portland, Oregon, 97204<br>503-595-5300 (phone)<br>503-595-5301 (fax) |                                                                        |

Petitioner consents to electronic service by email, with each service email addressed to each above email address and Moto-Largan@klarquist.com.

Pursuant to 37 C.F.R. § 42.10(b), concurrently filed with this Petition is a Power of Attorney executed by Petitioner and appointing the above counsel.

Motorola Mobility LLC (“Petitioner”) respectfully requests *inter partes* review (“IPR”) of claims 1-34 of U.S. Patent No. 9,366,845 (“’845 patent”) (EX1001), allegedly assigned to Largan Precision Co., Ltd. (“Patent Owner”). For the reasons set forth below, these claims should be found unpatentable and cancelled.

## **I. INTRODUCTION**

The ’845 patent relates to a seven-element “photographing optical lens assembly.” EX1001, 1:52-2:12. The challenged claims recite *inter alia* a particular arrangement of refractive powers (certain lenses having either positive or negative power) and sixth and seventh lenses with image-side surfaces having critical points that were generally the same vertical distance from the optical axis (recited as  $0.5 < Y_{c62}/Y_{c72} < 1.5$ ). EX1002, 863-64/880. These were the supposed points of distinction over the cited art.

Yet, seven-element lens systems with the recited arrangement of refractive powers were known before the earliest possible priority date of the ’845 patent, including both Fukaya (EX1004) and Cai (EX1005), each with a 2012 filing date. Further, the Fukaya and Cai lens designs included highly aspheric sixth and seventh lenses that were very similar to the ’845 patent.

And by the 2014 priority date of the ’845 patent, POSITAs were increasingly designing double “gullwing” 7-lens systems, with sixth and seventh lenses having a gullwing shape, in order to beneficially correct off-axis aberrations and control chief

ray angle. The ubiquity of these double gullwing design forms is reflected in numerous references discussed below. While those references may not use the same obscure language as the challenged claims, they describe lens forms that meet that claim language. POSITAs would have been motivated with a reasonable expectation of success to implement Fukaya and Cai with these well-known, desirable gullwing lens pairs. The resulting lens systems collectively render each challenged claim obvious, as explained in Grounds 1 and 2, thus warranting institution of IPR.

## **II. GROUND FOR STANDING PER 37 C.F.R. § 42.104(a)**

Petitioner certifies that the '845 patent is available for IPR and that Petitioner is not barred or estopped from requesting an IPR challenging the patent claims on the grounds identified in this petition.

## **III. IDENTIFICATION OF CHALLENGE**

### **A. Statement Of The Precise Relief Requested / Statutory Grounds**

Petitioner requests *inter partes* review of claims 1-34 (the “Challenged Claims”) of the '845 patent, on the following statutory grounds:

|                 | Reference(s)    | Basis           | Claims                                   |
|-----------------|-----------------|-----------------|------------------------------------------|
| <b>Ground 1</b> | Fukaya (EX1004) | 35 U.S.C. § 103 | 1-14, 16-27, 30, 32-34                   |
| <b>Ground 2</b> | Cai (EX1005)    | 35 U.S.C. § 103 | 1-4, 7, 9-13, 15-16, 18-21, 23-24, 28-31 |

For each ground, in Sections VIII and IX below, the petition presents evidence of unpatentability and establishes a reasonable likelihood that the Petitioner will prevail in establishing that each Challenged Claim is unpatentable.

With the filing of this petition an electronic payment of \$57,250 for the requisite fees is being charged to deposit account no. 02-4550. 37 C.F.R. § 42.15 (a). Any fee adjustments may be debited/credited to the deposit account.

**B. The Board Should Not Discretionarily Deny Under Section 325(d)**

Prior art reference Fukaya (EX1004) was listed on an IDS but not discussed on the record during prosecution, and nothing suggests that its teachings relied on herein, much less the implementation of those teachings as informed by expert testimony, were considered by the Examiner. Tsai (EX1032), a U.S. family member of prior art reference Cai (EX1005), was discussed during prosecution, but nothing suggests that the Examiner considered an obvious implementation of Cai based on the POSITA's knowledge of double gullwing design forms, much less one informed by expert testimony, as relied upon herein.

Moreover, the Examiner materially erred when examining the claims in view of the prior art. As one 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 “ $0.5 < Y_{c62}/Y_{c72} < 1.5$ ,” where  $Y_{c62}$  and  $Y_{c72}$  are vertical distances between an optical axis and non-axial critical point on the image-side surfaces of the

sixth and seventh lens elements, respectively. EX1002, 823/880; *id.*, 863-864/880 (allowing the claims amended to incorporate this element). The primary reference cited by the Examiner, Baik (EX1002, 809-22/880), actually disclosed lens arrangements satisfying this  $Yc62/Yc72$  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  $Yc62$  and  $Yc72$ , 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  $Yc62/Yc72$  condition. EX1003, ¶68.

The Examiner also erred by concluding that “none of the prior art” disclose a sixth lens element with positive refractive power or a fifth lens element with negative refractive power. EX1002, 824/880; *id.*, 863-864/880 (allowing the claims amended to incorporate these elements). EX1003, ¶68. The secondary reference, Tsai, discloses embodiments with the same refractive power layout as the '845 claims, including a sixth lens element with positive refractive power and a fifth lens element

with negative refractive power. *E.g.*, EX1032, 8:11-18, 22:5-13. Similarly, Fukaya discloses the same refractive power layout as the '845 claims, as well as many other elements. *E.g.*, EX1004, [0125] (Table 1); *infra* Section VIII (mapping Fukaya to the claims).

Thus, although Fukaya and Tsai were at least referenced during prosecution, the Examiner made material errors by “misapprehending or overlooking specific teachings of the relevant prior art where those teachings impact patentability of the challenged claims.” *Advanced Bionics, LLC v. Med-El Elektromedizinische Geräte GMBH*, IPR 2019-01469, Paper 6 at 8 n.9 (PTAB Feb. 13, 2020). Accordingly, this petition should not be denied under Section 325(d).

**C. No Parallel Litigation Involving Petitioner**

Patent Owner has not asserted this patent in any U.S. District Court litigation and thus there is no basis for discretionary denial under Section 314.

**IV. STATE OF THE ART**

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

A skilled lens designer begins with an older starting point design, and then implements various modifications to develop a new, optimized lens system. EX1003, ¶¶43-44. This process is shown below:

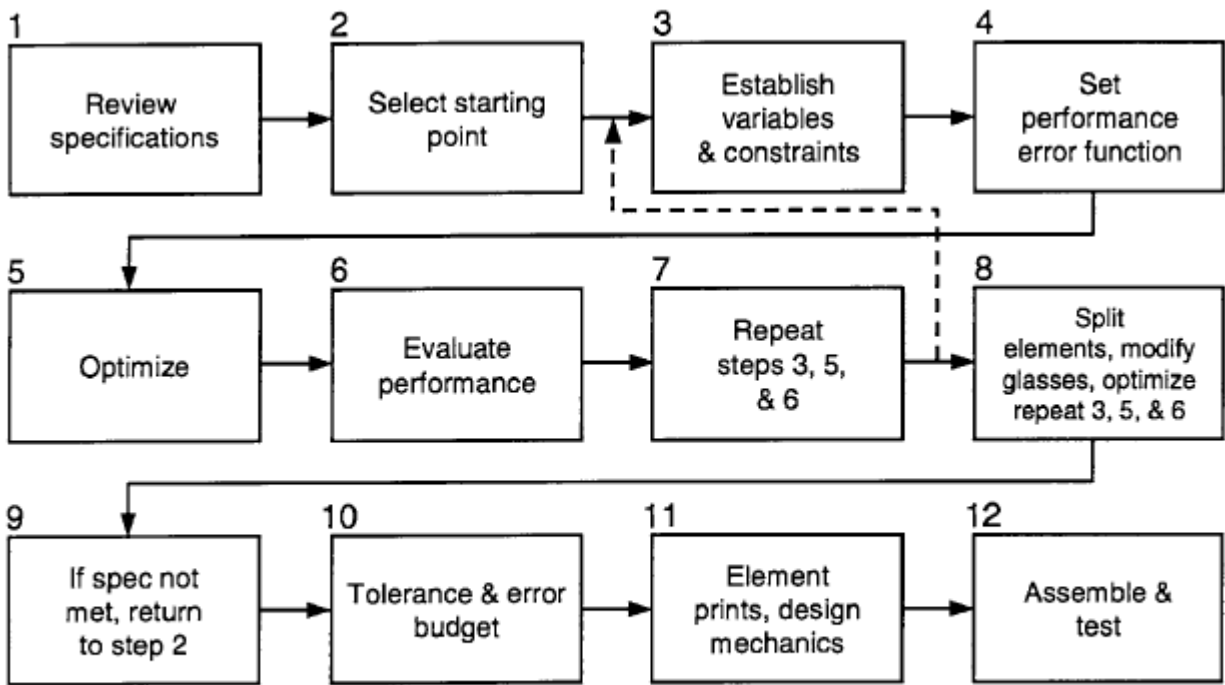


**Figure 9.2**  
Lens Design and Optimization Procedure

EX1011, 172; *see also id.*, 168, 171-76; EX1030, 9; EX1010, 11-69; EX1003, ¶45.

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.<sup>1</sup> A POSITA would have known how to best implement

<sup>1</sup>The 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”).

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, 41-43; EX1012, 6-7; EX1003, ¶46.

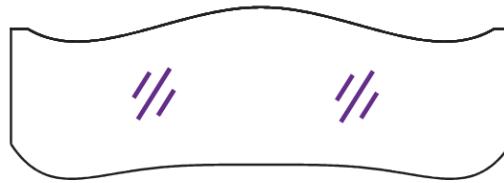
Below are some common and easily implemented design optimization techniques known and used by a POSITA. Using Zemax or similar software, designers with even a modest amount of experience would have naturally used them without issue in 2014. EX1003, ¶47.

***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; EX1003, ¶48.

***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; EX1003, ¶49.

**B. Gullwing Lenses Were Often Used To Perform Field Corrections And Control Chief Ray Angles**

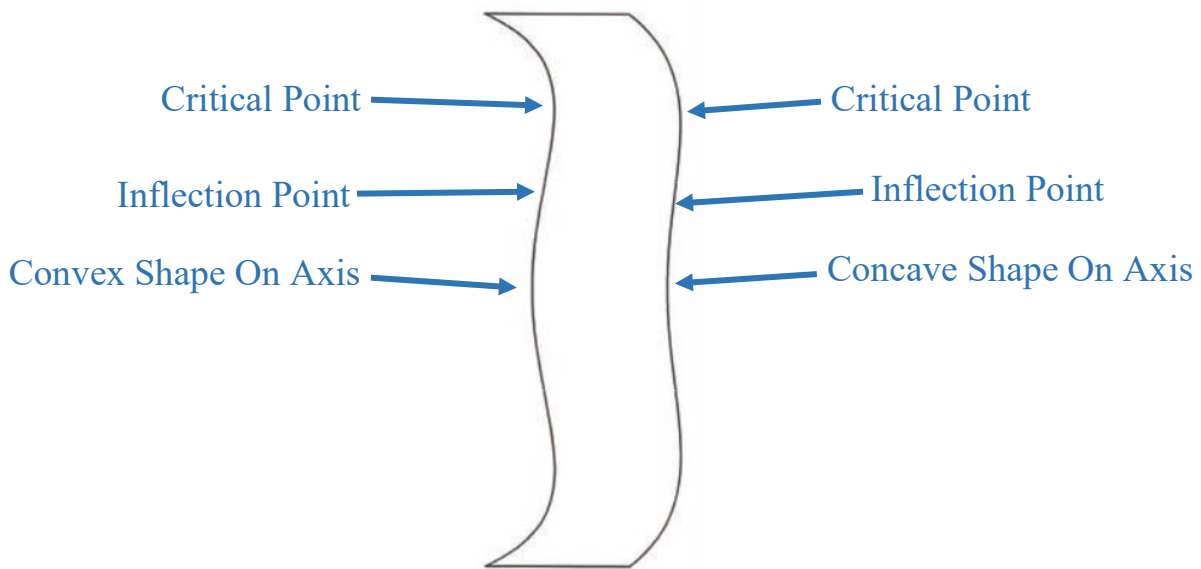
A highly aspheric lens shape that changes / inflects curvature from convex to concave (or vice versa) across the lens surface is sometimes referred to as a “gullwing asphere” or “gullwing lens” because the shape looks like the outspread wings of a flying gull. EX1018, 66:22-24, 76:12-13; EX1011, 125.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



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

EX1016, 61; EX1003, ¶50.

By at least 2009, the gullwing lens was often used in compact camera modules, such as those for cell phones. EX1009, 93-94; *id.*, 94 (gullwing lenses in “high-volume production”); EX1015, 78-79 (in 2010 “quite common in recent designs for camera modules for cell phone cameras”). Schaub depicted the following design as a “perfectly normal” lens shape “from a cell phone camera design” in 2009, which notably includes non-axial critical points, inflection points, and a meniscus shape on axis:



EX1009, 94, FIG. 4.14 (excerpted) (annotations added); EX1003, ¶51.

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; *see also* EX1016, 61; EX1018, 67:15–69:2, 75:11-16; EX1003, ¶¶52-53.

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

Compact cameras therefore typically included at least one gullwing lens near the image plane to perform field corrections and thus improve imaging performance across the field of view. 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; EX1020, 2:18-21, FIG. 1; EX1021, 2:20-23, FIG. 1; EX1022, 4:46-64, FIGS. 1-2. By 2006, a

gullwing surface near the image plane was “typical” in a cell phone camera. EX1013, 7-8. EX1003, ¶¶54-55.

**2. By 2013, Demands For Higher Performance Led To Designs With Seven Or More Lenses And Two Gullwing Lenses**

Although market trends emphasized compact size over image quality in 2006 (EX1013, 8), market demand in the 2010s began to also emphasize performance and image quality, which has driven lens designers to add additional lenses to meet this demand. *E.g.*, EX1006, [0005]-[0013]; EX1007, [0003]-[0010]; EX1008, [0005]-[0011]; EX1018, 71:5-15. By at least 2013, lens designers recognized that these additional lenses should include gullwing lenses; lens designs thus began to commonly include seven lenses with two gullwing lenses near the image plane, in order to better control ray angles and improve aberration corrections in the peripheral region. *E.g.*, EX1006, FIG. 1, [0035]-[0038]; EX1007, FIG. 1, [0090]-[0091]; EX1008, [0018], [0034]-[0035]; EX1024, FIG. 1, [0064]-[0068]; EX1025, FIG. 7, 4:37-58, 6:41-62, 9:22-53; EX1026, FIG. 4, 7:4-67; EX1027, FIG. 1, 3:18-29, 7:24-42; EX1028, FIG. 13; EX1029, FIG. 1. EX1003, ¶¶56-57.

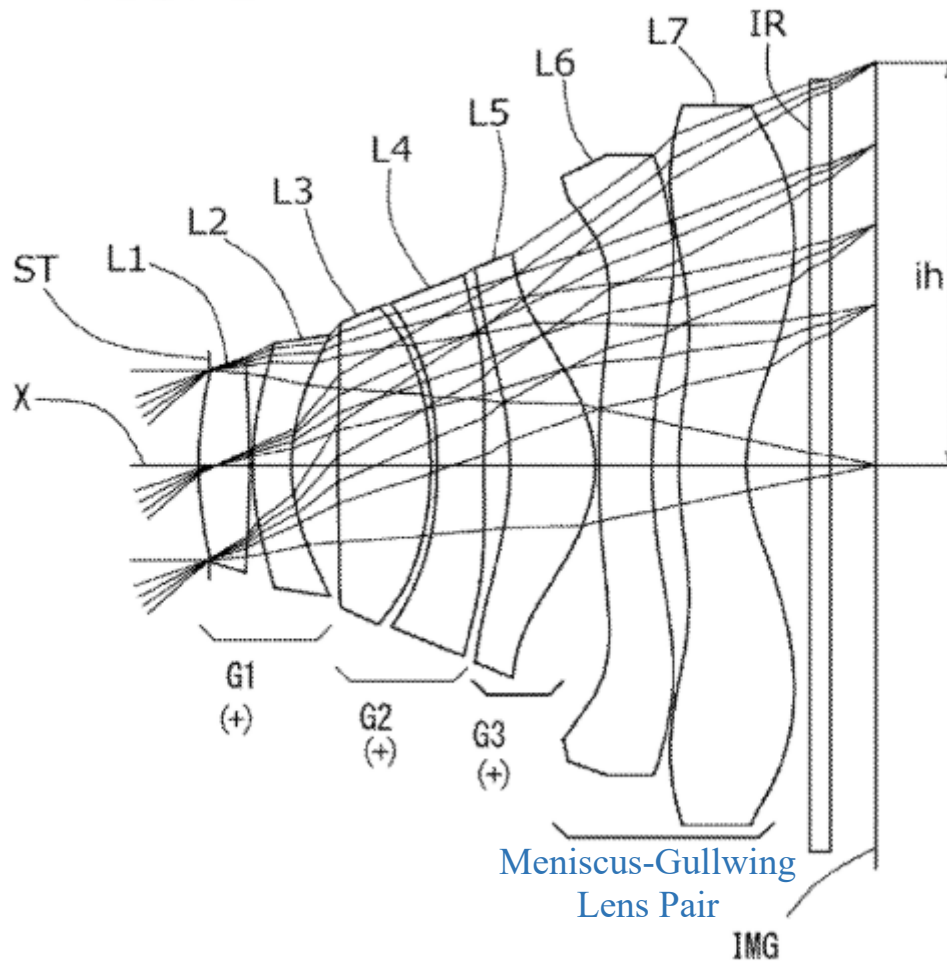
**3. By 2014, Lens Designers Knew That Gullwing Lens Pairs With Meniscus On-Axis Curvature Would Achieve Better Aberration Correction And Chief Ray Angle Control**

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. Further, as reflected in numerous patent applications filed throughout 2013 and 2014, POSITAs understood the specific advantages of using a meniscus-gullwing lens pair (i.e., two gullwing lenses with meniscus shapes on the optical axis, having 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], [0102], [0104], [0110]-[0111]; EX1024, [0064]-

[0068]; EX1025, 6:1-22, 9:22-53; EX1026, FIG. 4, 7:4-67; EX1027, 10:17-54, 10:54-58 EX1003, ¶¶58-59.

FIG. 1



EX1006, FIG. 1 (annotations added); EX1003, ¶58.

## V. THE '845 PATENT

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; EX1003, ¶60.

**A. The '845 Specification**

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 noted what POSITAs already knew about advantages of these features. *Compare id.*, 4:38-59, with *supra* Section IV.B.3. EX1003, ¶61.

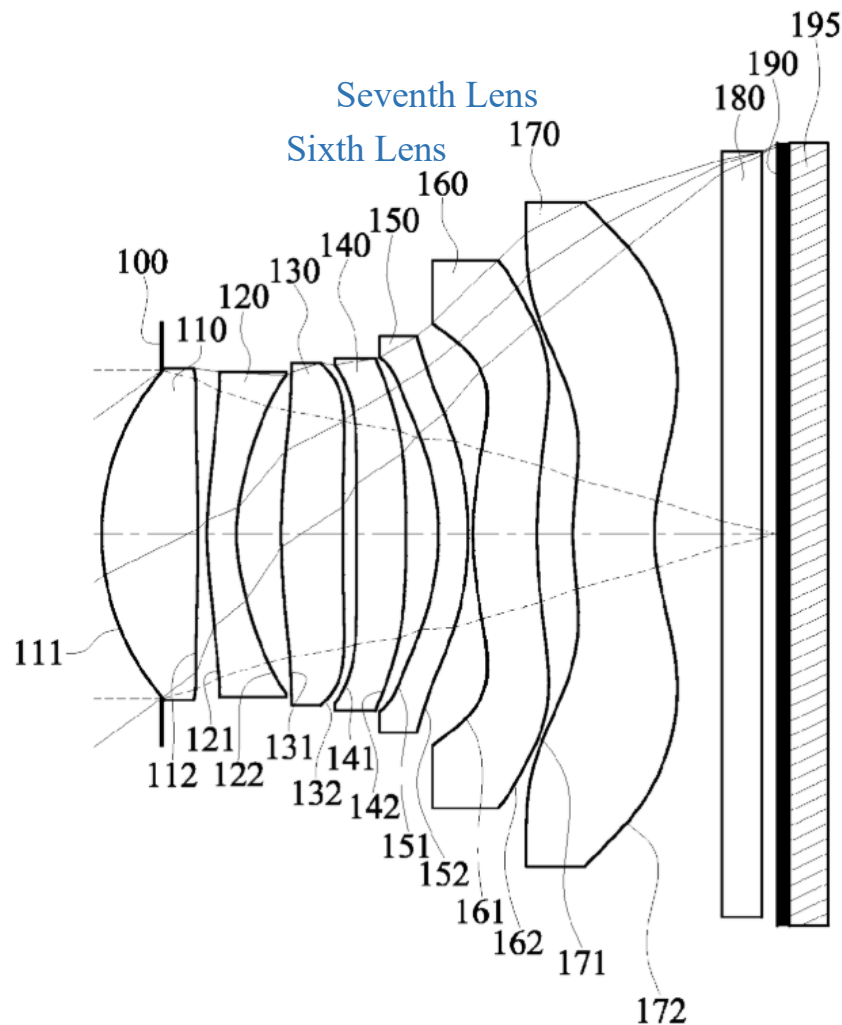


**FIG. 1**

EX1001, FIG. 1; EX1003, ¶61 (annotations added).

The '845 patent characterized the gullwing shapes of the sixth and seventh lenses through vertical distances Yc61 and Yc62 for the sixth lens and Yc72 for the seventh lens, measured from the optical axis to non-axial critical points on the surfaces of the sixth and seventh lenses. *Id.*, 9:35-52. It acknowledged the already-well-known advantages of these gullwing shapes. *Compare id.*, 4:60-5:2, 6:20-27, *with supra* Section IV.B.3. EX1003, ¶62.

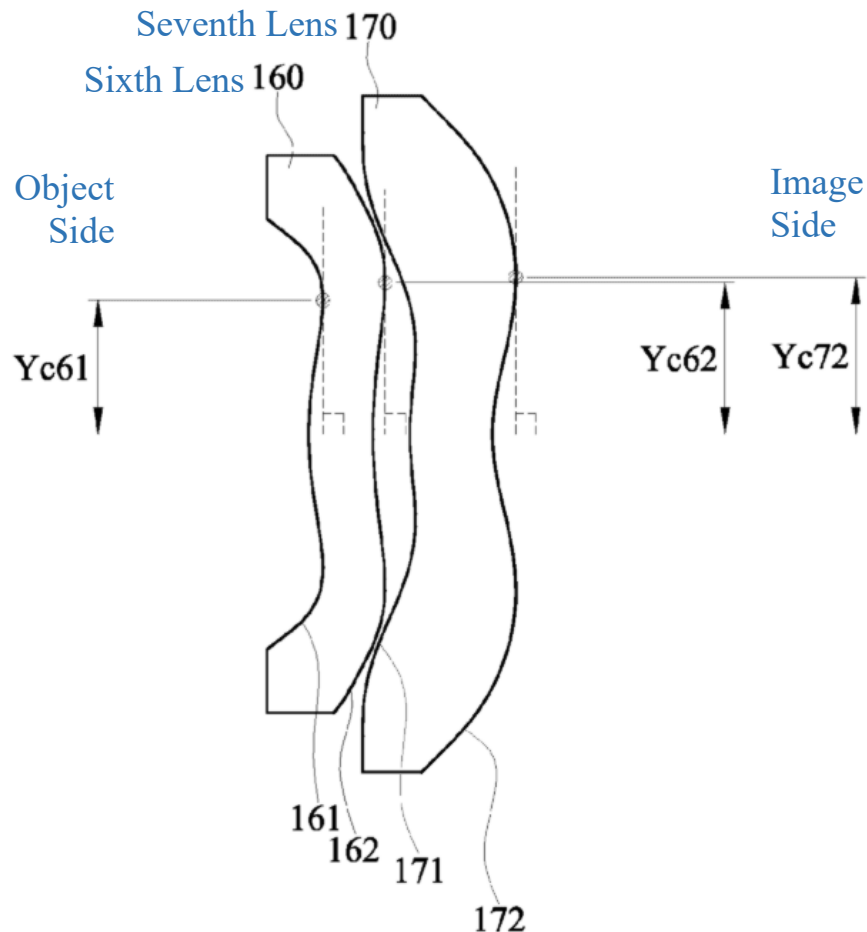


FIG.27

EX1001, FIG. 27; EX1003, ¶62 (annotations added).

**B. The Prosecution History**

An Office action rejected most original claims as obvious over Baik (EX1007) in view of Tsai (EX1032). EX1002, 809-22/880; EX1003, ¶¶63-64. However, the Examiner indicated that some claims contained allowable subject matter because, as some examples, 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  $Y_{c62}$ , the vertical distance between a non-axial critical point on the image-side surface of the seventh lens element and the optical axis is  $Y_{c72}$ , and the following condition is satisfied:  $0.5 < Y_{c62}/Y_{c72} < 1.5$ ” (*id.*, 823/880);
- “wherein the fifth lens element has negative refractive power” (*id.*, 824/880);
- “wherein the sixth lens element has positive refractive power” (*id.*).

EX1003, ¶65. In doing so, the Examiner failed to acknowledge that Baik and Tsai disclose these elements. Applicant amended the independent claims to incorporate this allegedly allowable subject matter, without further explanation. *Id.*, 852/880. EX1003, ¶66. The Examiner allowed the amended claims, citing the incorporation

of the allegedly allowable subject matter into the independent claims as the specific reason for allowability. *Id.*, 863-64/880. EX1003, ¶67.

### C. Claims Listing

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:<br>$0.5 < Yc62/Yc72 < 1.5$ ;<br>$0.1 < Yc72/f < 0.9$ ; and<br>$ f1/f7  < 3.0$ . |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

A full claims listing is submitted as Exhibit 1031. EX1003, ¶¶69-70.

## VI. LEVEL OF SKILL IN THE ART

A person having ordinary skill in the art (“POSITA” or “skilled artisan”) would include someone who had, in 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. Lack of work experience could have been offset by additional education, and vice versa. EX1003, ¶33.

POSITAs had experience in analyzing, adjusting, and optimizing multi-lens imaging systems, and would have been familiar with the specifications of lens systems. POSITAs understood the fundamentals of optical aberration theory and understood and used standard techniques for improving lenses, especially for lens systems used in mobile devices. POSITAs knew 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. POSITAs 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. *Supra* Section IV.A. Lens design

books, including Schaub (EX1009), Smith (EX1010), Fischer (EX1011), and Bentley (EX1016) reflect the knowledge of a POSITA, and Section IV herein describes specific knowledge and skills possessed by POSITAs. EX1003, ¶¶34-42.

## **VII. CLAIM CONSTRUCTION**

Petitioner applies the plain and ordinary meaning of all claim terms, without waiving any rights to raise additional issues of claim construction, indefiniteness, or invalidity in any litigation. EX1003, ¶¶71-72.

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

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 claims obvious. EX1003, ¶73.

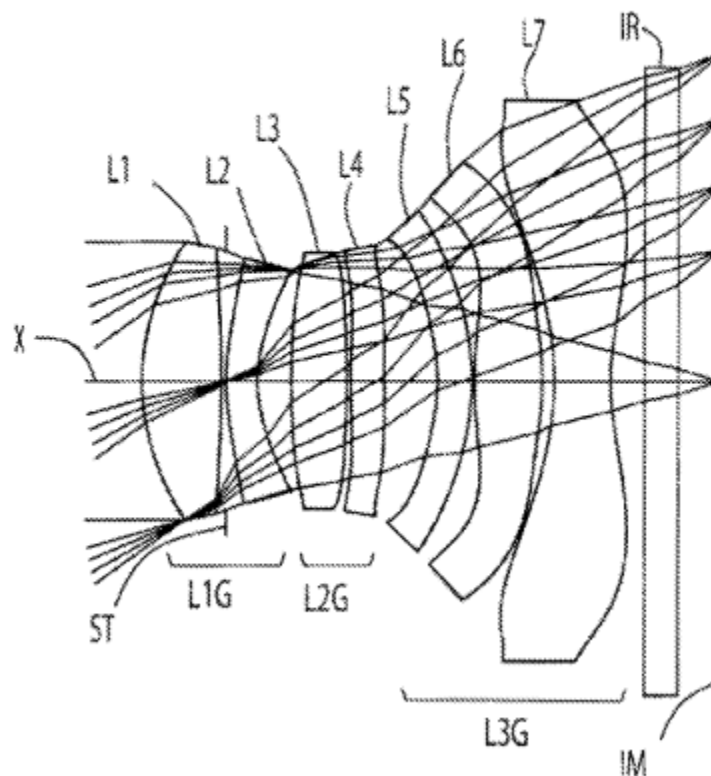
### **A. Fukaya (EX1004)**

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; EX1003, ¶74.

Fukaya discloses various seven-element lens systems “which can correct various aberrations properly.” EX1004, [0012]. Fukaya discloses a gullwing seventh lens with an image-side surface having an aspheric shape that “changes from concave to convex” from the optical axis to the periphery. *Id.*, [0014].

FIG. 1



EX1004, FIG. 1; EX1003, ¶75.

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 the challenged claims obvious. EX1003, ¶76.

**B. A POSITA Would Have Implemented Fukaya With A Gullwing Sixth Lens**

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. EX1003, ¶77. The resulting double-gullwing Fukaya imaging lens satisfies the challenged claims. *Infra* Section VIII.C.

POSITAs knew that gullwing lenses were useful for off-axis field corrections. *Supra* Section IV.B. 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.” EX1006, [0036]; *supra* Sections IV.B.2-IV.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]; EX1003, ¶78.

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 IV.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

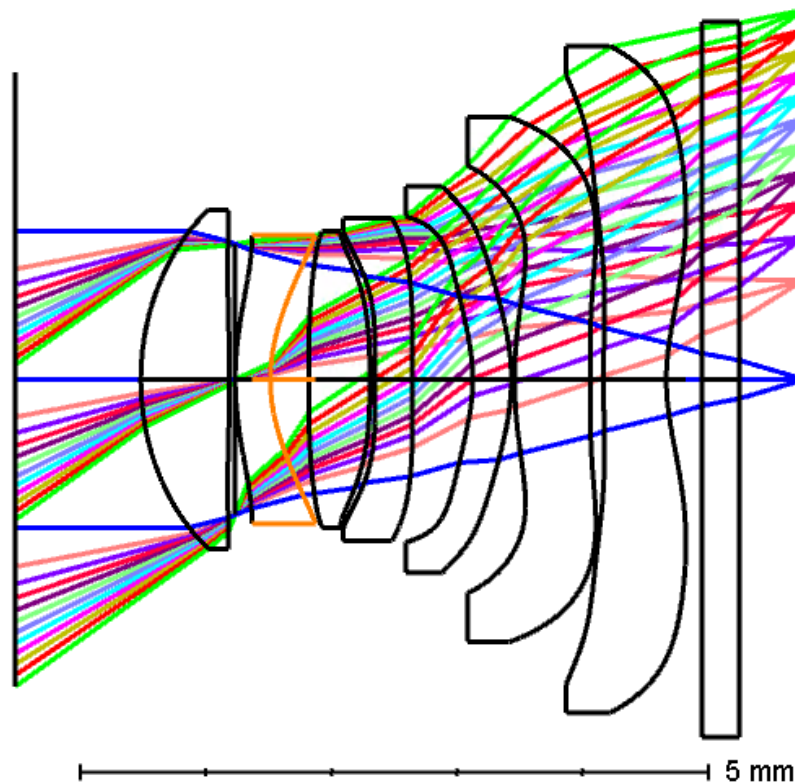
obvious to use the known technique of using a double-gullwing lens pair to predictably achieve the desired goal of performing field corrections and controlling the chief ray angle. EX1003, ¶79.

Further, the POSITA would have further recognized that simply making the object-side surface of the seventh lens convex on axis would complement and balance the change to the image-side surface on the sixth lens. *E.g.*, EX1010, 47. 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 IV.B.3

(explaining how meniscus-gullwing lens pairs were common and well-understood by 2014); EX1003, ¶80.

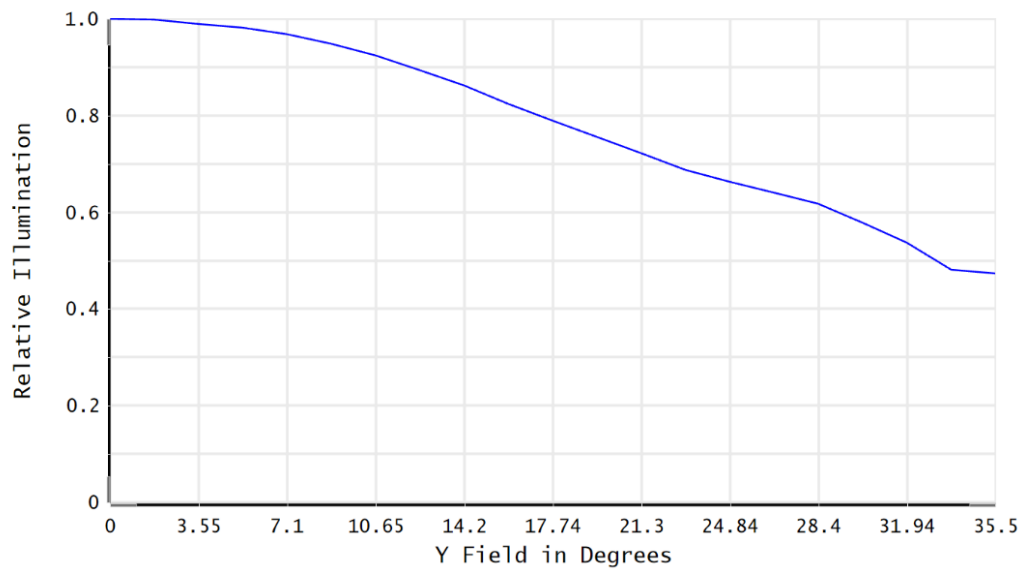
A POSITA would have had a reasonable expectation of success implementing Fukaya with a concave image-side surface on the sixth lens and a convex object-side surface on the seventh lens, because implementing these changes would be a straightforward application of the incremental, iterative lens design process to improve a known starting point. *Supra* Section IV.A. A POSITA further would have had a reasonable expectation of success because the resulting configuration (a meniscus-gullwing lens pair) was well understood as reflected by prior art designs with this same configuration. *Supra* Section IV.B.3; EX1003, ¶81.

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. 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:

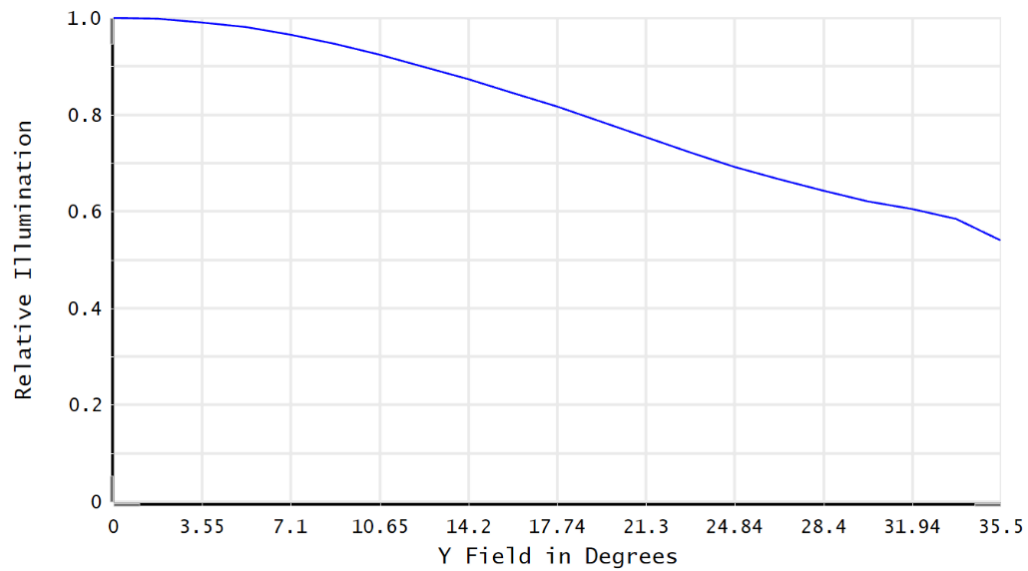


EX1003, ¶¶82-85 (explaining the incremental and iterative process of optimizing the Fukaya imaging lens).

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:



EX1003, ¶86. A POSITA would have known that lens specifications require a relative illumination “greater than 50% at the edge of the field.” EX1013, 7; *id.* (“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. *E.g.*, 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). As expected, 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:



EX1003, ¶86.

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. As discussed in the following section, when implemented with a meniscus-gullwing lens pair, the modified Fukaya imaging lens renders obvious claims 1-14, 16-27, 30, and 32-34. EX1003, ¶87.

C. **Claim Mapping**

1. **Claim 1**

a) **Element 1.1**

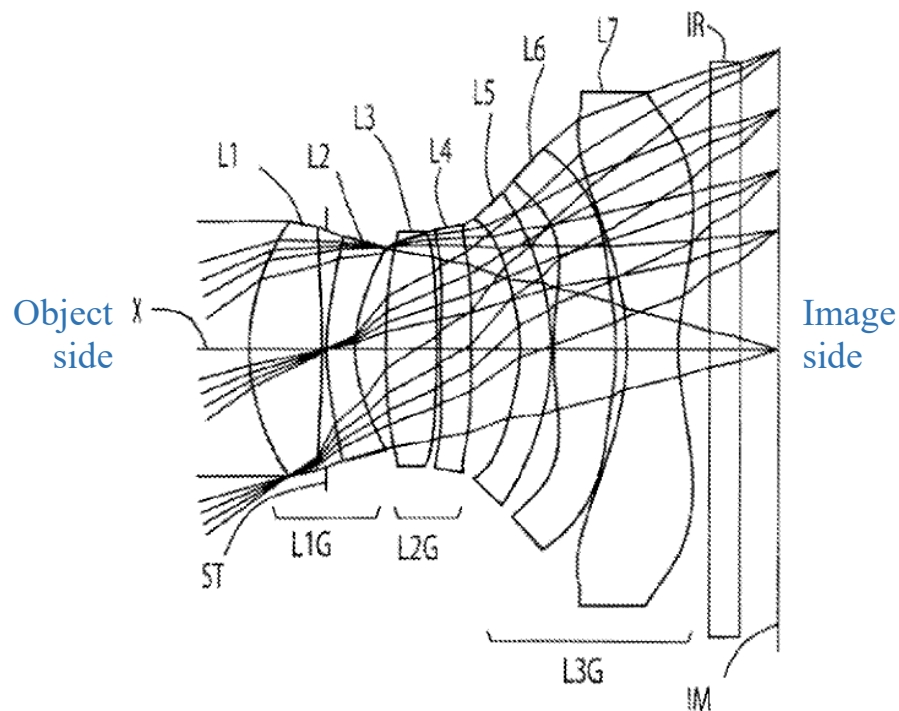
[1.1]<sup>2</sup> A photographing optical lens assembly comprising, in order from an object side to an image side:

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:

---

<sup>2</sup> Reference numbers in the format of [claim#.element#] are added throughout for ease of reference.

FIG. 1



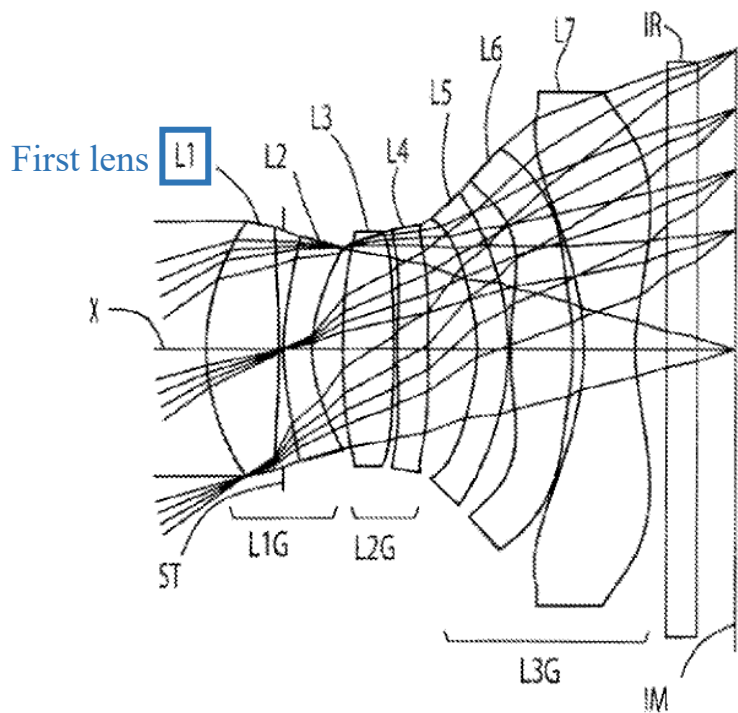
EX1004, FIG. 1 (annotations added); *id.*, [0095]; EX1003, ¶88.

**b) Element 1.2**

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

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]. 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             | -4.915       |
| 3                     | 5             | 12.175       |
| 4                     | 7             | 13.714       |
| 5                     | 9             | -10.937      |
| 6                     | 11            | 2.612        |
| 7                     | 13            | -2.057       |

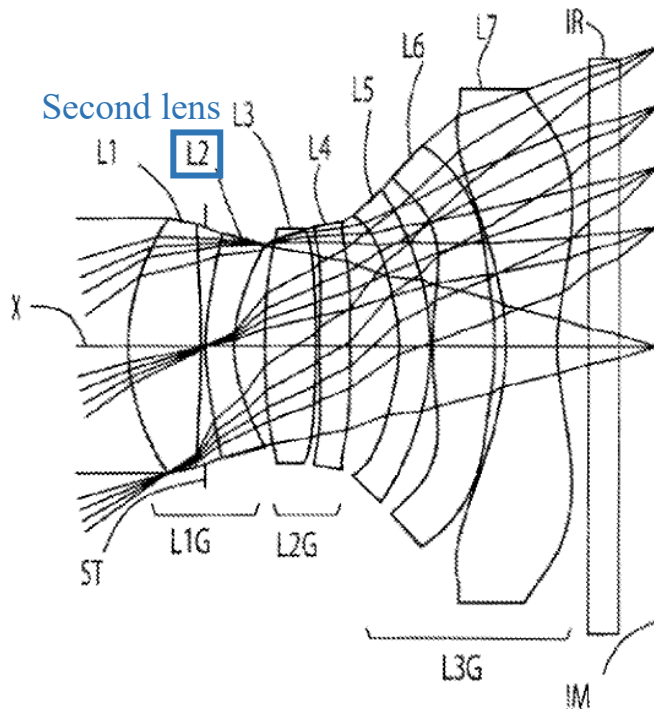
EX1004, [0125] (Table 1) (excerpted) (annotations added). EX1003, ¶89.

c) **Element 1.3**

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

Fukaya discloses a “second lens L2 with negative refractive power.” EX1004, [0096]; *id.*, [0102]. 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       |

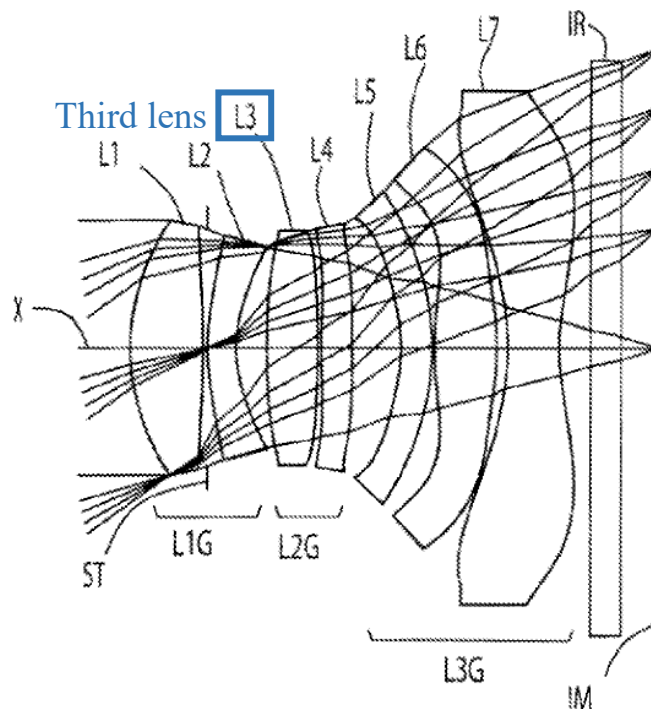
EX1004, [0125] (Table 1) (excerpted) (annotations added). EX1003, ¶90.

d) **Element 1.4**

[1.4] a third lens element;

Fukaya discloses a “third lens L3.” EX1004, [0099]. FIG. 1 depicts the third lens L3 in Embodiment 1:

**FIG. 1**



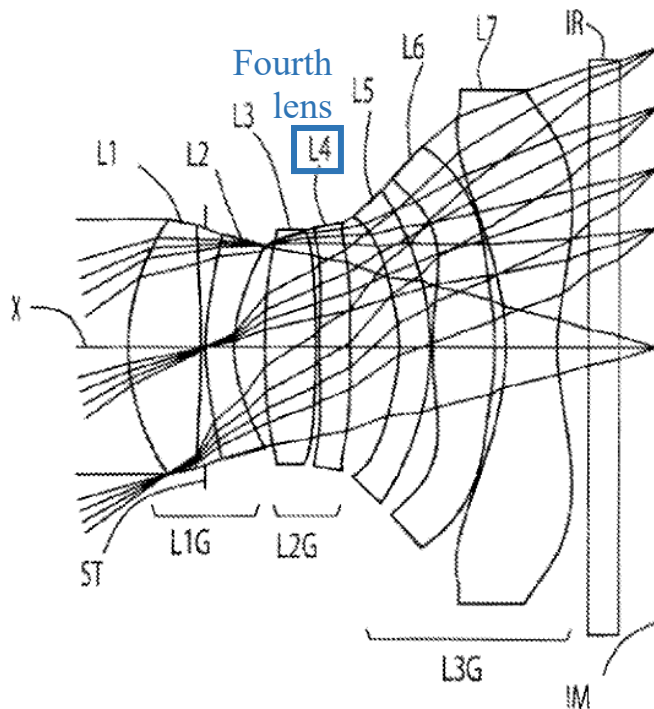
EX1004, FIG. 1 (annotations added). EX1003, ¶91.

e) **Element 1.5**

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

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). EX1003, ¶92.

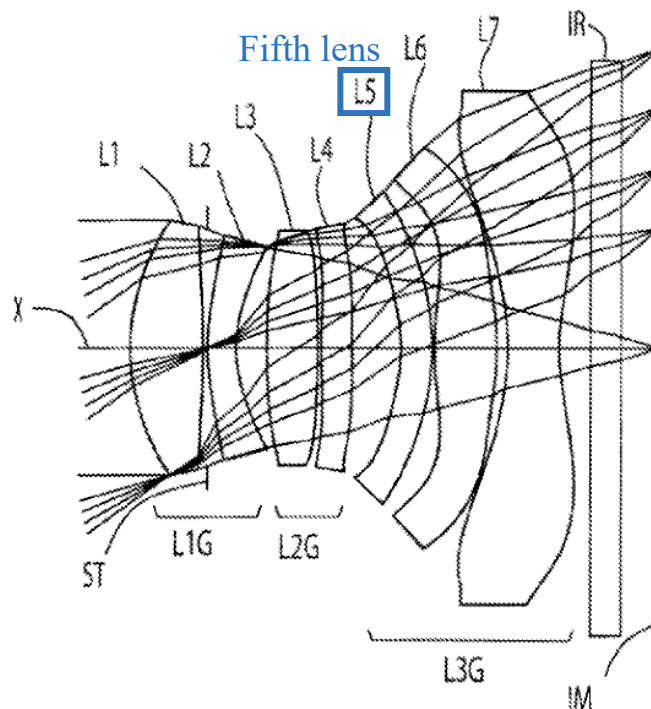
f) **Element 1.6**

[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;

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). EX1003, ¶93. 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). EX1003, ¶94.

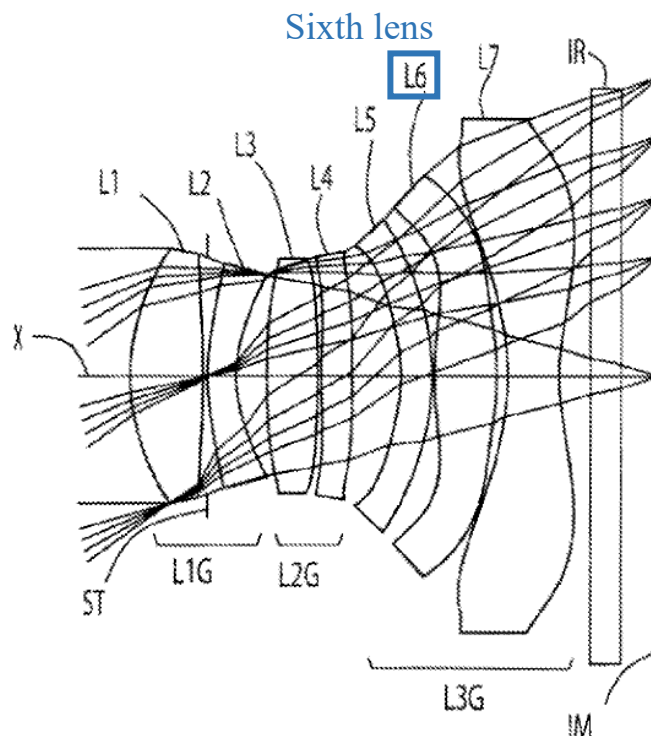
**g) Element 1.7**

[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

Fukaya discloses a “sixth lens L6.” EX1004, [0100]. Fukaya discloses “both the surfaces of the sixth lens are aspheric.” *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). EX1003, ¶95.

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) (excerpted) (annotations added). These values confirm at least one inflection point on the image-side surface of the sixth lens L6. EX1003, ¶96.

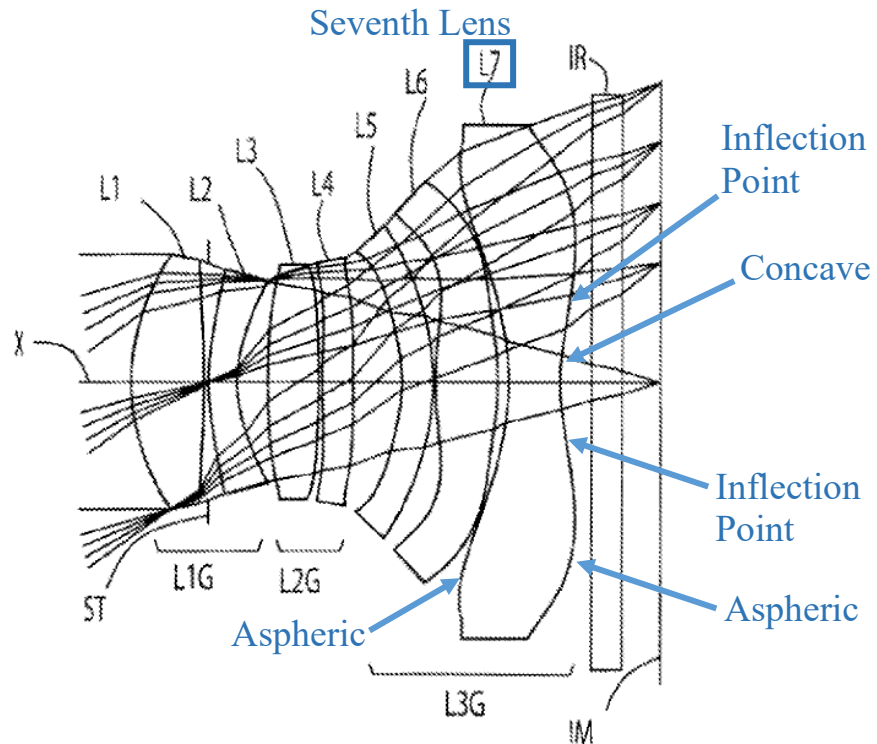
Regarding the image-side surface being concave in a paraxial region thereof, Fukaya discloses the sixth lens L6 with a convex image-side surface in the paraxial region. EX1004, [0022], [0100], [0125] (negative curvature radius for surface number 12). As explained *supra* Section VIII.B, a POSITA would have found it obvious 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. Fukaya thus renders this element obvious. EX1003, ¶97.

**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;

Fukaya discloses a “seventh lens L7 in which ... the image-side surface [is] concave.” EX1004, [0100]. Both surfaces 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



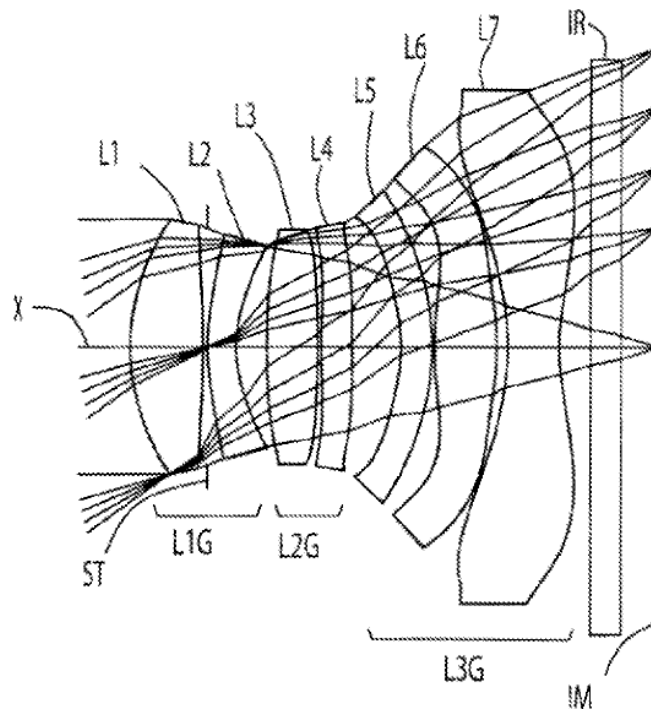
EX1004, FIG. 1 (annotations added). EX1003, ¶98.

i) **Element 1.9**

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

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; EX1003, ¶99.

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:

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

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

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

**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       |

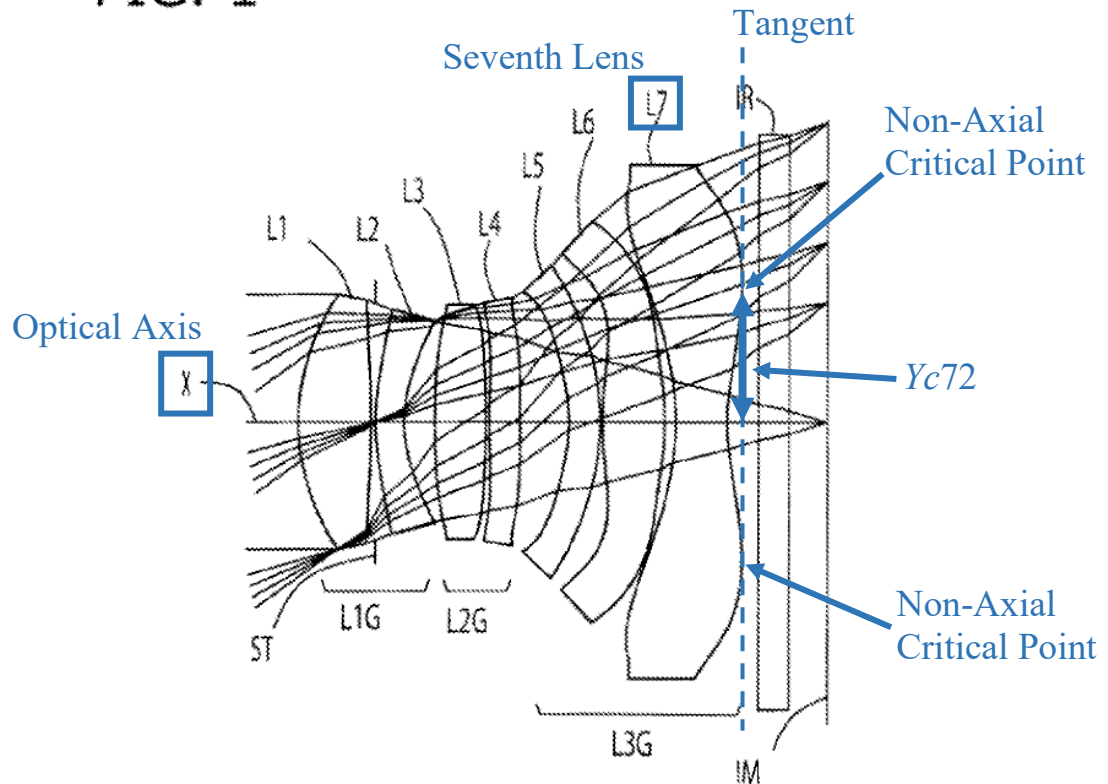
EX1004, [0125] (Table 1) (excerpted) (annotations added); EX1003, ¶100.

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

| Numerical Example 1<br>in mm                                        |
|---------------------------------------------------------------------|
| $f = 4.06$<br>$Fno = 1.64$<br>$\omega(deg) = 35.49$<br>$ih = 2.934$ |

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:

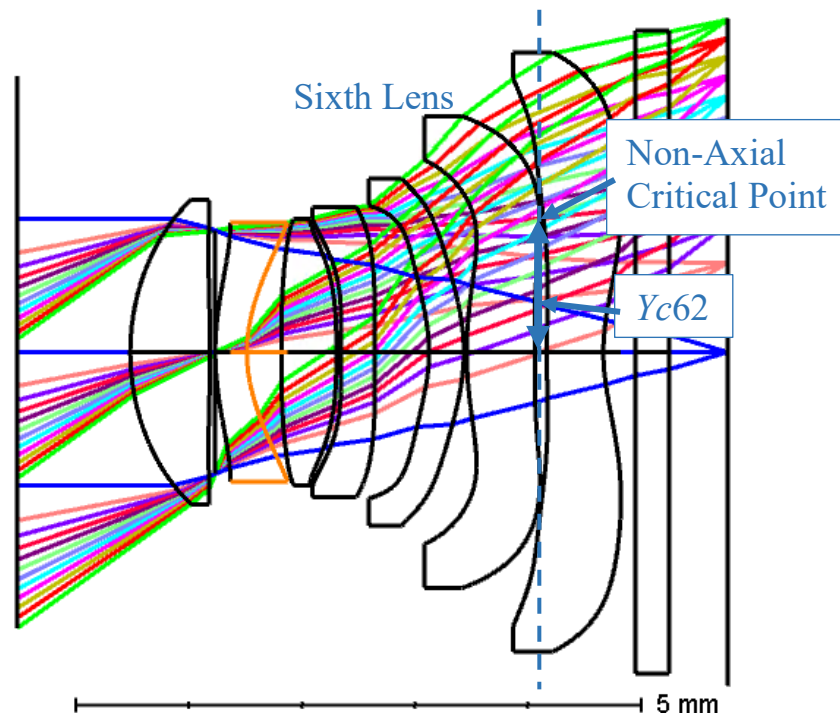
FIG. 1



EX1004, FIG. 1 (annotations added). The vertical distance  $Y_{c72}$ , 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  $Y_{c72}/f=0.33$ , within the range  $0.1 < Y_{c72}/f < 0.9$ . EX1003, ¶101.

**Regarding the  $Y_{c62}/Y_{c72}$  condition,** Fukaya does not disclose non-axial critical points on the image-side surface of the sixth lens L6. However, as discussed *supra* Section VIII.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. So implemented, the modified Fukaya

imaging lens includes non-axial critical points 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 points on the image-side surface of the sixth lens L6 and the optical axis is  $Y_{c62}=1.173\text{mm}$ .



EX1003, ¶102. 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. Fukaya thus renders this element obvious. EX1003, ¶102.

## 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.

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. EX1003, ¶103.

### 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.

Fukaya discloses the seventh lens L7 with an object-side surface that is concave in a paraxial region thereof. EX1004, [0100], [0104], [0125]. As discussed *supra* Section VIII.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      |

Fukaya thus renders this claim obvious. EX1003, ¶104.

#### 4. Claim 4

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

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. EX1003, ¶105.

## 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,

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); EX1003, ¶106.

**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:  
 $0 < R14/f < 0.7$ .

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  $R14/f=0.478$ , satisfying the condition:

| Numerical Example 1<br>in mm                                        |                       |                       |                        |                   |
|---------------------------------------------------------------------|-----------------------|-----------------------|------------------------|-------------------|
| $f = 4.06$<br>$Fno = 1.04$<br>$\omega(deg) = 35.49$<br>$ih = 2.934$ |                       |                       |                        |                   |
| Surface Data                                                        |                       |                       |                        |                   |
| Surface No. i                                                       | Curvature<br>Radius r | Surface<br>Distance d | Refractive<br>Index Nd | Abbe Number<br>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. EX1003, ¶107.

## 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:  
 $0 < f/R12 < 5.0$ .

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 concave (negative), so  $f/R12$  is negative and outside the claimed range.

| Numerical Example 1<br>in mm                                        |                       |                       |                        |                   |
|---------------------------------------------------------------------|-----------------------|-----------------------|------------------------|-------------------|
| $f = 4.06$<br>$Fno = 1.04$<br>$\omega(deg) = 35.49$<br>$ih = 2.934$ |                       |                       |                        |                   |
| Surface Data                                                        |                       |                       |                        |                   |
| Surface No. i                                                       | Curvature<br>Radius r | Surface<br>Distance d | Refractive<br>Index Nd | Abbe Number<br>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). EX1003, ¶108.

However, as discussed *supra* Section VIII.B, a POSITA would have found it obvious to implement the sixth lens L6 with a (positive) 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  $f/R12=0.410$ , satisfying the condition:

|    | 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. EX1003, ¶109.

## 7. Claim 7

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

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. EX1003, ¶110.

## 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:  
 $0 < (R13 - R14) / (R13 + R14) < 1.5$ .

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. EX1003, ¶111.

However, as discussed *supra* Sections VIII.B and VIII.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. Fukaya thus renders this claim obvious. EX1003, ¶112.

## 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:  
 $0.20 < \sum AT / ImgH < 0.60$ .

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<br>in mm                                        |                       |                       |                        |                   |
|---------------------------------------------------------------------|-----------------------|-----------------------|------------------------|-------------------|
| $f = 4.06$<br>$Fno = 1.64$<br>$\omega(deg) = 35.49$<br>$ih = 2.934$ |                       |                       |                        |                   |
| Surface Data                                                        |                       |                       |                        |                   |
| Surface No. i                                                       | Curvature<br>Radius r | Surface<br>Distance d | Refractive<br>Index Nd | Abbe Number<br>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 range. This ratio remains unchanged after modification. EX1003, ¶113.

**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:  
 $0.80 < TL/f < 1.80$ .

**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]; EX1003, ¶114.

**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  $TL/f=1.269$ , satisfying the condition:

| Numerical Example 1<br>in mm                                                |                       |                       |                        |                   |
|-----------------------------------------------------------------------------|-----------------------|-----------------------|------------------------|-------------------|
| $f = 4.06$<br>$F\# = 1.64$<br>$\omega(\text{deg}) = 35.49$<br>$i_h = 2.934$ |                       |                       |                        |                   |
| Surface Data                                                                |                       |                       |                        |                   |
| Surface No. i                                                               | Curvature<br>Radius r | Surface<br>Distance d | Refractive<br>Index Nd | Abbe Number<br>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             |
| 6*                                                                          | -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. EX1003, ¶115.

## 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:  
 $1.640 \leq N_{\max} < 1.750$ .

Fukaya discloses a maximum refractive index  $N_{\max}$  of 1.635 for two of the lens elements of Embodiment 1, just outside the claimed range. EX1004, [0125]. However, lens materials with a higher refractive index within the claimed range were

known to POSITAs and used in similar devices. *E.g.*, EX1005, [0176] (disclosing  $N_{\max}=1.640$ ), [0292] (disclosing  $N_{\max}=1.650$ ); EX1009, 15-16. 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. Zemax modeling confirms that the Fukaya lenses with  $N=1.635$ , when substituted with material having  $N=1.640$ , perform nearly identically. EX1003, ¶¶116-117.

## 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:  $V_2 < 26.0$ .

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); EX1003, ¶118.

### 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:

$$3.0[\text{mm}] < f < 6.5[\text{mm}].$$

Fukaya discloses a focal length  $f$  of 4.06mm, satisfying the condition:

|                              |
|------------------------------|
| $f = 4.06$                   |
| $FNO = 1.64$                 |
| $\omega(\text{deg}) = 35.49$ |
| $ih = 2.934$                 |

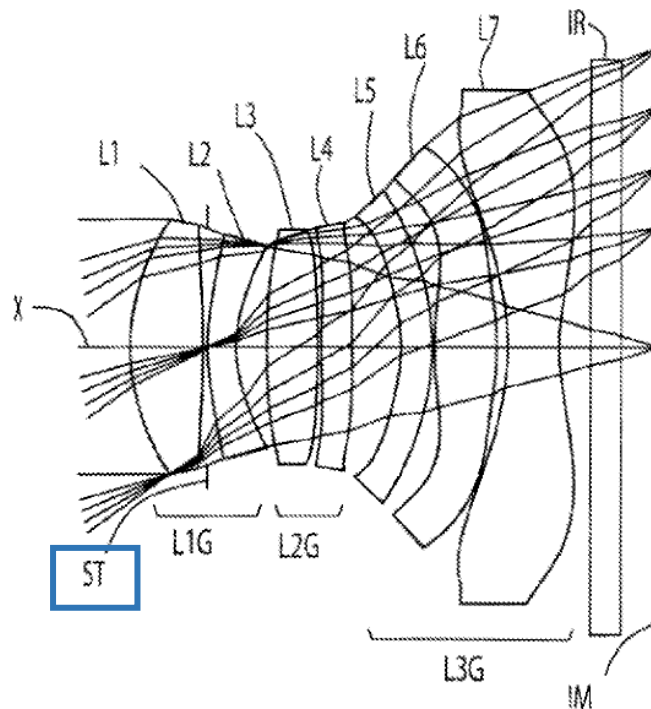
EX1004, [0125] (Table 1) (excerpted) (annotations added). The condition remains satisfied after the modification. EX1003, ¶119.

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:  
 $0.75 < SD/TD < 1.1$ .

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 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). These can be summed to determine the axial distance between any two surfaces, including the distance SD and the distance TD. Fukaya thus discloses SD=3.433mm and TD=4.184mm, so SD/TD=0.821, satisfying the condition. The stop remains in the same position after modification, so the condition remains satisfied after modification. EX1003, ¶120.

## 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  
 $15[\text{deg.}] < \text{HFOV} < 45[\text{deg.}]$ .

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 and thus an  $f$ /EPD of 1.64, satisfying the condition, and a “half angle of view” (HFOV) of 35.49 degrees, satisfying the condition:

| Numerical Example 1<br>in mm |  |
|------------------------------|--|
| $f = 4.06$                   |  |
| Fno = 1.64                   |  |
| $\omega(\text{deg}) = 35.49$ |  |
| $\text{Hf} = 2.934$          |  |

EX1004, [0125] (Table 1) (excerpted) (annotations added); *id.*, [0068], [0124]. The conditions remain satisfied after modification. EX1003, ¶121.

## 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  
 $0.5 < T23/T34 < 4.5$ .

Fukaya discloses central thickness  $CT1=0.706\text{mm}$  of the first lens L1, central thickness  $CT2=0.280\text{mm}$  of the second lens L2, axial distance  $T23=0.304\text{mm}$  between the second and third lenses, and 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, satisfying the condition. EX1003, ¶122.

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 T23/T34 condition while also achieving the objectives of Fukaya. EX1004, [0128] (T23/T34=1.9), [0134] (T23/T34=0.93), [0137] (T23/T34=2.97), [0140] (T23/T34=2.88), [0143] (T23/T34=1.59), [0146] (T23/T34=2.75), [0149] (T23/T34=3.97), [0152] (T23/T34=4.38), [0155] (T23/T34=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 found it obvious to simply substitute the known elements with predictable results. EX1003, ¶123.

**17. Claim 18**

**a) Element 18.1**

[18.1] An image capturing unit, comprising:

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.” EX1003, ¶124.

**b) Element 18.2**

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

Fukaya renders the photographing optical lens assembly of claim 1 obvious. *Supra* Section VIII.C.1; EX1003, ¶125.

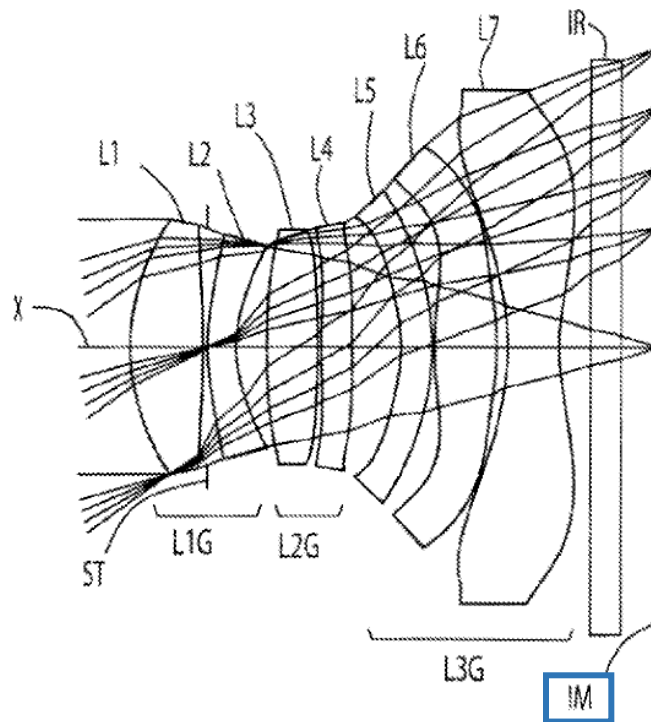
**c) Element 18.3**

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

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). 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). EX1003, ¶126.

**18. Claim 19**

**a) Element 19.1**

[19.1] An electronic device, comprising:

Fukaya discloses “imaging lenses which are built in image pickup devices mounted in mobile terminals such as smart phones and mobile phones, ... 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. EX1003, ¶127.

**b) Element 19.2**

[19.2] the image capturing unit of claim 18.

Fukaya renders obvious the image capturing unit of claim 18. *Supra* Section VIII.C.18; EX1003, ¶128.

**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;

Fukaya discloses these elements. *Supra* Sections VIII.C.1.a)-VIII.C.1.f), VIII.C.4; EX1003, ¶129.

**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

Fukaya renders this obvious. *Supra* Sections VIII.B, VIII.C.1.g). Fukaya discloses a sixth lens L6 with aspheric surfaces and at least one inflection point on the image-side surface. *Supra* Section VIII.C.1.g). 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* Section VIII.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. The sixth lens L6 of the modified Fukaya imaging lens maintains positive refractive power. EX1003, ¶130.

**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,

Fukaya discloses these elements. *Supra* Sections VIII.C.1.h), VIII.C.1.i); EX1003, ¶131.

**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:

$0.1 < Y_{c72}/f < 0.9$ ;  
 $|f_1/f_2| < 2.0$ ; and  
 $TL/ImgH < 2.20$ .

Fukaya discloses a non-axial critical point on the image-side surface of the seventh lens L7 satisfying the  $Y_{c72}/f$  condition. *Supra* Section VIII.C.1.j). Fukaya discloses a maximum image height  $i_h$  ( $ImgH$ ) of 2.934mm, and a track length ( $TL$ ) of 5.151mm. *Supra* Sections VIII.C.9, VIII.C.10. Fukaya thus discloses  $TL/ImgH=1.756$ , satisfying the condition. EX1003, ¶132.

Fukaya 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  $|f_1/f_2|=0.659$ , satisfying the condition:

| 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 modification. EX1003, ¶133.

## 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.

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 modification. EX1003, ¶134.

## 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.

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<br>Radius r | Surface<br>Distance d | Refractive<br>Index Nd | Abbe Number<br>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. EX1003, ¶135.

## 22. Claim 23

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

Fukaya discloses this. *Supra* Section VIII.C.1.f); EX1003, ¶136.

## 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.

Fukaya discloses this. *Supra* Section VIII.C.1.f); EX1003, ¶137.

**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  $R_{12}$ , and the following condition is satisfied:  
 $0 < f/R_{12} < 3.0$ .

Fukaya renders this claim obvious. *Supra* Section VIII.C.6; EX1003, ¶138.

**25. Claim 26**

26. The photographing optical lens assembly of claim 20, wherein 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:  
 $|f_1| < |f_i|$ , wherein  $i=2, 3, 4, 5, 6, 7$ .

Fukaya discloses a focal length  $f_1$  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 (*see supra* Section VIII.B), because increasing their focal lengths decreases their refractive power accordingly, thereby allowing the sixth and seventh lenses to primarily affect off-axis performance. Further, a POSITA would have expected the focal length of the sixth and seventh lenses to naturally increase because

they understood that the double meniscus-gullwing lens configuration enables weaker lenses. *E.g.*, EX1026, 7:61-67. Implementing the sixth and seventh lenses as a meniscus-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 condition. EX1003, ¶139.

**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:  
 $-2.0 < (R11 - R12) / (R11 + R12) < 0.2$ .

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 VIII.B and VIII.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 are  $R_{11}=3.067\text{mm}$ ,  $R_{12}=10.000\text{mm}$ , so  $(R_{11}-R_{12})/(R_{11}+R_{12})=-0.531$ , satisfying the condition:

|    | 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      |

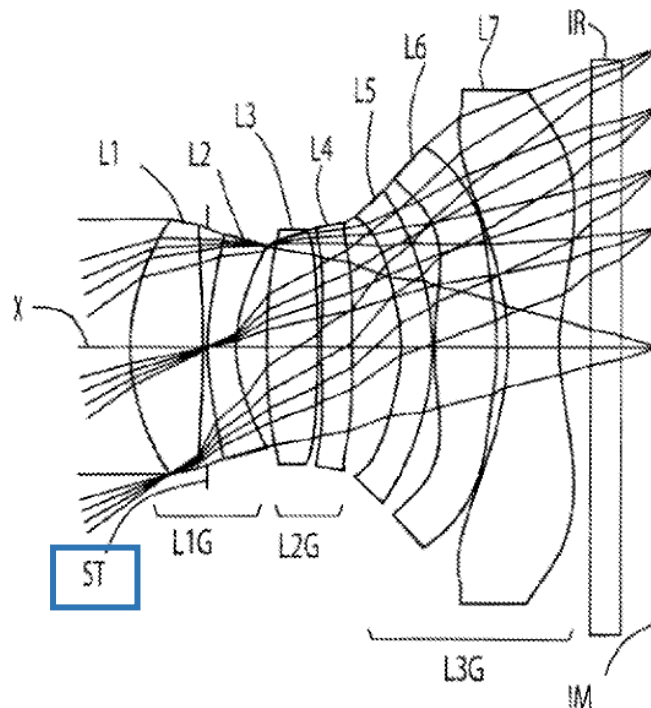
EX1003, ¶140.

## 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.

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); EX1003, ¶141.

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:

$$-0.5 < f/f_3 < 0.6.$$

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. EX1003, ¶142.

## 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:  
 $0 < (T_{12}/T_{23}) + (T_{34}/T_{45}) + (T_{56}/T_{67}) < 3.8.$

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  $(T_{12}/T_{23}) + (T_{34}/T_{45}) + (T_{56}/T_{67}) = 1.219$ , 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). This condition remains satisfied after modification. EX1003, ¶143.

**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  
 $-1.0 < f/R6 < 2.5$ .

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. EX1003, ¶144.

## IX. **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**

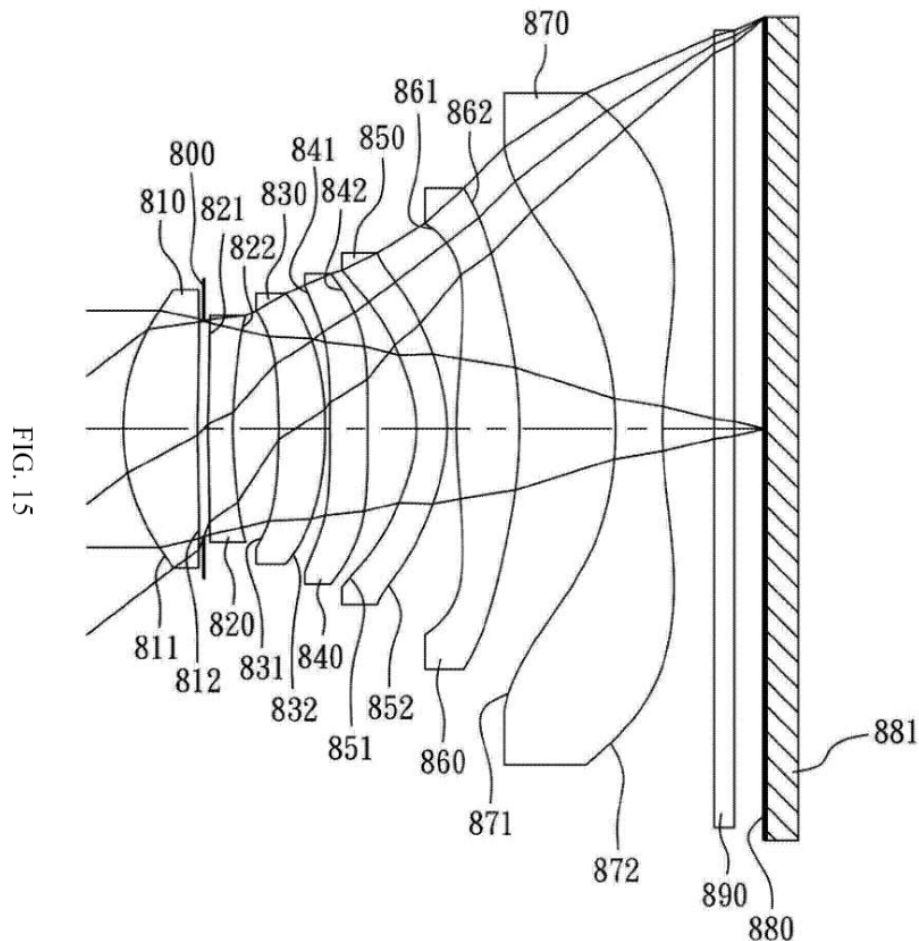
As explained below, claims 1-4, 7, 9-13, 15-16, 18-21, 23-24, and 28-31 are obvious over Cai in view of the knowledge of a POSITA. EX1003, ¶145.

### A. **Cai (EX1005)**

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; EX1003, ¶146.

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. EX1003, ¶147.

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 all challenged claims obvious. EX1003, ¶148.

**B. A POSITA Would Have  
Implemented Cai With A Gullwing Sixth Lens**

As discussed below and herein, a POSITA would have been motivated, with a reasonable expectation of success, to implement Cai with two gullwing lenses. 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 improves aberration correction and control of the chief ray angle. *Supra* Section IV.B.3; EX1003, ¶149. So implemented, Cai discloses all elements of the challenged claims. *Infra* Section IX.C.

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, 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. EX1003, ¶150.

As discussed *supra* Sections IV.B.2-IV.B.3, through rapid 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. EX1003, ¶151.

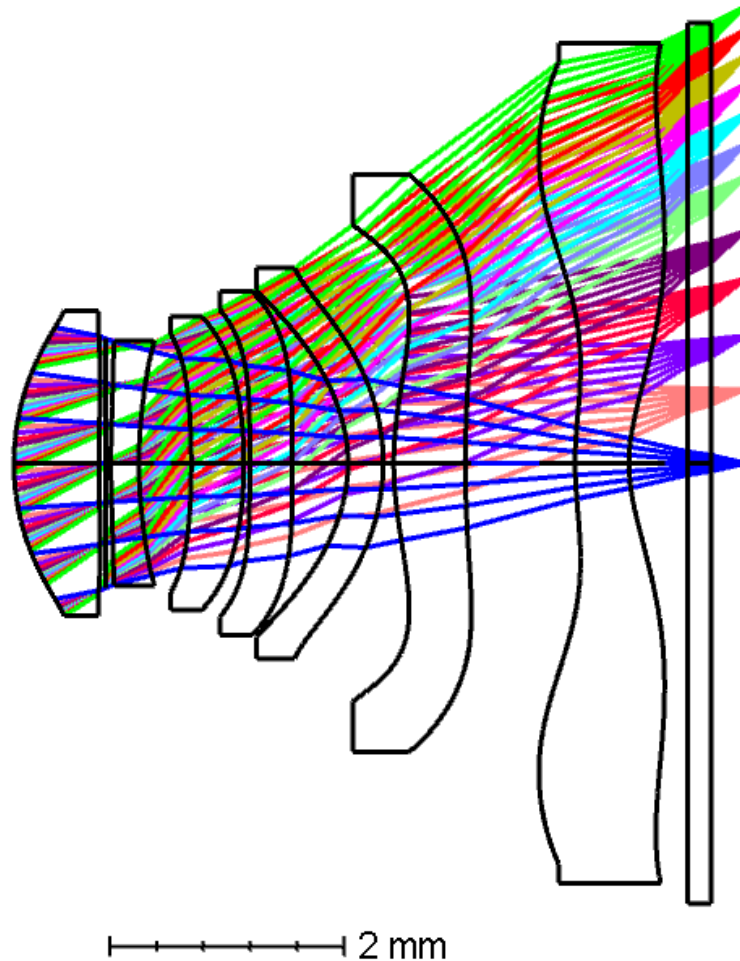
A POSITA thus would have been motivated to implement Cai with a sixth lens with a gullwing image-side surface in order to achieve a meniscus-gullwing lens pair that enables improved off-axis aberration correction, compact length, and improved control of chief ray angle. To do so, a POSITA would have 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. *Compare* EX1005, [0292] ( $f_6=4.50\text{mm}$ ), *with id.*, [0176] ( $f_6=1.92\text{mm}$ ), [0242] ( $f_6=2.53\text{mm}$ ). 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 similarly varying the object-side curvature of the seventh lens from concave to convex to balance the change to the image-side surface of the sixth lens, 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. EX1003, ¶¶152-153.

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. *Supra* Section IV.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) and its benefits were well-understood, as reflected by prior art designs with this configuration. *Supra* Section IV.B.3; EX1003, ¶154.

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. 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:



EX1003, ¶¶155-157 (explaining the process of optimizing Cai). This modified Cai design satisfies the challenged claims. *Infra* Section IX.C.

Thus, a POSITA would have found it obvious to use the known technique of meniscus-gullwing lens pairs in a seven-lens system to predictably improve the Cai lens system. EX1003, ¶158.

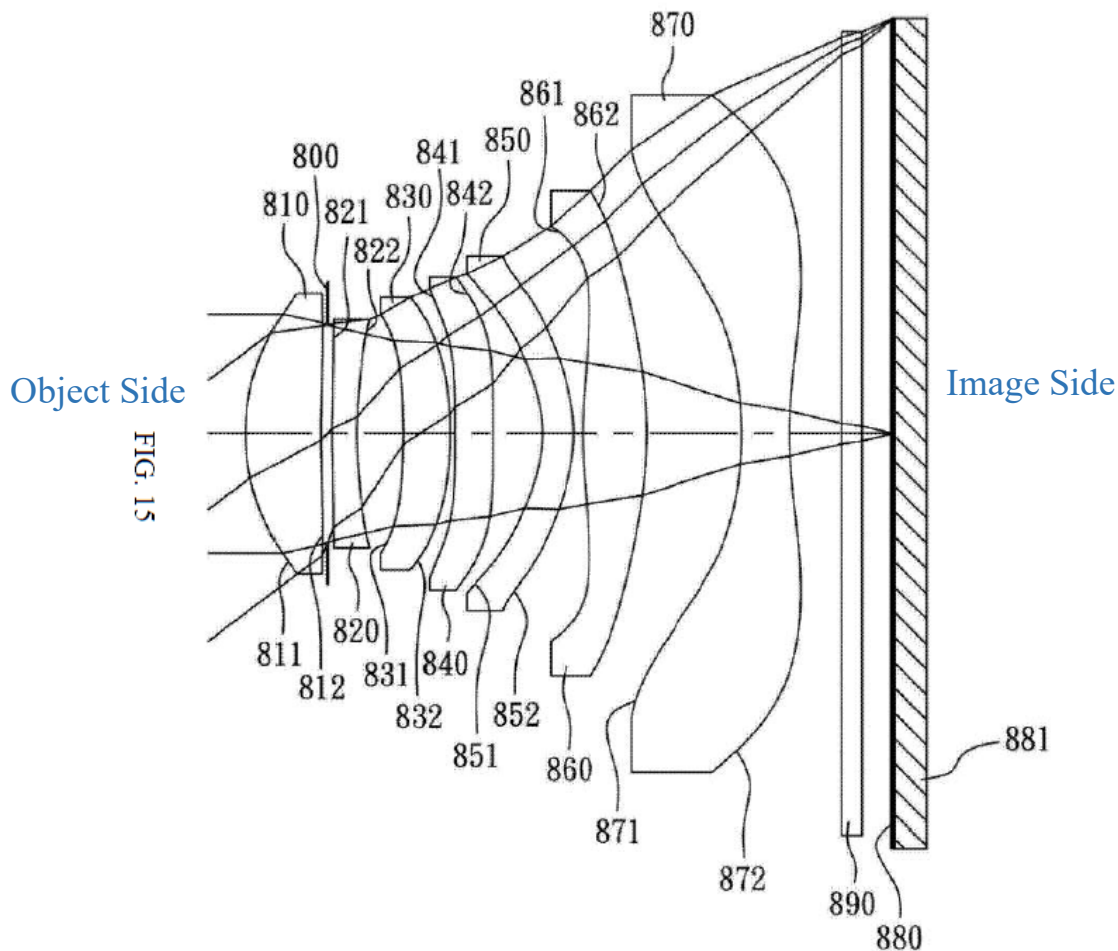
C. **Claim Mapping**

1. **Claim 1**

Cai discloses or renders obvious each element of the claim. EX1003, ¶159.

a) **Element 1.1**

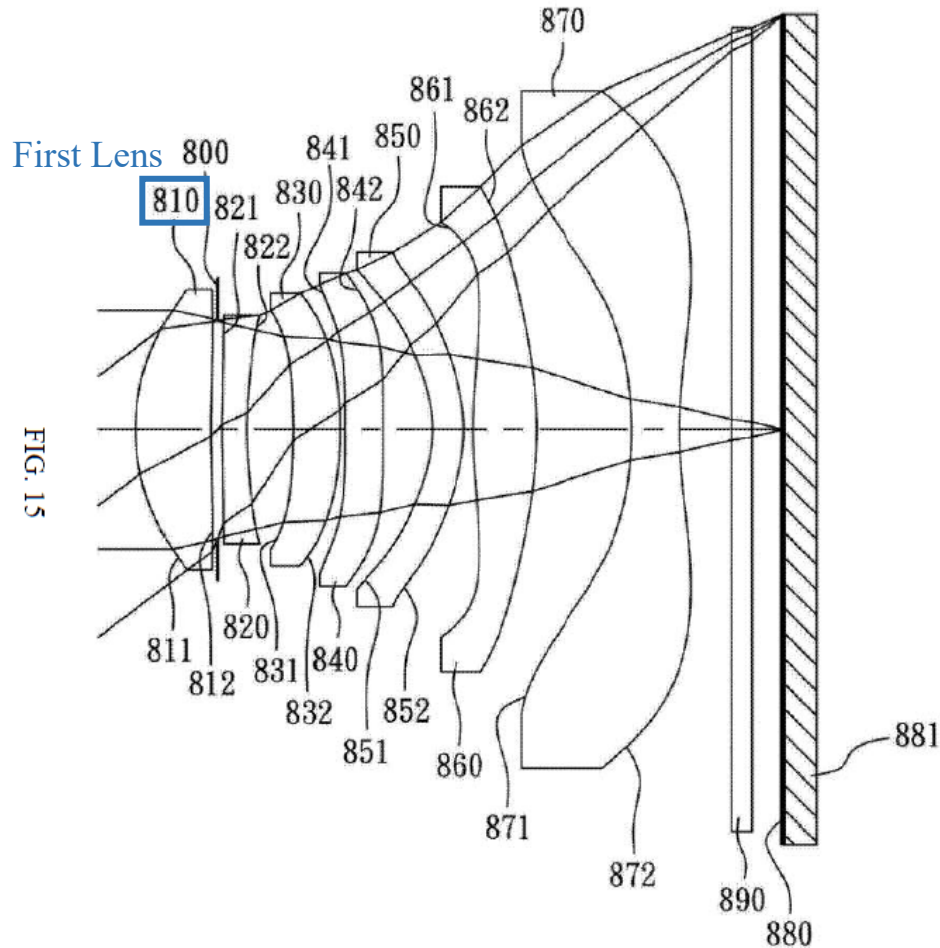
Cai discloses “[a]n optical image capturing system set in order from an object side to an image side.” EX1005, [0124]; *id.*, [0149], [0006], [0031], [0282].



EX1005, FIG. 15 (annotations added). A POSITA would understand an “optical image capturing system” is a “photographing optical lens assembly.” EX1003, ¶160.

**b) Element 1.2**

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:



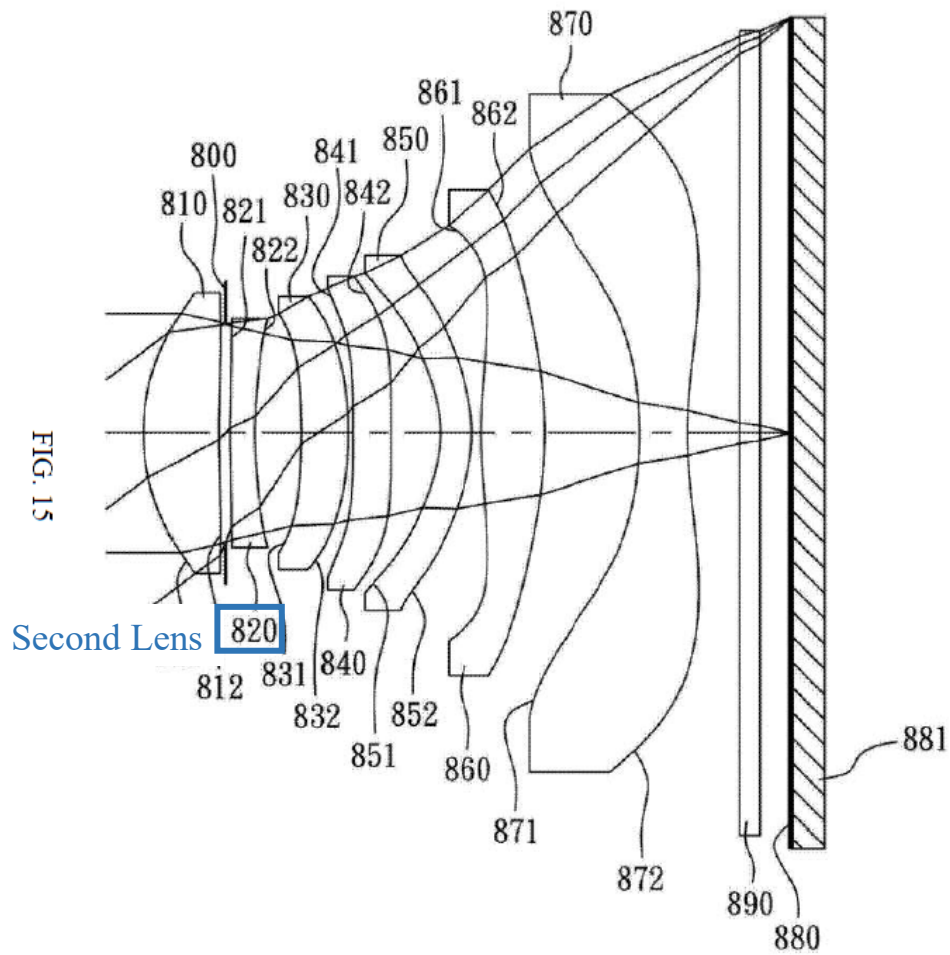
EX1005, FIG. 15 (annotations added). Table 15 discloses a positive focal length, and thus positive refractive power, for the first lens 810:

| 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). EX1003, ¶161.

**c) Element 1.3**

Cai discloses a “second lens 820 with negative refractive power.” EX1005, [0284]. FIG. 15 depicts the second lens 820:



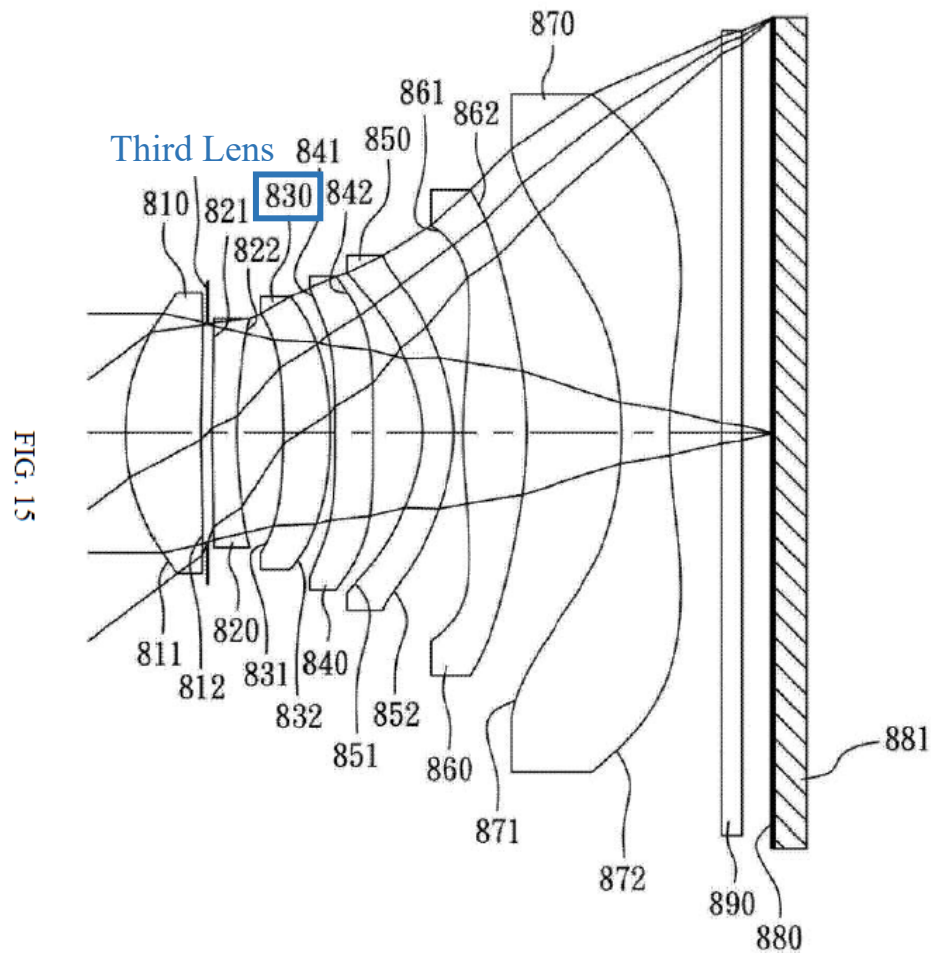
EX1005, FIG. 15 (annotations added). Table 15 discloses a negative focal length, and thus negative refractive power, for the second lens 820:

| 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). EX1003, ¶162.

**d) Element 1.4**

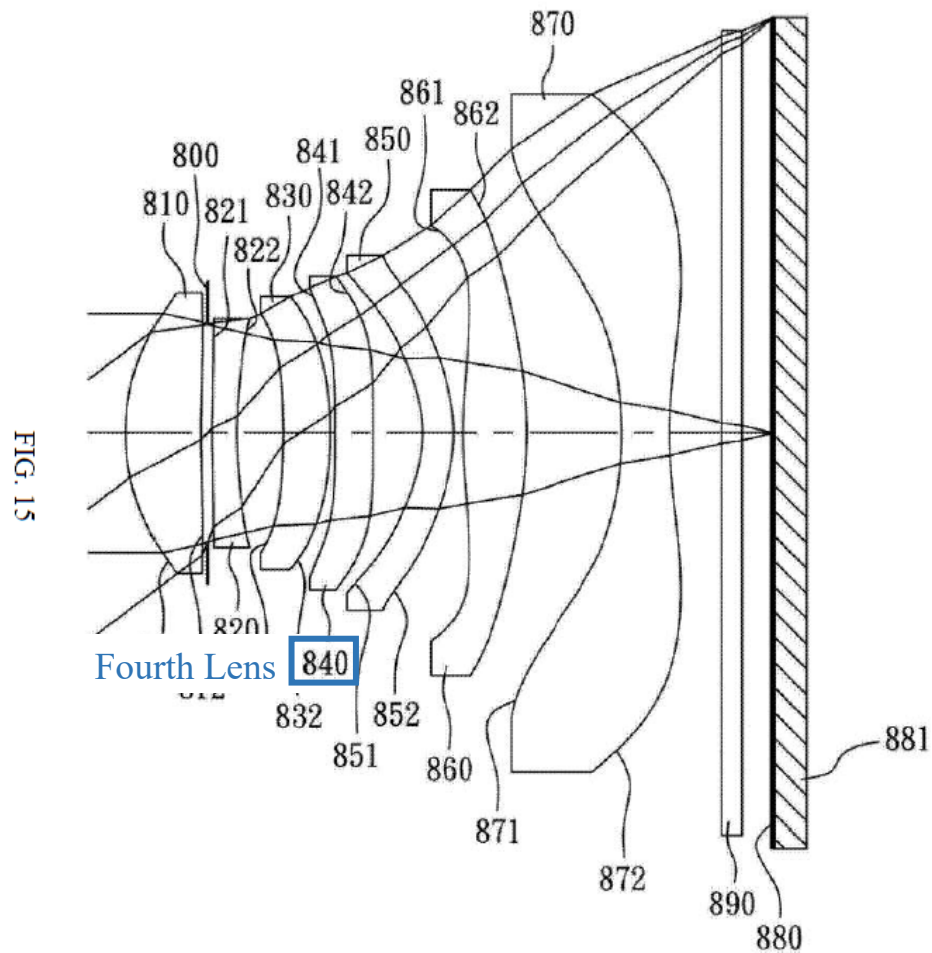
Cai discloses a “third lens 830.” EX1005, [0285]. FIG. 15 depicts the third lens 830:



EX1005, FIG. 15 (annotations added). EX1003, ¶163.

e) **Element 1.5**

Cai discloses a “fourth lens 840 with positive refractive power.” EX1005, [0286]. FIG. 15 depicts the fourth lens 840:



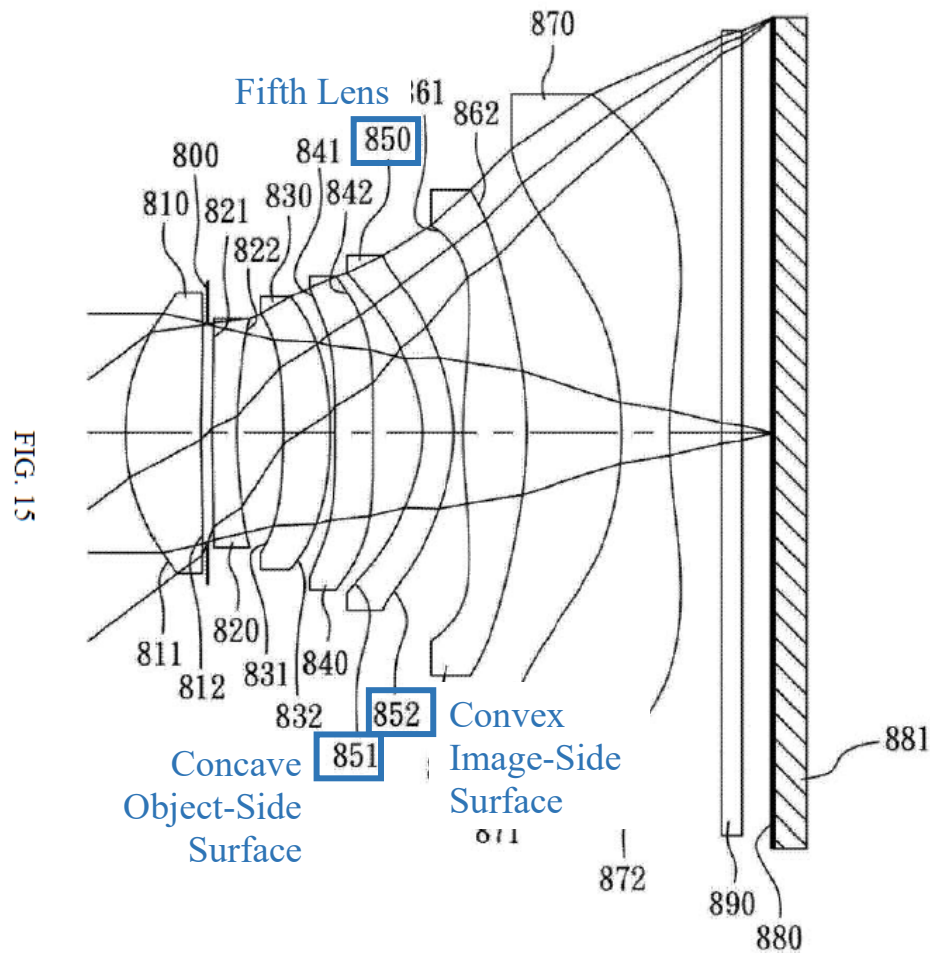
EX1005, FIG. 15 (annotations added). Table 15 discloses a positive focal length, and thus positive refractive power, for the fourth lens 840:

| 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). EX1003, ¶164.

**f) Element 1.6**

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:



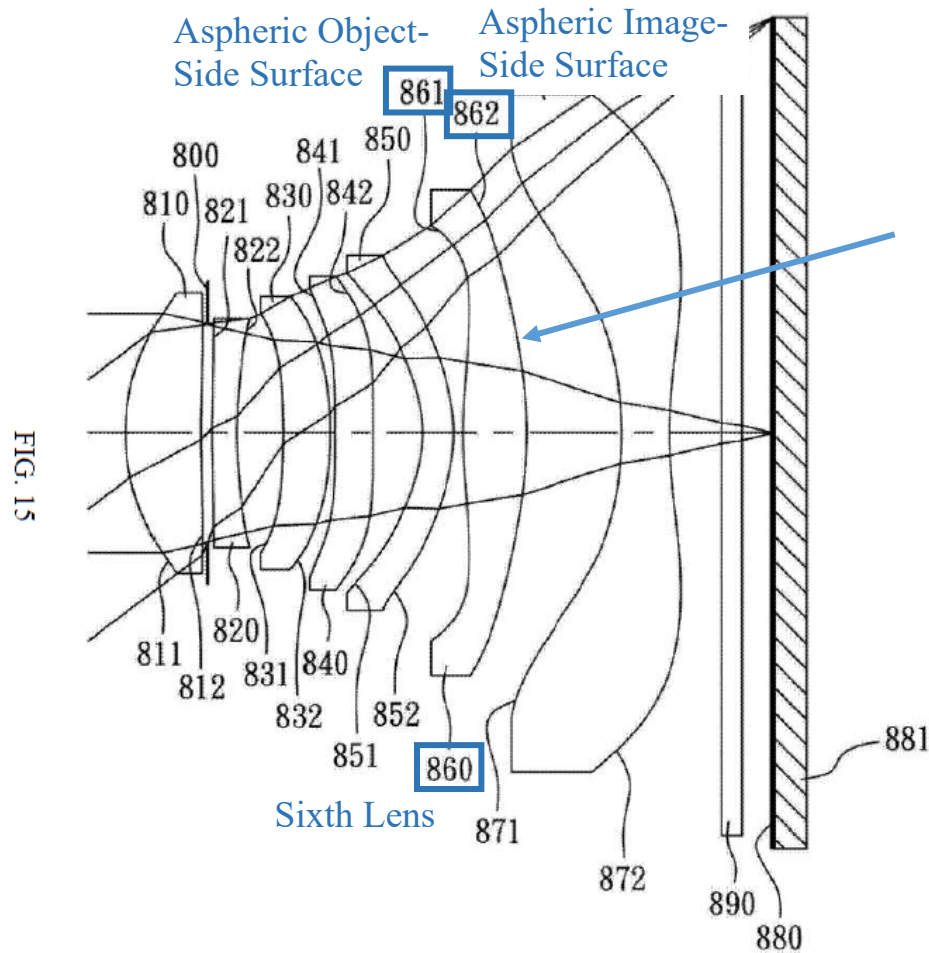
EX1005, FIG. 15 (annotations added). Table 15 discloses a negative focal length for the fifth lens 150, confirming a negative refractive power, as well as negative curvature radius for the object-side surface (Surface 10) and negative curvature radius for the image-side surface (Surface 11), confirming 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). EX1003, ¶165.

**g) Element 1.7**

Cai discloses a “sixth lens 860” where the object-side and image-side surfaces “both are aspheric.” EX1005, [0288], [0292]. FIG. 15 depicts the sixth lens 860 with aspheric surfaces:



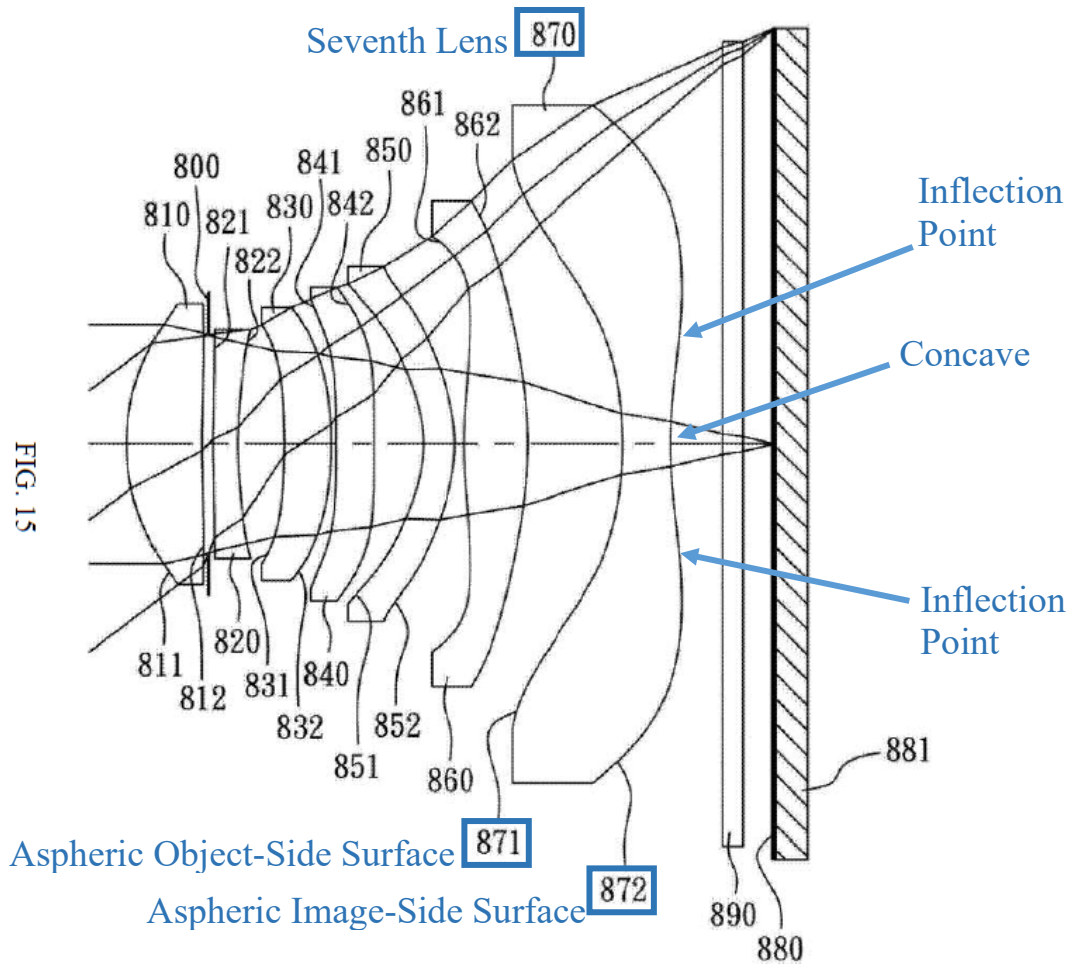
EX1005, FIG. 15 (annotations added).

Regarding the image-side surface having an inflection point and being concave in a paraxial region thereof, Cai discloses a highly aspheric surface for the sixth lens 860, with a convex curvature radius. EX1005, [0288], [0292]-[0293], [0158]-[0165] (aspheric equation), FIG. 15. As explained *supra* Section IX.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 and includes at least one inflection point 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. EX1003, ¶¶166-167.

**h) Element 1.8**

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). EX1003, ¶168.

**i) Element 1.9**

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], FIG. 15. EX1003, ¶169.

j) **Element 1.10**

**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  $Y_{c72}/f = 0.30$ , satisfying the condition. 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:

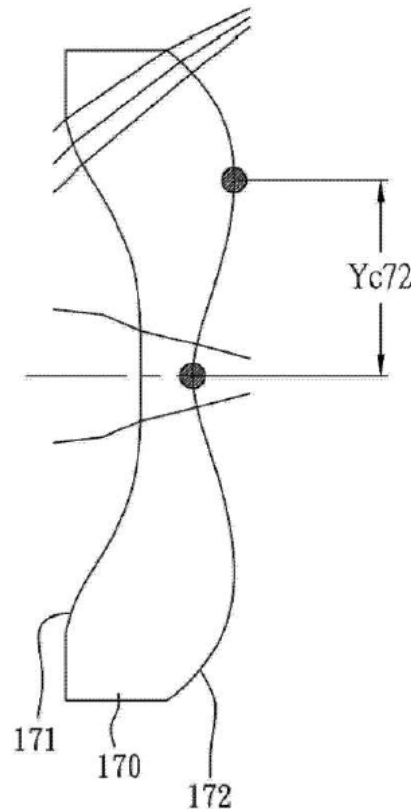
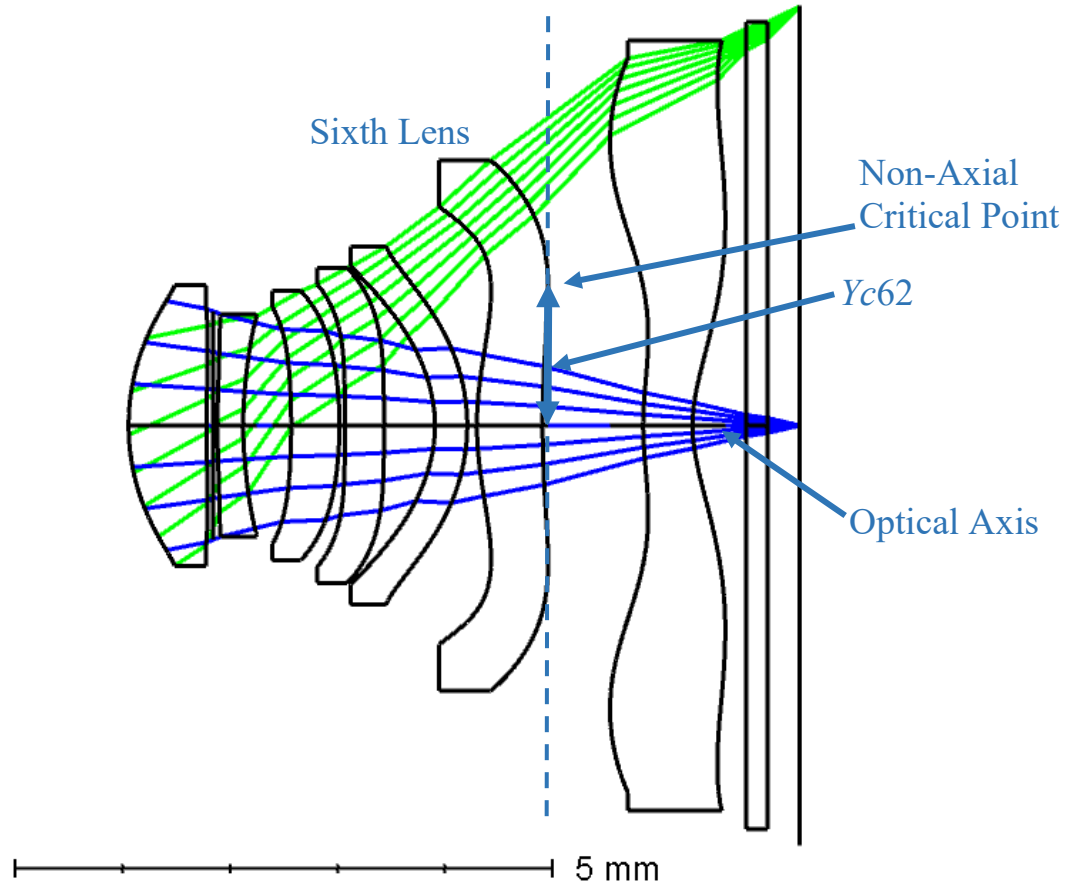


FIG. 22

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). EX1003, ¶170.

**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 IX.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. EX1003, ¶171.

**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. EX1003, ¶172.

## 2. Claim 2

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. EX1003, ¶173.

### 3. Claim 3

Cai discloses the seventh lens 870 with “a concave object-side surface 871.”

EX1005, [0289]. As discussed *supra* Section IX.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, because 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, and reduced axial aberrations arising from that change to the sixth lens. 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       | -         |             |

EX1003, ¶174.

#### 4. Claim 4

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 third lens remains positive after modification. EX1003, ¶175.

## 5. Claim 7

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 seventh lens remains negative after modification. EX1003, ¶176.

## 6. Claim 9

Cai discloses “a half of the diagonal length of the effective sensing area of the image sensing element is  $\text{ImgH}$ , and a distance between the object-side surface of the first lens and the image plane is  $\text{TTL}$ .” 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  $\Sigma\text{AT}/\text{ImgH}=0.517$ , satisfying the claimed condition. This condition remains satisfied after modification. EX1003, ¶177.

7. **Claim 10**

**Regarding aspheric surfaces**, all lens surfaces in Cai, including those of the first through fifth lenses, are aspheric. EX1005, [0142], [0283]-[0293]; EX1003, ¶178.

**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. EX1003, ¶179.

## 8. Claim 11

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). EX1003, ¶180.

## 9. Claim 12

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). EX1003, ¶181.

## 10. Claim 13

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); EX1003, ¶182.

## 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:  
 $-0.2 < R1/R2 < 0.2$ .

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  $R1/R2=0.128596$ , satisfying the condition -  $0.2 < R1/R2 < 0.2$ :

| 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. EX1003, ¶183.

## 12. Claim 16

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

| 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. EX1003, ¶184.

**13. Claim 18**

**a) Element 18.1**

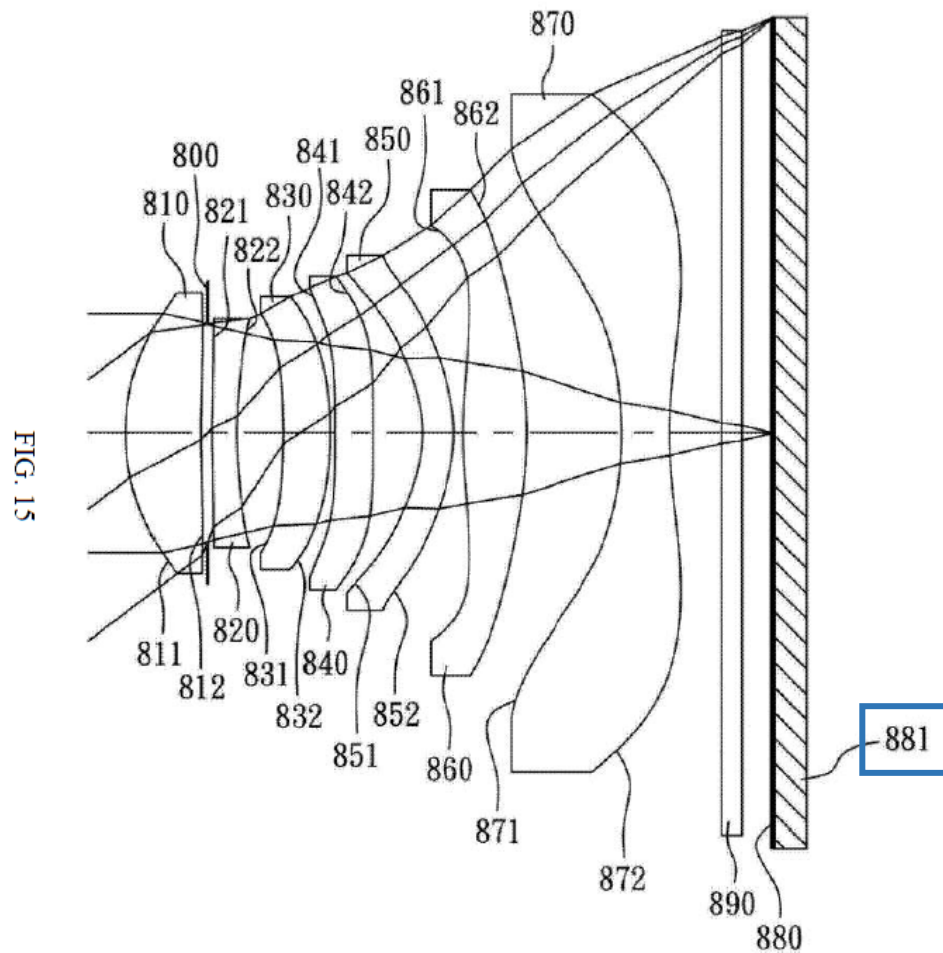
Cai discloses an “optical image capturing system” which is an image capturing unit. EX1005, [0124], [0282]; EX1003, ¶185.

**b) Element 18.2**

Cai renders the photographing optical lens assembly of claim 1 obvious. *Supra* Section IX.C.1; EX1003, ¶186.

**c) Element 18.3**

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], [0145], [0002]. FIG. 15 depicts the image sensing element 881 at the image side:



EX1005, FIG. 15 (annotations added). EX1003, ¶187.

#### 14. Claim 19

##### a) Element 19.1

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. EX1003, ¶188.

**b) Element 19.2**

Cai renders obvious the image capturing unit of claim 18. *Supra* Section IX.C.18; EX1003, ¶189.

**15. Claim 20**

**a) Elements 20.1-20.6**

Cai discloses these elements. *Supra* Sections IX.C.1.a)-IX.C.1.f), IX.C.4, EX1003, ¶190.

**b) Element 20.7**

Cai renders this obvious. *Supra* Section IX.C.1.g). 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 IX.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. *Supra* Sections IX.B, IX.C.1.g). So implemented, the sixth lens 860 of the modified Cai system maintains positive refractive power. EX1003, ¶191.

c) **Elements 20.8-20.9**

Cai discloses these elements. *Supra* Sections IX.C.1.h), IX.C.1.i); EX1003, ¶192.

d) **Element 20.10**

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 IX.C.1.j). EX1003, ¶193.

Cai discloses a maximum image height  $ImgH=4.055mm$  and a track length  $TL=6.245mm$ . *Supra* Sections IX.C.6, IX.C.7. Cai thus discloses  $TL/ImgH=1.540$ , satisfying the condition  $TL/ImgH<2.20$ . EX1003, ¶194.

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); EX1003, ¶195.

## 16. Claim 21

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. EX1003, ¶196.

### 17. Claim 23

Cai discloses this. EX1005, [0287], [0292]; *supra* Section IX.C.1.f); EX1003, ¶197.

**18. Claim 24**

Cai discloses this. EX1005, [0287], [0292]; *supra* Section IX.C.1.f); EX1003, ¶198.

**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  $j=1, 2, 3, 4, 5, 6, 7$ .

Cai discloses focal lengths that satisfy this condition, 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. EX1003, ¶199.

## 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  $i=1, 2, 3, 4, 5, 6, 7$ .

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

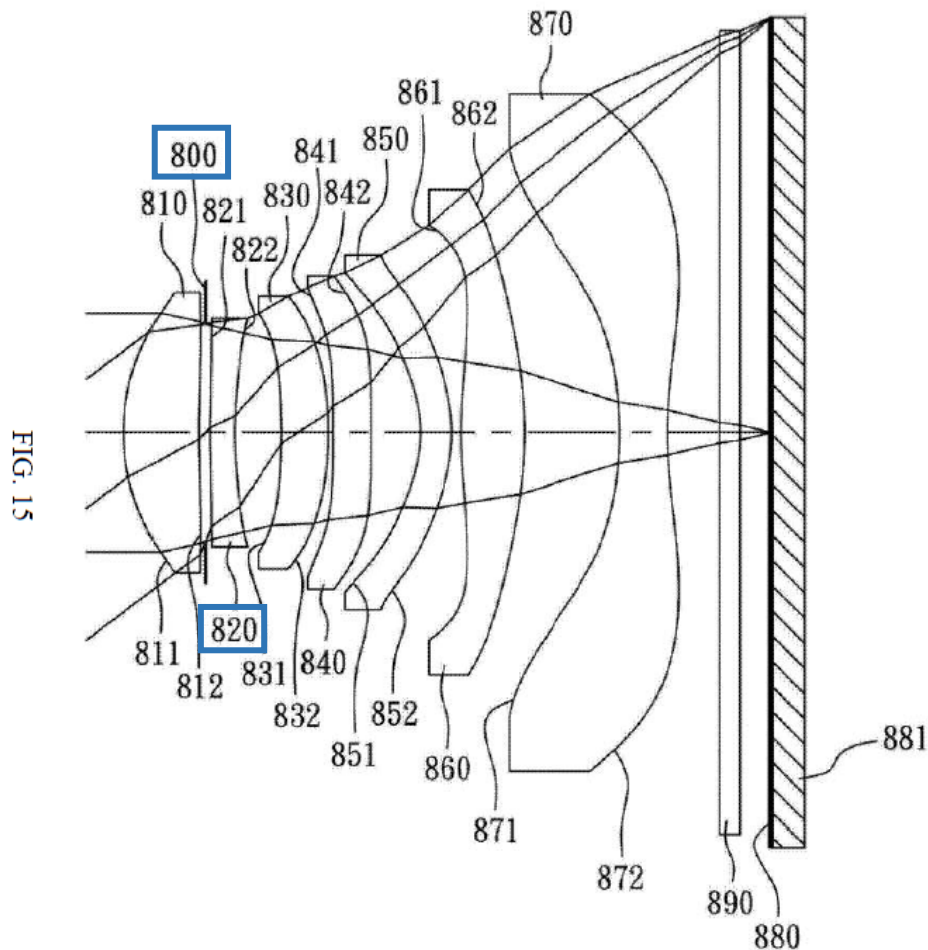
| TABLE 15: 8th Embodiment                                                                  |             |                   |           |          |       |        |              |
|-------------------------------------------------------------------------------------------|-------------|-------------------|-----------|----------|-------|--------|--------------|
| 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). A POSITA would have found it obvious, however, to implement Cai with at least three lenses having Abbe numbers satisfying the 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; EX1010, 52. A POSITA knew that, 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 IX.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 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); EX1003, ¶200.

21. Claim 30

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:

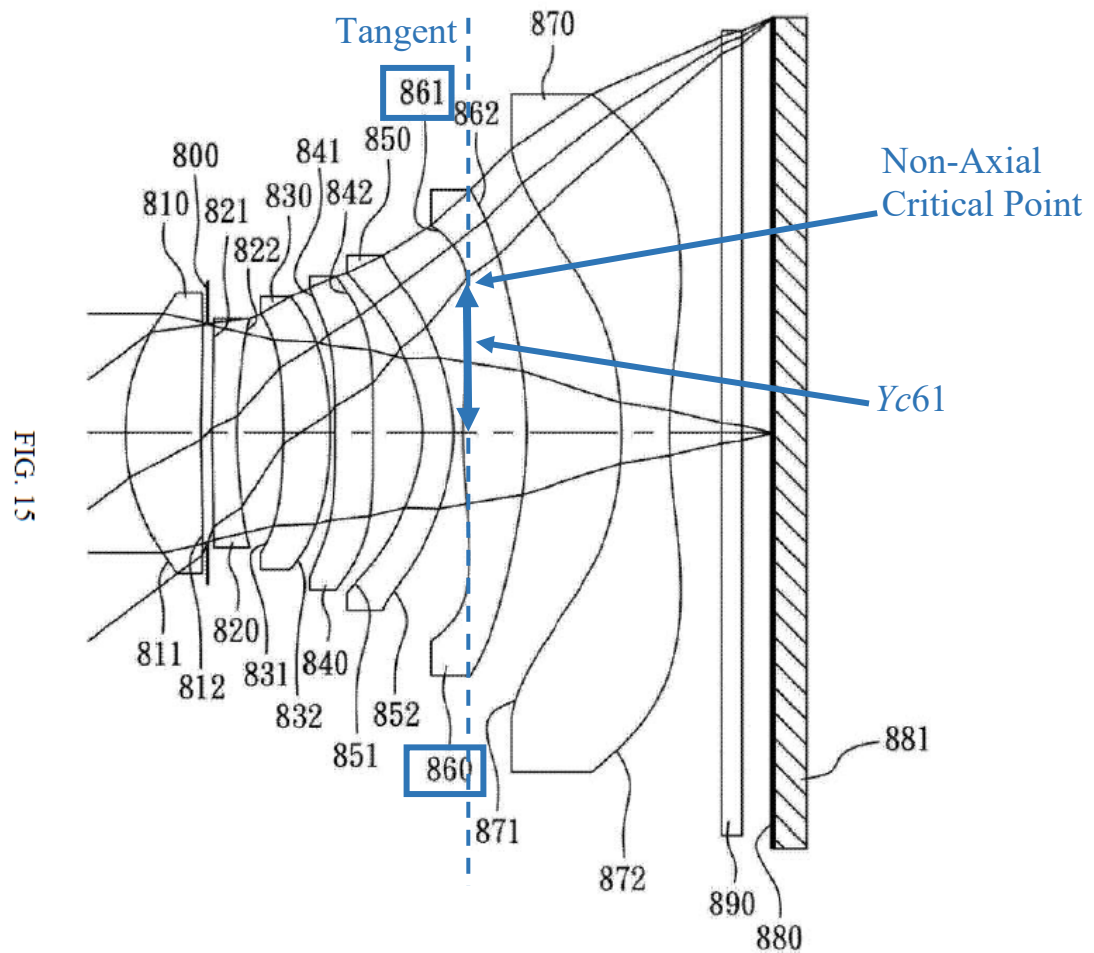


EX1005, FIG. 15 (annotations added). EX1003, ¶201.

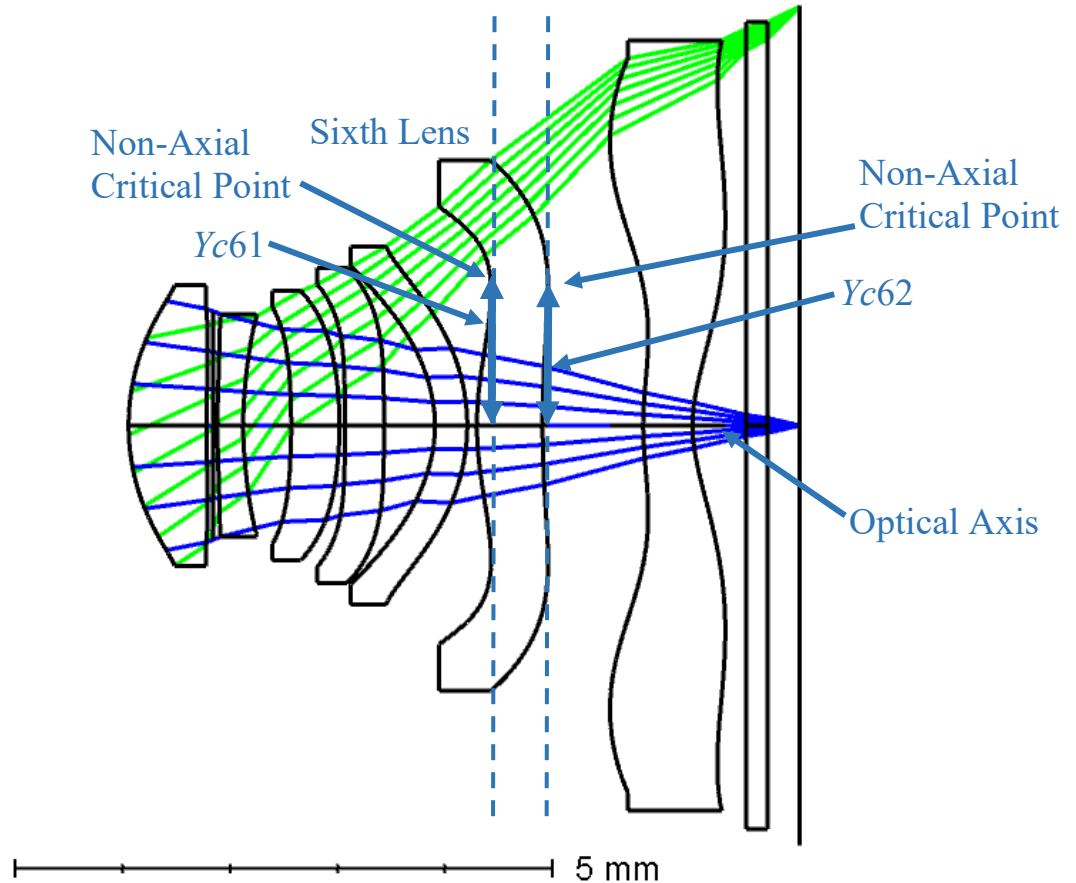
22. Claim 31

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:  
 $0.30 < Y_{c62}/Y_{c61} < 1.80$ .

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 IX.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 (with non-axial critical points) to improve off-axis performance and reduce the burden on the seventh lens:



So implemented, the vertical distance  $Y_{c61}=1.271\text{mm}$ , the vertical distance  $Y_{c62}=1.233\text{mm}$ , and  $Y_{c62}/Y_{c61}=0.970$ , satisfying the condition. EX1003, ¶202.

#### **X. NO OBJECTIVE INDICIA OF NON-OBVIOUSNESS**

There are no objective indicia of non-obviousness as to any challenged claim.

**XI. CONCLUSION**

Petitioner requests institution for claims 1-34, on Grounds 1 and 2 specified in this petition.

Respectfully submitted,

Dated: July 1, 2024

By: /Andrew M. Mason/

Andrew M. Mason (Reg. No. 64,034)

andrew.mason@klarquist.com

KLARQUIST SPARKMAN, LLP

One World Trade Center, Suite 1600

121 S.W. Salmon Street

Portland, Oregon 97204

Tel: 503-595-5300

Fax: 503-595-5301

Counsel for Petitioner

**CERTIFICATE OF COMPLIANCE WITH  
TYPE-VOLUME LIMITATION PURSUANT TO 37 C.F.R. § 42.24**

This brief complies with the type-volume limitation of 37 C.F.R. § 42.24(a)(1)(i).

The brief contains 13,649 words, excluding the parts of the brief exempted by 37 C.F.R. § 42.24(a).

The brief has been prepared in a proportionally spaced typeface using Microsoft Word for O365 in a 14-point Times New Roman font.

Dated: July 1, 2024

By: /Andrew M. Mason/  
Andrew M. Mason (Reg. No. 64,034)  
andrew.mason@klarquist.com  
KLARQUIST SPARKMAN, LLP  
One World Trade Center, Suite 1600  
121 S.W. Salmon Street  
Portland, Oregon 97204  
Tel: 503-595-5300  
Fax: 503-595-5301

Counsel for Petitioner

**CERTIFICATE OF SERVICE**  
**IN COMPLIANCE WITH 37 C.F.R. § 42.6(e)(4)**

The undersigned certifies that the **PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 9,366,845 AND EXHIBITS 1001 - 1032** were served on July 1, 2024, via **Express Mail** on the Patent Owner at the following address of record as listed on the USPTO Patent Center:

Locke Lord LLP  
Attn: IP Docketing  
PO Box 55874  
Boston, MA 02205

By: /Andrew M. Mason/  
Andrew M. Mason (Reg. No. 64,034)  
andrew.mason@klarquist.com  
KLARQUIST SPARKMAN, LLP  
One World Trade Center, Suite 1600  
121 S.W. Salmon Street  
Portland, Oregon 97204  
Tel: 503-595-5300  
Fax: 503-595-5301

Counsel for Petitioner