

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 IPR2024-00688
U.S. Patent No. 9,997,660
Issued: June 12, 2018
Application No. 15/434,163
Filed: February 16, 2017

Title: LIGHT BLOCKING SHEET, IMAGING LENS MODULE AND
ELECTRONIC APPARATUS

DECLARATION OF TOM D. MILSTER, Ph.D.

MOTOROLA MOBILITY EXHIBIT 1003

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

I. INTRODUCTION AND ENGAGEMENT

1. I have been retained as an independent expert on behalf of Motorola Mobility LLC in connection with the above-captioned Petition for Inter Partes Review (“IPR”) to provide my analyses and opinions on certain technical issues related to U.S. Patent No. 9,997,660 (hereinafter “the ’660 patent”).

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

3. Specifically, I have been asked to provide my opinions regarding whether claims 1-22 (each a “challenged claim” and collectively the “challenged claims”) of the ’660 patent would have been obvious to a person having ordinary skill in the art (“POSITA”) as of November 14, 2016. It is my opinion that each challenged claim would have been obvious to a POSITA after reviewing the prior art discussed herein.

II. BACKGROUND AND QUALIFICATIONS

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

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

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

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

7. I have written over 100 peer-reviewed papers in the field of optics. A number of these papers relate specifically to miniature optical devices and systems. My technical research has earned several recognitions and awards. For example, my 1995 paper entitled "Linear behavior of a near-field optical scanning system" was

selected as a landmark paper in near-field optics.¹ My 1997 paper entitled “Objective lens design for multiple-layer optical data storage” was selected as one of the most 300 influential papers in lens design.² A recent paper entitled “Multiple-order diffractive engineered surface lenses” has been on the Applied Optics ‘Top Downloads’ list for three consecutive months.³ Two related papers, “Design aspects of large-aperture MODE lenses” in OSA Continuum,⁴ and “High-harmonic diffractive lens color compensation” in Applied Optics⁵ were also editor’s picks and top downloads.

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

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

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

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

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

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

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

10. One significant accomplishment I have achieved through my research is breaking the “diffraction barrier” by applying the techniques of near-field

scanning optical microscopy (NSOM)⁶ (*see* Footnote 1), developing specialized near-field probes⁷, and applying the solid immersion lens (SIL) in various ways⁸⁹. This work led me to develop new, more efficient miniature optical probes and high-performance miniature optical systems.¹⁰ In these projects, my students and I applied a mixture of theory, optical design and fabrication techniques to produce real

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

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

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

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

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

examples of the miniature and micro-optical lenses that we envisioned. One of my recent conference presentations entitled “Practical measurement of cell-phone camera focal length,” specifically addresses the properties of modern cell-phone camera lenses.¹¹

11. One of my current projects is directly related to molding optical elements. A recent paper entitled “Precision glass molding of diffractive optical elements with high surface quality” specifically addresses issues for molding small glass structures.¹² My students, staff and I developed a complete process for molding glass structures with micrometer-size structures and extremely high quality. Although not mentioned in the publication, we also worked on molding plastic lens structures. This experience relates directly to the fabrication of miniature optical components, like those under review for this case.

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

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

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

13. In addition to my research, I have served as a technical expert in both district courts and ITC patent litigation in the United States of America. In the last 10 years, I have testified in the following matters: *American Medical Systems, Inc. and Laserscope v. Laser Peripherals, LLC*, Civil Action No. 08-CV-4798, United States District Court for the District of Minnesota; *American Medical Systems, Inc. and Laserscope v. Biolitec, Inc., Biolitec AG, Biolitec SIA, Ceramoptec Industries, Inc., Ceramoptec GmbH and Andaoptec, LTD*, Civil Action No. 3:08-CV-30061-MAP, United States District Court for the District of Massachusetts, as well in an arbitration matter between Corephotonics Ltd. and Ningbo Sunny Opotech Co., Ltd., Case No. HKIAC/A19025; *Apple vs. Corephotonics, Ltd.*, Case Nos. IPR2020-00878, IPR2020-00896, and IPR2020-00897; *Motorola Mobility LLC v. Largan Precision Co., Ltd.*, IPR Nos. IPR2022-01023, IPR2022-01022, IPR2022-01156, IPR2022-01170, and IPR2022-01172.

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

**III. MATERIALS CONSIDERED AND
INFORMATION RELIED UPON REGARDING '660 PATENT**

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

LIST OF EXHIBITS

No.	Description
1001	U.S. Patent No. 9,997,660 (“ the '660 Patent ”)
1002	File History of U.S. Patent No. 9,997,660
1003	N/A
1004	Certified Translation and Original Copy of Chinese Patent Application Publication No. CN 104460182 A (“ CN182 ”)
1005	Certified Translation and Original Copy of Chinese Patent Application Publication No. CN 101634738A (“ CN738 ”)
1006	U.S. Patent Application No. 2015/0022896 (“ Cho ”)
1007	Michael P. Schaub, <i>The Design of Plastic Optical Systems</i> (SPIE Press 2009) (excerpts) (“ Schaub ”)
1008	Robert E. Fischer et al., <i>Optical System Design</i> (SPIE Press, 2nd ed. 2008) (excerpts) (“ Fischer ”)
1009	Julie Bentley & Craig Olson, <i>Field Guide to Lens Design</i> (SPIE Press 2012) (excerpts) (“ Bentley ”)
1010	Michael Bass, <i>Handbook Of Optics, Volume II</i> (3d ed. 2010) (excerpts) (“ Handbook_Vol2 ”)
1011	Michael Bass, <i>Handbook Of Optics, Volume IV</i> (3d ed. 2010) (excerpts) (“ HandbookVol4 ”)

No.	Description
1012	U.S. Patent Application No. 2015/0015713 to Wang et al. (“ Wang ”)
1013	U.S. Patent No. 2,738,700 to Taylor (“ Taylor ”)
1014	Jean-Jacques Arnoux, <i>Star Sensor Baffle Optimization: Some Helpful Practical Design Rules</i> , Proc. SPIE 2864 (Nov. 11, 1996) (“ Arnoux ”)
1015	Certified Translation and Original Copy of Chinese Patent Grant No. CN 107045249 B (“ CN249 ”)
1016	James D. Plummer et al., <i>Silicon VLSI Technology</i> (Prentice Hall 2000) (excerpts) (“ Plummer ”)
1017	Jane Bareau & Peter P. Clark, <i>The Optics of Miniature Digital Camera Modules</i> (2006) (“ Bareau ”)
1018	U.S. Patent No. 7,457,052 to Hirata (“ Hirata ”)
1019	U.S. Patent No. 7,663,812 to Chang (“ Chang ”)
1020	U.S. Patent No. 8,570,673 to Lai et al. (“ Lai ”)
1021	U.S. Patent No. 9,128,267 to Ogino et al. (“ Ogino ”)
1022	U.S. Patent Application No. 2016/0161702 to Yang (“ Yang ”)
1023	Full Claims Listing (Claims 1-22)
1024	U.S. Patent Application No. 2006/0033010 to Jiang et al. (“ Jiang ”)
1025	U.S. Patent Application No. 2015/0103226 to Takahashi et al. (“ Takahashi ”)
1026	U.S. Patent Application No. 2013/0155495 to Wang (“ Wang-495 ”)
1027	Bernhard Braunecker et al, <i>Advanced Optics Using Aspherical Elements</i> (SPIE Press 2008) (excerpts) (“ Braunecker ”)

No.	Description
1028	Expert Report of Dr. Julie L. Bentley dated 1 June 2023 (“ Bentley Report ”)
1029	Rudolf Kingslake, <i>A History of the Photographic Lens</i> (Academic Press 1989) (excerpts) (“ Kingslake ”)
1030	John E. Greivenkamp, <i>Field Guide to Geometrical Optics</i> (SPIE Press 2004) (excerpts) (“ Greivenkamp ”)
1031	U.S. Patent No. 9,405,042 to Toshima (“ Toshima ”)
1032	PCT Publication No. WO 2005/045500 to Cahall et al. (“ Cahall ”)
1033	U.S. Patent Application No. 2009/0268299 to Furui et al. (“ Furui ”)
1034	U.S. Patent No. 6,818,287 to Ogawa et al. (“ Ogawa ”)

IV. UNDERSTANDING OF PATENT LAW

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

17. I understand that when considering the scope of the claims of a patent that the patent claim terms should generally be given the ordinary meaning that the terms would have to a person of ordinary skill in the art in question after reading the patent as of the earliest claimed priority date.

18. I understand that the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the term appears, but in the context of the entire patent, including the specification. I further

understand that the principal considerations regarding the scope and meaning of the claims are the plain language of the claim (including the surrounding claim language and context), the patent specification, and the prosecution history. I understand that while a claim is to be read in light of the specification, one must generally avoid importing limitations into the claim from the specification. I am also informed that the prosecution history can often inform the meaning of the claim by demonstrating how the inventor understood the invention and whether the inventor limited the invention in the course of prosecution, making the claim scope narrower than it would otherwise be. I applied these understandings when considering the scope and meaning of the claims of the '660 patent.

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

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

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

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

23. I further understand that certain factors may support or rebut the obviousness of a claim. I understand that such secondary considerations include,

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

24. I am not aware of any allegations by the named inventors of the '660 patent or any assignee of the '660 patent that any secondary considerations tend to rebut the obviousness of any challenged claim of the '660 patent.

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

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

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

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

V. SUMMARY OF OPINIONS

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

- a) The documents listed above;
- b) My education, knowledge, skills, and experience in the fields of optics and lens design; and
- c) The level of skill of a person having ordinary skill in the art (“POSITA”) at the time of the alleged invention of the ’660 patent, which I have assumed is November 14, 2016.

30. As I explain in further detail below, it is my professional and expert opinion that claims 1-22 of the ’660 patent are obvious over the prior art.

VI. LEVEL OF ORDINARY SKILL IN THE ART

31. I understand that in evaluating the validity of the ’660 patent claims, the content of a patent or printed publication prior art should be interpreted the way a person of ordinary skill in the art (“POSITA”) would have interpreted the prior art as of the effective filing date of the challenged patent claims. I assume that the

effective filing date is the date of the Taiwanese patent application to which the '660 patent alleges priority, namely November 14, 2016. My understanding of a POSITA, as set forth below, would not materially differ if the effective filing date were the U.S. application date of the '660 patent, namely February 16, 2017.

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

33. A person having ordinary skill in the art ("POSITA") would include someone who had, in November 2016, (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, including stray light suppression. More education, e.g., a Master's or Ph.D., would compensate for less work experience and vice versa. A POSITA would understand the fundamentals of stray light suppression. EX1008, 587:18-20 ("It is important that the designer be reasonably fluent in ... baffling and stray light control."); *id.*, 595:32-33 ("Good engineering in this area is imperative."); xiii:24-26 ("With this new second edition, other critical technologies including ... stray light suppression are now included.");

id., 167 (“[The designer] needs to be fully confident that [stray light is] understood and under control.”). A POSITA could be part of a closely collaborating team that includes a lens designer and a stray light specialist. EX1007, 120 (discussing stray light issues and noting “it is useful for the stray light analyst and the optomechanical designer (if they are not the same person) to be in close collaboration”) (parentheticals original).

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

35. Further, a POSITA would have had experience in analyzing, adjusting, and eliminating stray light in multi-lens optical systems, and would have been familiar with the specifications of both optical and non-optical elements of lens systems and their fabrication. The POSITA would have understood the fundamentals

of optical aberration theory and understood and used standard techniques for making lenses cheaper and more effective, especially for lens systems used in mobile devices. The POSITA also would have understood the fundamentals of stray light suppression and would have understood how to use techniques such as nonsequential ray tracing to analyze lens systems and identify sources of stray light, as well as how to address stray light using light traps, coatings, and other methods.

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

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

A. Publications Reflecting The Knowledge Of A POSITA

38. The knowledge of a POSITA is reflected in several known books on lens design, including Schaub (EX1007), Fischer (EX1008), Bentley (EX1009), and the Handbook of Optics (EX1010). Other well-known industry publications also reflect the knowledge of a POSITA. These books and publications, which confirm my own opinions as to the knowledge of a POSITA, are noted in the following paragraphs.

39. Schaub (EX1007) was published by SPIE in 2009, as part of the SPIE “Tutorial Texts” series (*e.g.*, EX1007, v). Schaub discusses many aspects of

designing optical systems with plastic lenses. At least due to its publication by SPIE, Schaub would have been known and readily available to a POSITA in November 2016.

40. Fischer (EX1008) published in 2008 and has been a well-known and consulted treatise on lens design. It would have been known and readily available to a POSITA in 2008 and later.

41. Bentley (EX1009) was published by SPIE in 2012 as a part of its “SPIE Field Guides” series, which are “written directly for the practicing engineer or scientist” as “a hand desk or briefcase reference that provides basic, essential information about optical principles, techniques, or phenomena.” EX1009, iii. It would have been known and readily available to a POSITA in 2012 and later.

VII. STATE OF THE ART

A. Lens Designers Have Long Used Light-Blocking Elements To Reduce Stray Light And Glare

42. Stray light and the associated glare have long been well-known problems for optical system designers. EX1008, 703 (“Stray light can be the curse of an optical system. The optical engineer may toil to optimize and build a system, only to have the performance destroyed by an unexpected glare, glint, or smear of light!”); EX1007, 118 (“Stray light is unwanted light that degrades the performance of a system.”). Accordingly, designers have long identified and addressed sources

of stray light during the lens design process, because “[i]n many cases, simple up-front design changes [can] eliminate[] the stray light problem.” EX1007, 118-119; EX1009, 3 (explaining that “a complete design process and performance evaluation includes ... stray light analysis”); *id.*, 89 (encouraging designers to “identify any design changes needed to reduce the stray light”). Sources of stray light include reflections from optical surfaces as well as non-optical surfaces, such as “any housings, baffles or sun shields, spacers, lens flanges, barrel walls or openings, and even the aperture stop of the system.” EX1007, 120; EX1009, 89 (stray light sources include “glints from mechanical structures”).

43. Both historically and in miniature camera modules, designers have reduced stray light using light-blocking elements, often referred to as light-blocking sheets, light shield sheets, shading rings, glare stops, flare stops, spacers, baffles, or vanes. *E.g.*, EX1018, 1:14-40 (describing a “light shield member” or “light shield sheet used for a lens stop” to prevent flare and ghost images); EX1019, 3:24-28 (specifying diameter of a spacer between lenses “to prevent stray light from entering into the lens group” after the spacer); EX1020, 1:10-12 (disclosing a “spacer [] disposed between the first lens and the second lens and for blocking off-axis light rays to avoid aberrations”); EX1004, [0002] (“3 to 5 pieces of shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to adjust the aperture of the light and to block other stray light”); EX1007, 118 (“an opaque

spacer ... will not allow light to pass”); EX1009, 90 (explaining that field stops, aperture stops, “Lyot or glare stops,” “baffles, vanes, and knife edges” are used to eliminate stray light by blocking light paths); EX1032, 11:29-30 & 13:6-7 (referring to a “glare stop” as a type of “baffle”); *id.*, FIG. 10; EX1007, 117 (describing use of “stray light baffles”); EX1021, 6:38-50 (describing “a flare stop for suppressing a flare component” where “the flare stop St1 is a stop that restricts rays at peripheral angles of view”); EX1006, [0004] (spacers are disposed between lens elements or between the barrel and a lens element), [0006] (outer surfaces of spacers have an “anti-reflection capability”); EX1010, 7.11:16-17 (explaining that “[o]ther authors have used the term ‘baffles,’ or ‘glare stops,’ to describe these vanes[, which] are structures put on baffles to affect the scatter characteristics of the surface”); *id.*, 7.12-7.13 (FIGURE 19, stray light is “blocked by vanes”).

44. While historically metal disks were used, as in Taylor, the use of plastic materials, such as polyethylene terephthalate (PET), for glare stops and other elements has become more common as production technology improves and the associated costs decrease. *E.g.*, EX1004, [0002]; EX1007, 3-6 (discussing advances in plastic materials and production technology that enable precision manufacturing with low costs at high volume).

45. The 2009 Schaub book illustrates an example of a stray light path that might exist in the absence of light-blocking elements:

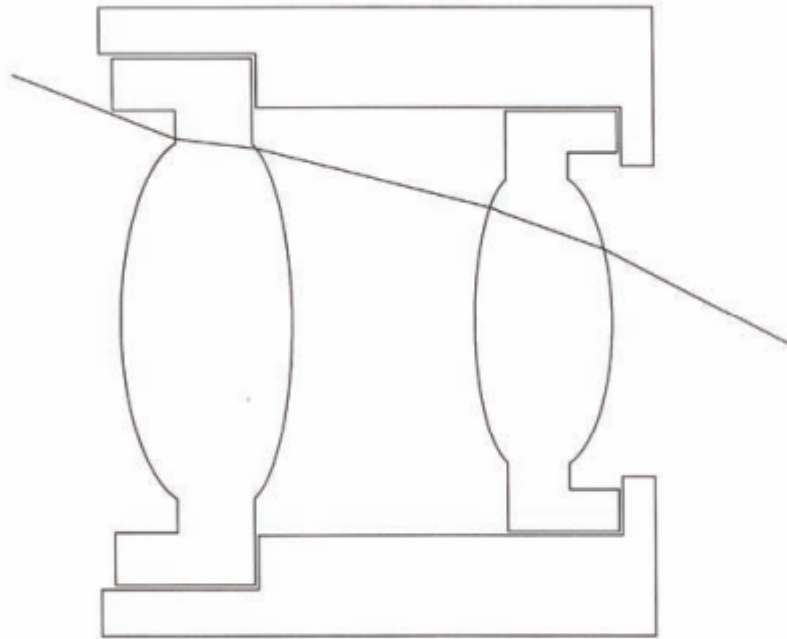
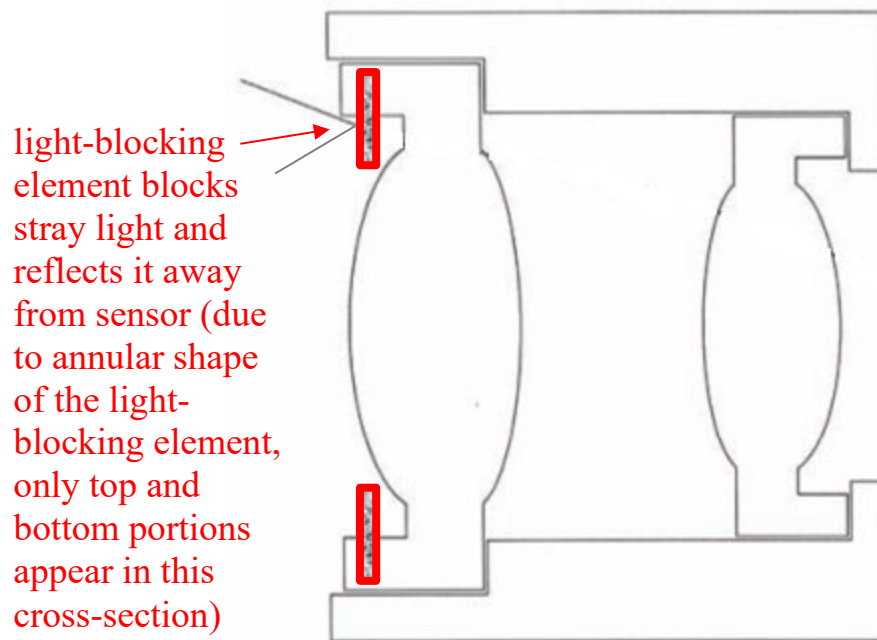


Figure 4.25 Stray-light path through lens transition zone on first element.

EX1007, 124. Schaub then explains to “place a baffle or blocking structure in front of the first element” or “[i]f a blocking structure cannot be placed in front of the element, the direct path could also be blocked behind the lens.” *Id.*, 125. The following annotated version of Schaub Figure 4.25 illustrates the described addition of a light blocking structure in front of the first element:



EX1007, 124 (Figure 4.25 with red annotations added, original stray light path modified to illustrate blocking described on Schaub page 125). A light-blocking element “may serve a dual purpose” such as a spacer that both “sets the distance between the two lenses as well as blocks the direct path.” *Id.*, 125; *id.*, 117:9-22 (describing lens assembly with lenses “along with any apertures, spacers, or stray light baffles”).

46. The ’660 patent describes these known light-blocking elements, depicting a “conventional light blocking sheet” in Figs. 1A-1B and explaining how these sheets “block unnecessary lights” and were used in “suppressing stray lights.” EX1001, 1:27-37; 1:55-61. Fig. 1A shows the “annular” or ring shape of conventional light-blocking sheets:

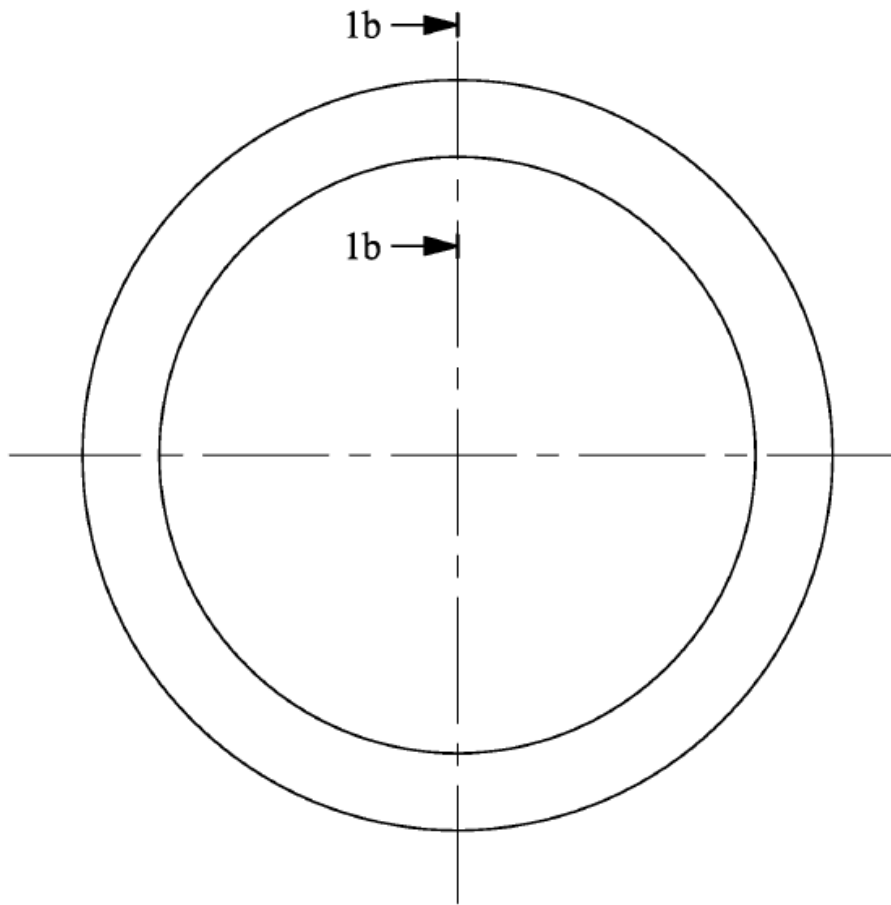


Fig. 1A (prior art)

And Fig. 1B provides a cross-sectional view, illustrating the “three-layer structure,” as shown in the following annotated copy:

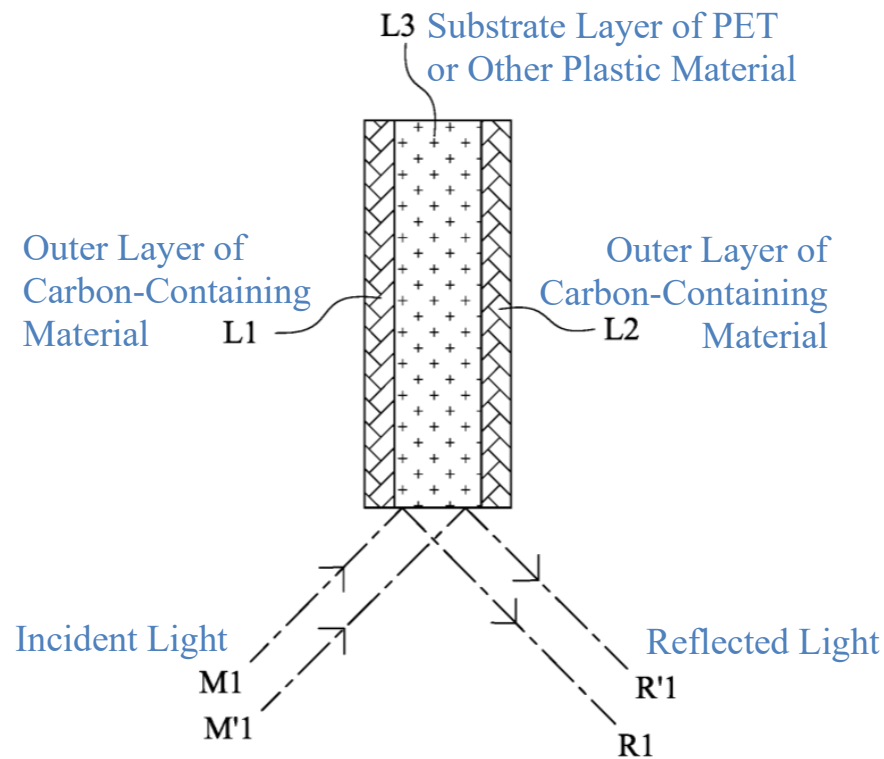
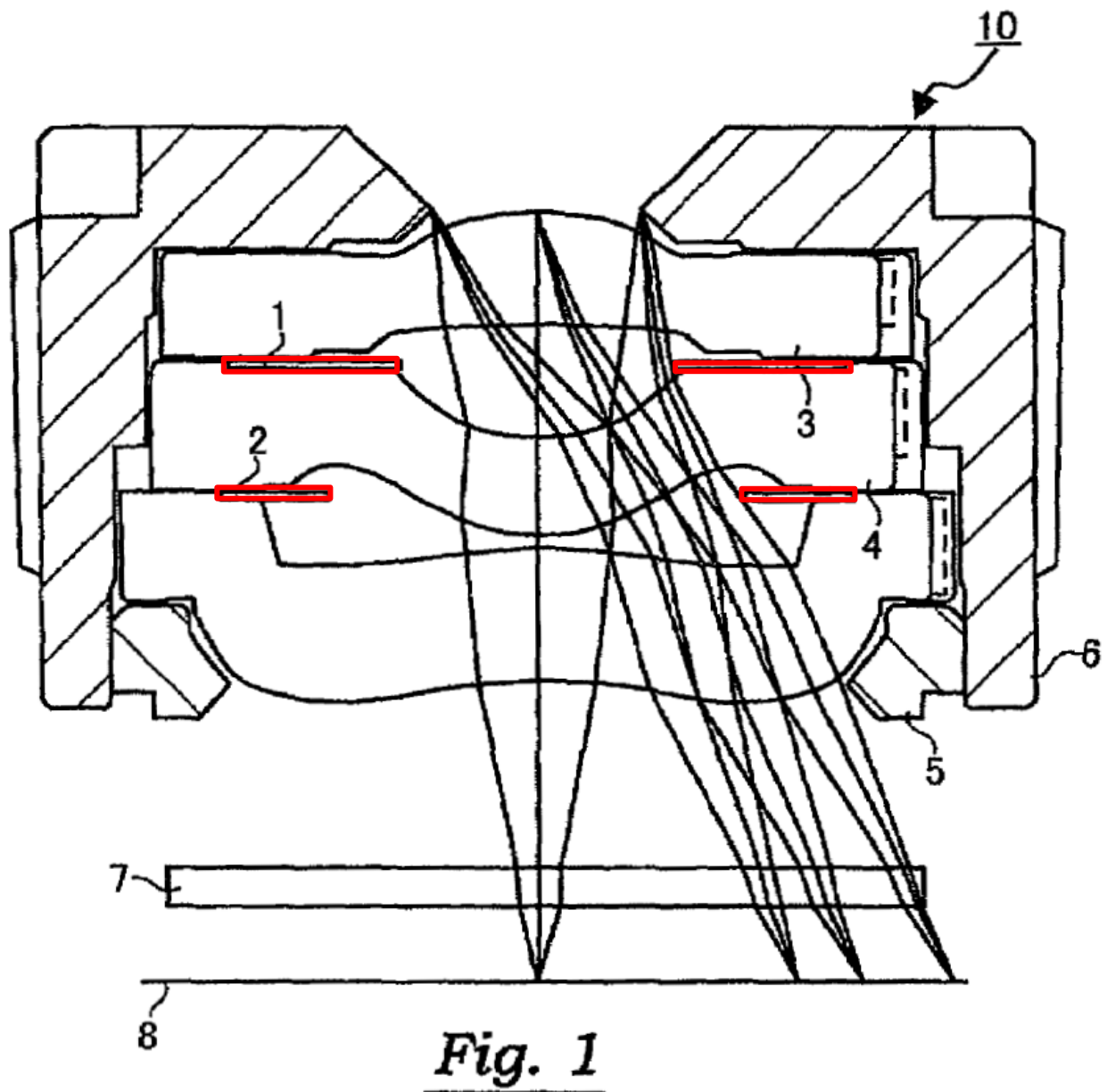


Fig. 1B (prior art)

Id., Fig. 1B (blue annotations added); *id.*, 1:55-2:14. These prior art light-blocking sheets included “a substrate layer made of a plastic material, such as a polyethylene terephthalate (PET), sandwiched by two outer layers made of a carbon-containing material.” *Id.*, 1:33-37. The carbon-containing material can “absorb lights due to its black surfaces.” *Id.*, 1:39-41.

47. A 2008 patent to Hirata (EX1008) also describes the annular shape, and PET and carbon black structure, of known light-blocking sheets (called a “light

shield sheet” in Hirata). *E.g.*, EX1018, 3:63-4:4:12 (explaining how the sheet provides a “light shielding effect and prevents light transmission that causes flare and ghost”); *id.*, Fig. 2. Hirata also illustrates how light-blocking sheets (labeled 1 and 2, and annotated in red below) were placed between lenses in the optical system, “shaped and arranged so as not to obstruct a light transmission area that is determined by the aperture stop” (i.e., light through the center of the system that properly forms the image) but “to shield unwanted light.” *Id.*, 4:35-38.

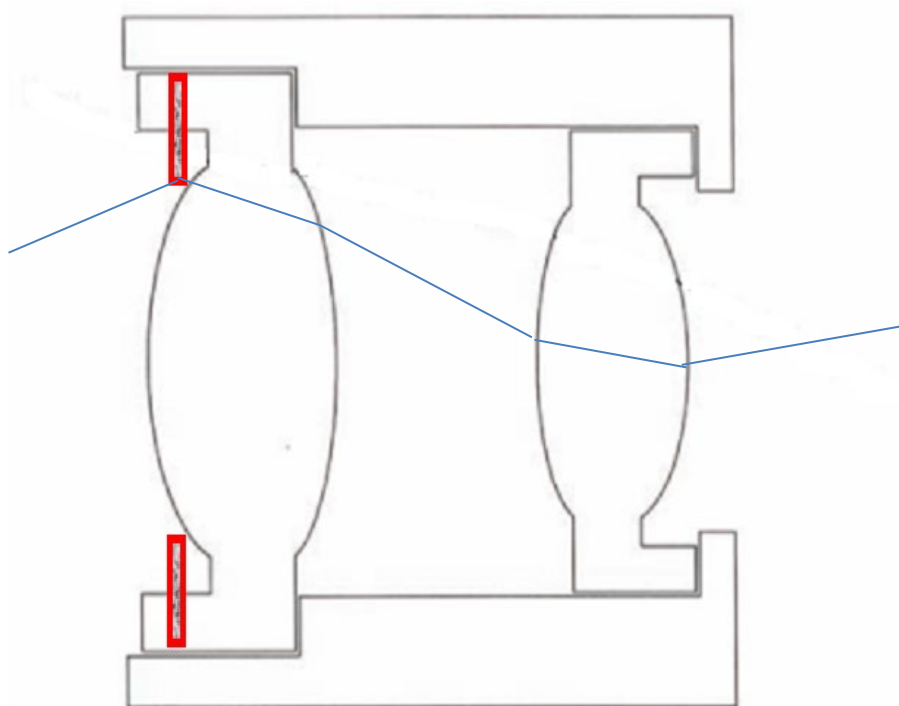


EX1018, Fig. 1 (red annotations added to highlight light-blocking elements).

B. It Was Also Known That, Ironically, Glare Arose From Stray Light Reflecting Off The Inner Edges Of Light-Blocking Elements

48. Just as lens designers have long used light-blocking elements to reduce stray light and glare in optical systems, they have also long been familiar with the ironic problem where the edge of the light-blocking element itself contributes to

glare when light bounces off that edge and through to the image plane. For example, Schaub notes the problem of stray light reflections off of light-blocking elements such as “baffles,” “spacers,” “and even the aperture stop of the system.” EX1007, 120. The following modified and annotated version of Schaub Figure 4.25 illustrates stray light bouncing off the inner edge of a light-blocking element and towards the sensor end of the system:



EX1007, 124 (Figure 4.25 with red annotations added, original gray stray light path removed and blue stray light path added page). This known phenomenon is discussed in Schaub and other lens treatises, and is also acknowledged by the 660 patent itself, which shows light bouncing off the edges of “prior art” light-blocking

elements in FIG. 1B. *See also* EX1005, Figure 5 (2008 patent application showing stray light bouncing off of inner surface of light-blocking spacer); EX1018, Figs. 3b-5 (2008 patent illustrating how stray light would bounce off of unmodified inner surface of light-blocking element, as represented by dashed lines).

49. A 1956 patent to Taylor (EX1013) describes the use of a ring-shaped light-blocking “glare stop” to “reflect stray light back through the entrance to the optical system.” EX1013, 1:32-40. It notes concerns with light reflecting off the edge or inner surface and causing glare:

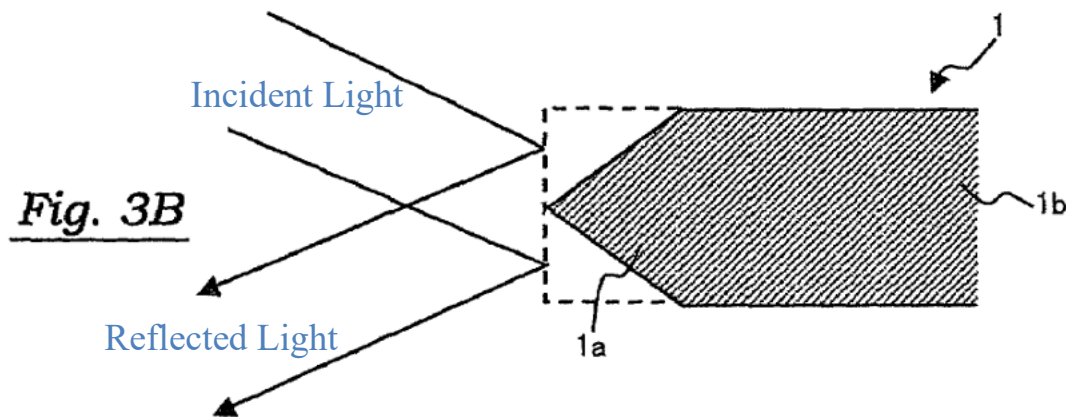
In optical systems ... *the usual means* for providing the systems with glare-stops is the placing of *apertured blackened discs in the system with the apertures thereof concentric with the optic axis* of the system and so spaced along the axis ... Some of the *light diffused from the edges of the stop apertures*, however, always reaches the field, and *provides glare, or noise*, or reduced contrast in visual, electronic or photographic systems respectively.

EX1013, 1:13-24 (emphasis added). To reduce this problem, Taylor teaches making the “edge” of the glare stop incredibly thin—“only on the order of a few molecules thick”—so that it “diffuses a minimum of light into the field of the optical system.” *Id.*, 1:32-40; *see also id.*, 2:8-13 (same).

50. More modern, miniaturized lens systems also suffer from glare caused by stray light reflecting off the inner edges of light-blocking elements. For example,

Bareau's 2006 article on miniature camera lens design notes "stray light considerations" and cautions that scaled down "aperture[s] or baffle feature[s]" might "cause a larger fraction of the light to scatter from their edges, resulting in flare or veiling glare." EX1017, 3.¹³

51. Hirata's 2008 mobile phone lens system patent also noted this problem, explaining that, "since the light shield sheet used for a lens stop has a certain thickness, incident light is reflected on its side face to cause ghost or flare." EX1018, 1:14-20, 1:35-37. Much like the '660 patent would later do, Hirata illustrated this known phenomenon, e.g., its Fig. 3B shows how the inner edges of a light shield might reflect stray light if left flat and wide, as "indicated by the dotted line":



EX1018, FIG. 3b (blue annotations added); *see also id.*, 5:2-9 (describing one approach to reducing this light reflection), 3:16-17.

¹³ Citations are to page numbering added by Petitioner.

52. The '660 patent Fig. 1B (prior art) also shows the known phenomenon of “stray lights” reflecting off the inner edge of the sheet’s hole and reducing image quality. *Id.*, 1:48-54; *see also id.*, 2:7-14.

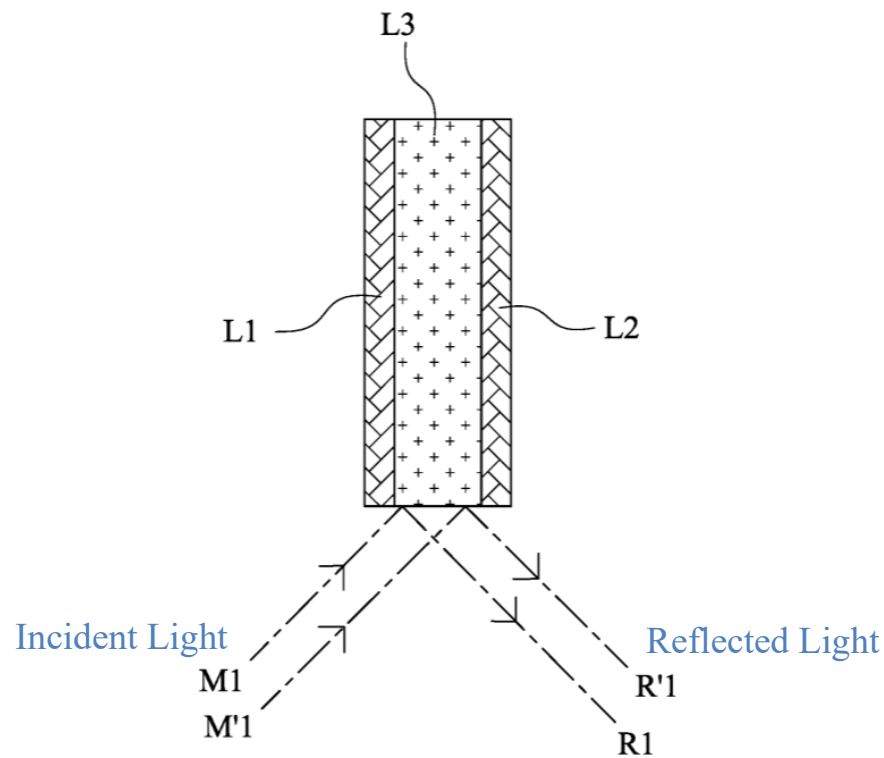


Fig. 1B (prior art)

Id., Fig. 1B (blue annotations added).

C. Lens Designers Used Three Known Techniques, Often Together, To Reduce Reflections Off Of Light-Blocking Elements

53. Schaub, a 2009 book published by the Society of Photo-Optical Instrumentation Engineers (“SPIE”), lays out three known approaches that were “usually” employed when dealing with stray light reflecting off inner surfaces of light-blocking sheets and other non-optical surfaces in a design. Sources of stray light include reflections from non-optical surfaces, such as “any housings, baffles or sun shields, spacers, lens flanges, barrel walls or openings, and even the aperture stop of the system”—in other words, light-blocking elements. EX1007, 120; *see also* EX1009, 89 (stray light sources include “glints from mechanical structures”).

54. Schaub explains that “[s]tray light due to reflection from a nonoptical surface is usually handled using *one or more of* three methods.” EX1007, 120 (emphasis added). **First**, “prevent the reflection from reaching the image plane through the use of baffling,” i.e., light traps. *Id.* **Second**, “alter the shape, location, or orientation of the surface that is causing the stray-light reflection.” *Id.* **Third**, “alter the reflective nature of the offending surface, which can be accomplished in several ways,” including “apply[ing] an absorptive coating to the surface, such as paint or black ink,” and “chang[ing] the part reflectance by texturing the surface.” *Id.*, 121.

55. POSITAs used these methods in combination as “it may require multiple techniques to prevent unwanted reflections from reaching the image plane.” *Id.*, 121; *id.*, 122:18-40 (providing specific example design that used two techniques together) EX1009, 90 (Dr. Bentley book, describing use of both baffles/vanes and “blackening or roughening” of surfaces for “Stray Light Reduction”).

1. Baffles Or “Light Traps”
Reduce Stray Light By Trapping It

56. POSITAs regularly used baffle features to trap and suppress stray light in optical systems. *E.g.*, EX1008, 587 (noting “[i]t is important that the designer be reasonably fluent in ... baffling and stray light control”). A February 2013 patent application to Wang explains the well-known “light trap” concept in the context of an automotive camera system:

The light trap or baffles, formed of light absorbing materials/surfaces, may trap the extraneous light and limit or preclude or reduce the extraneous light from reflecting towards the camera. The light baffle or light trap may comprise dark or light absorbing baffles or ribs or columns or pits or depressions or the like (such as baffles or ribs formed of a dark or black plastic material or the like) to limit or reduce the amount of light that reflects off of the baffles.

EX1012, [0106]. FIG. 46 of Wang shows how adjacent baffles trap light, causing it to reflect several times within the “trap” rather than undesirably reflecting forward into the system:

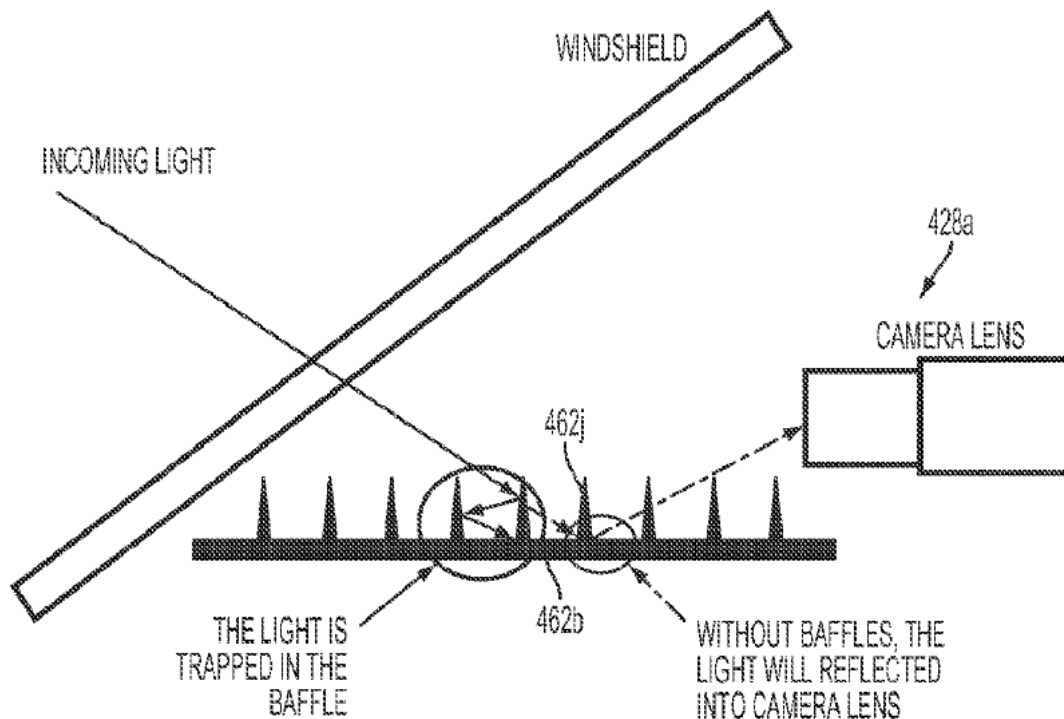
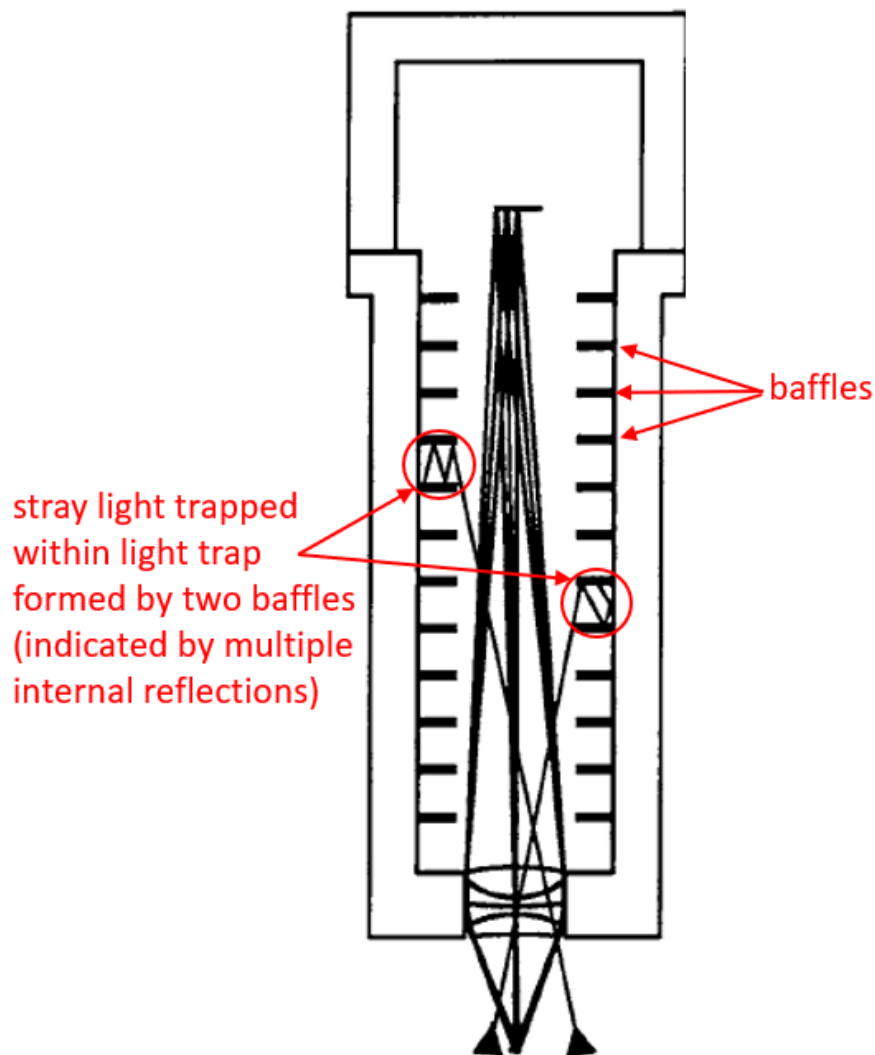


FIG. 46

EX1012, FIG. 46. POSITAs use terms such as “vanes,” “baffles,” and “glare stops” in similar fashion to refer to structures that implement the well-known baffle concept of blocking and trapping stray light in a recess or cavity. EX1010, 7.10-7.11 (defining terms for clarity because “[o]ther authors have used their own different

definitions”); *see also* EX1009, 90 (describing “blocking light with baffles, vanes, and knife edges” and providing figure showing “Knife-Edge Baffles”).

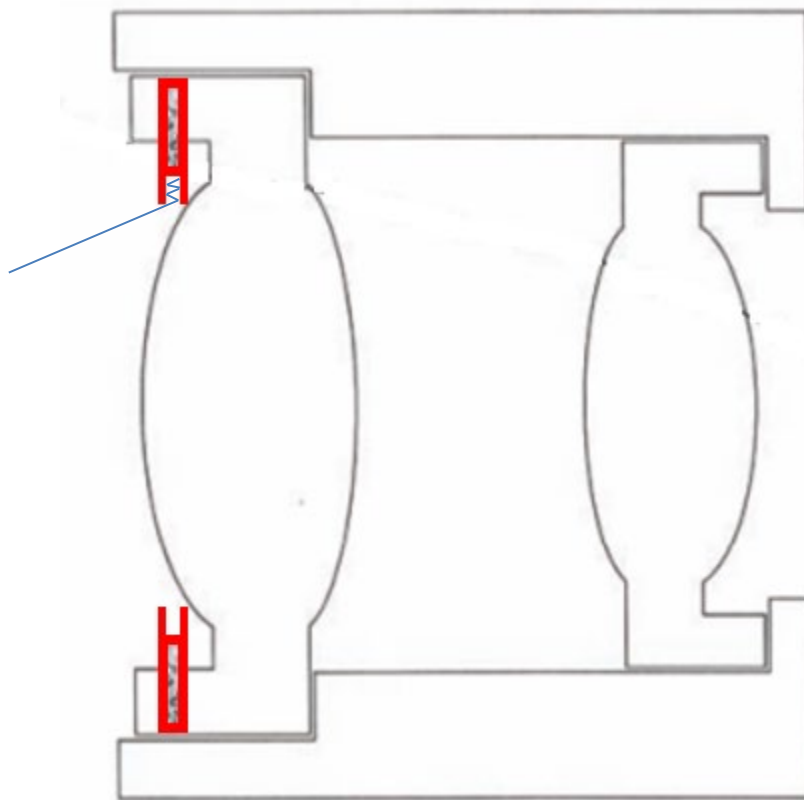
57. Fischer explains the subject of stray light suppression using a machine vision optical system example (EX1008, 595:32-596:4) and shows how baffle features trap stray light:



Fischer, FIG. 21.7(a) (annotated)

EX1008, 598. “[O]ptimum stray-light attenuation” involves incorporating “baffle features.” *Id.*, 597:19-27 (describing Figures 21.7(a-b); 601:18-33 (noting that the “design of the mechanics ... is extremely important” and “must aid in attenuation of stray light,” often by “providing stray light baffles at strategic locations.”). Dr. Bentley’s Field Guide on lens design also specifies that “stray light paths can be eliminated by blocking light with **baffles**, **vanes**, and **knife edges**.” EX1009, 90 (emphasis original); *id.* (“Mechanical surfaces and edges of optical elements can be treated to absorb or scatter light by blackening or roughening. **Rifling** or **threading** barrels and mechanical surfaces is a common and economical way of reducing stray light.”) (emphasis original).

58. Thus, the “use of baffling” to handle “[s]tray light due to reflection from a nonoptical surface,” as noted by Schaub (EX1007, 120), would be understood to include use of well-known baffled light traps on light-blocking elements. The following annotated version of Schaub Figure 4.25 illustrates how such baffles trap stray light (in blue), with multiple reflections within the light trap, and reduce the chances of it bouncing off the inner edge of the light-blocking element:



EX1007, 124 (Figure 4.25 with red annotations added, original gray stray light path removed, blue stray light path added).

59. In 1996, Arnoux described use of baffles (sometimes called “vanes”) to form a light trap on the surface of a light-blocking element, thus reducing stray light edge reflections, in the context of a lens system for star sensing. EX1014, 2, (explaining that “some helpful practical design rules” for optimizing baffles include using “an additional vane” at “the sharp edge of the vane” “to prevent scattering at large source angle[s]”); *id.*, 5. As depicted in Arnoux’s Figure 9, such a light trap at

the edge of the vane includes an air layer formed by the two vanes (the vane and the additional vane). *Id.*

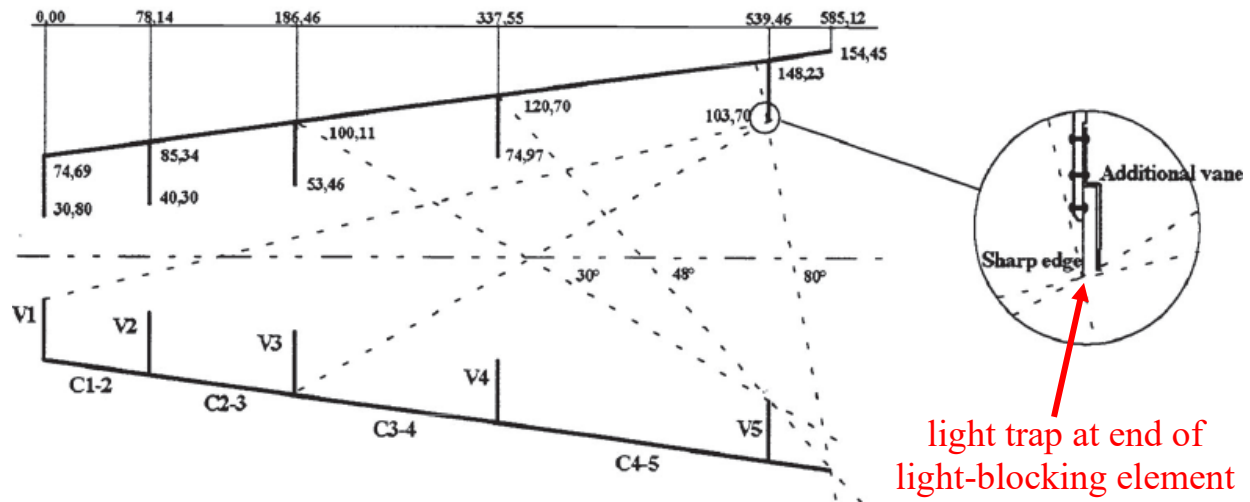


Figure 9 : Baffle Final design

EX1014, 5 (red annotations added). Just as the series of vanes V1, V2, V3, V4, and V5 are positioned to reduce stray light reflections on the baffle (i.e., the conical housing), the same concept is applied at the edge of a vane itself to reduce stray light reflections on the edge of the vane. *Id.*

60. Arnoux's technique of adapting a baffle design to block a potential source of stray light is a standard procedure in stray light analysis. For example, the OSA Handbook of Optics provides the figure below, which is "an abstract representation of the process of reducing stray light in a sensor system." EX1010, 7.10. After "identify[ing] all the possible sources of stray light to the detector," the

optical designer “can then work at decreasing their number by slightly redesigning the baffles and stops.” *Id.*

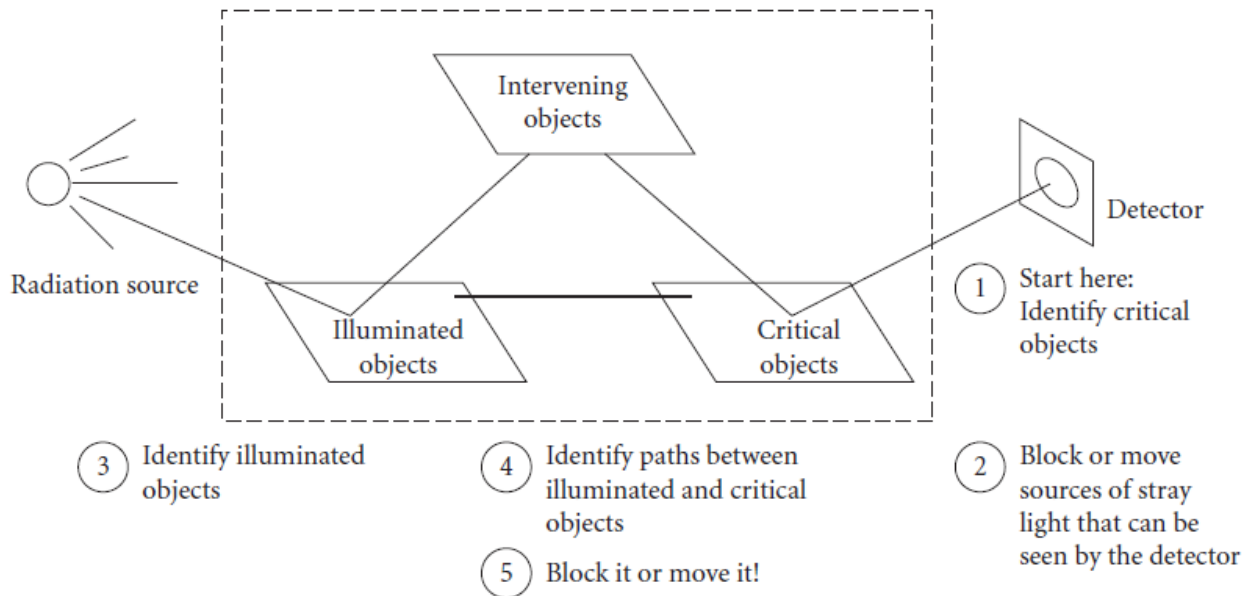


FIGURE 15 The first step in a stray light analysis begins from the detector plane, not from the source.

EX1010, 7.11, FIG. 15.

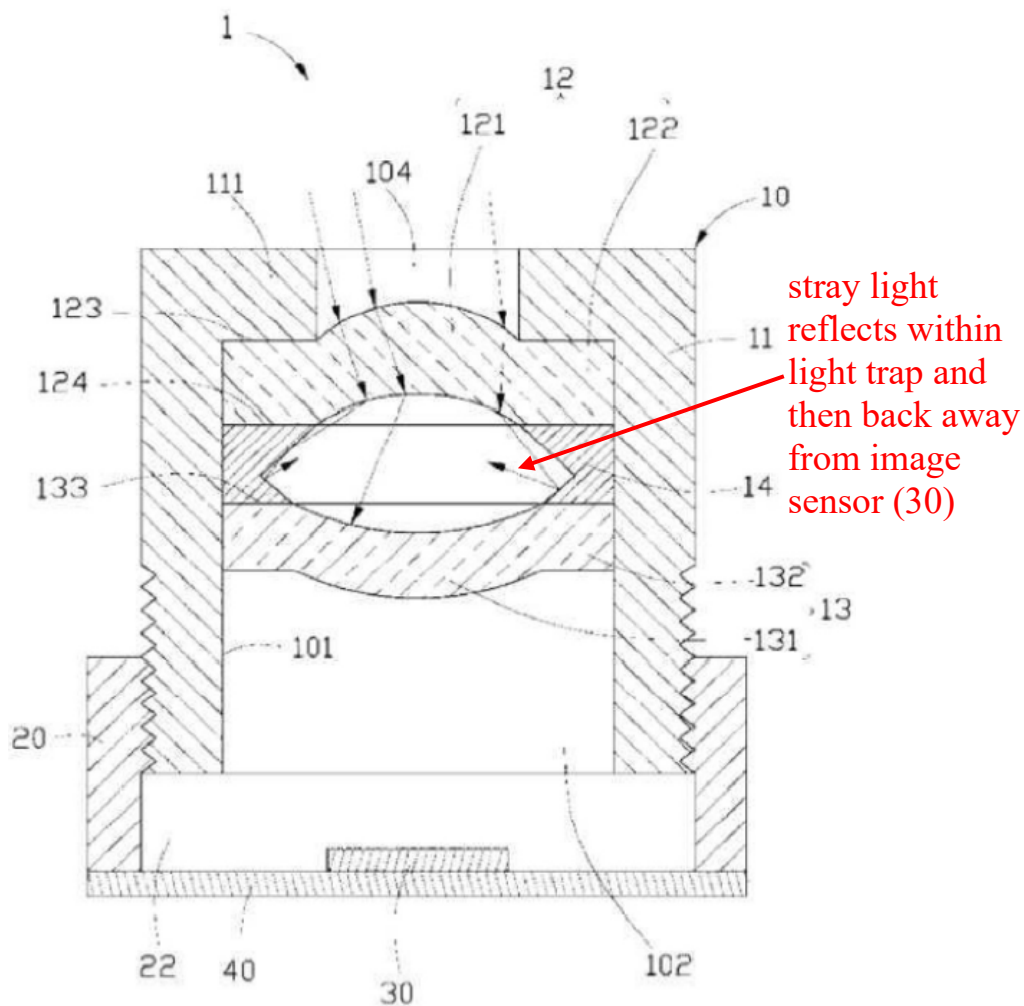
2. Altering The Shape Of The Edge Surface Traps Or Reflects Stray Light Away From The Image Sensor

61. Schaub’s “second method of handling reflections” includes “altering the shape ... of the surface that is causing the stray-light reflection.” EX1007, 120. Schaub gives an example of “altering the spacer geometry from a cylindrical section to a conical section” such that “a given reflection can be shifted from going to the detector to going into the rear flanging of the barrel where it is blocked.” EX1007, 121. Schaub further explains that “[i]t may be that due to the range of input angles, there is not a suitable angle for the spacer such that reflections for all input angles

are dealt with,” and “[i]f so, it may require multiple techniques to prevent unwanted reflections from reaching the image plane.” *Id.*

62. One known approach to altering the shape of an edge was to bevel it to redirect the light away from the image sensor, instead of towards it. *E.g.*, EX1010, 7:11-7:14 (discussing the “bevel of vanes” for redirecting light); EX1020, 1:10-15 (“The spacer is typically annular and includes a cylindrical inner surface, and defines a chamfer facing an object-side end of the lens module to efficiently reflect off-axis light rays”).

63. In 2008, a Chinese patent application described a light trap formed on the inner surface of a light-blocking “spacer ring,” “to avoid the formation of glare” in lens systems for “mobile phones” and other devices. EX1005 (“CN738”), 6:32-37, 7:24-36. A POSITA would understand that the CN738 spacer ring is a light-blocking element because it is “made of an opaque plastic material” and thus blocks or reflects any incoming light that hits its surface. CN738 uses “inclined planes” to trap and / or reflect light away from the image sensor. EX1005, 6 (describing how light is “scattered or reflected” between the inclined planes and back to the object side direction).



EX1005, 8 (Figure 1) (red annotations added).

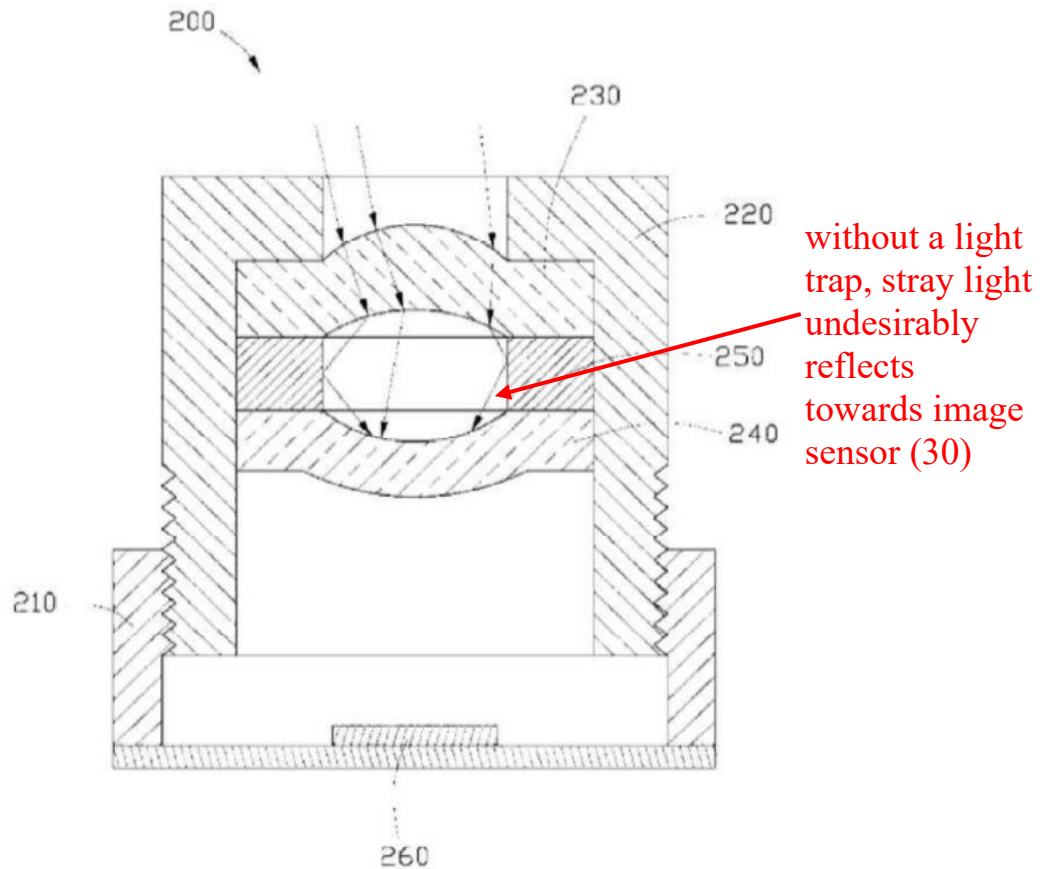
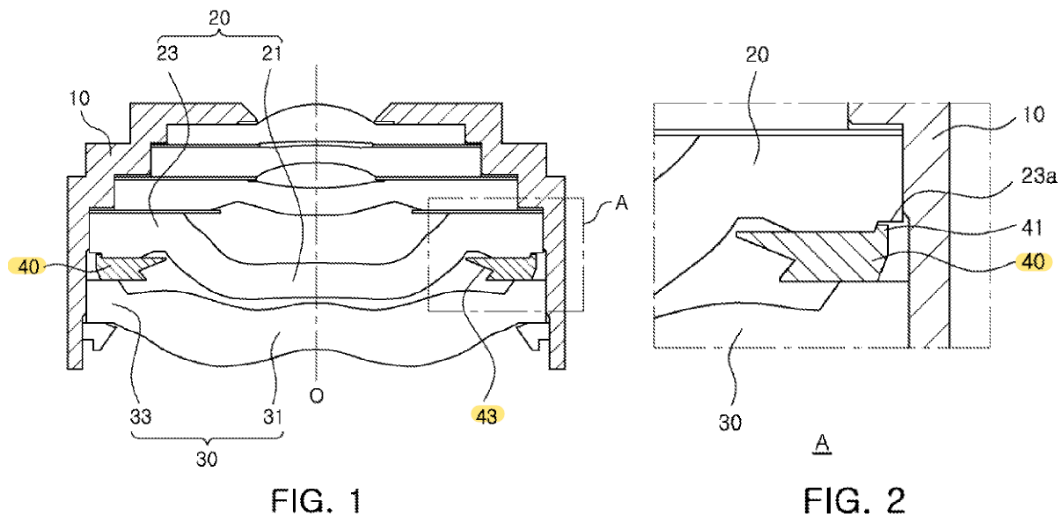


Figure 5

EX1005, 12 (Figure 5) (red annotations added).

64. Yang similarly discloses modifying the inner edge of a spacer to create a “light shielding hole” to redirect stray light away from the sensor. Yang explains that its “light shielding hole 43 includes a plurality of inclined surfaces that are discontinuously formed in an inner diameter of the spacer 40 in order to prevent a flare phenomenon due to reflection of incident light on, or transmitted through, an inner circumferential surface of the light shielding hole 43.” EX1022, [0033], FIGS. 1-2.



EX1022, FIGS. 1-2 (highlighting added). This stray light reduction technique is similar to that used in the threaded baffle light traps described in Fischer, which also rely on reflections off inclined planes. *E.g.*, EX1008, 597 (discussing baffle features “for optimum stray light attenuation”), 598 (Fig. 21.7b)). Like Arnoux, Yang and CN738 thus use a form a type of light trap on the edge of a light-blocking element “to prevent scattering at large source angle.” EX1014, 5; *supra* ¶¶ 56-60. Rather than adding additional structures to trap or redirect the light, Yang and CN738 form this light trap by shaping the edge of the light-blocking element. These known solutions all incorporate a baffle feature into the inner edge of a light-blocking element, thereby invoking the “three-bounce rule” to reduce stray light and thus reduce glare. EX1008, 717-18; *infra* ¶71. Arnoux, with its vanes that provide a light trap having right-angled corners, is more similar to Fischer 21.7a, whereas Yang and CN738, with their angular surfaces, are more similar to Fischer 21.7b. All rely on the same

basic light-trapping principles, and employ light trap features on the inner edge of a light-blocking element.

**3. Changing The Reflectivity Of The Edge Surface
Absorbs Or Redirects Stray Light Away From The Sensor**

65. Schaub explained that “[t]he third method of dealing with reflections from nonoptical surfaces is to alter the reflective nature of the offending surface, which can be accomplished in several ways,” including “apply[ing] an absorptive coating to the surface, such as paint or black ink,” and “chang[ing] the part reflectance by texturing the surface.” EX1007, 121; *see also* EX1009, 90 (“Mechanical surfaces and edges of optical elements can be treated to absorb or scatter light by blackening or roughening.”).

66. In addition to making the surface absorptive, an antireflective coating, sometimes referred to as an antireflection (AR) coating or film, is often applied to the surface to reduce reflections. *E.g.*, EX1007, 110 (explaining that antireflection coatings “are typically used” for “reducing the surface reflectance”); EX1009, 91 (“Optical surfaces require antireflection (AR) coatings to reduce stray light and improve transmission.”). For example, it was also well known that “an antireflection (AR) coating” is a “commonly used coating for plastic optics,” and multiple coatings are often used. EX1007, 111; *id.*, 120 (“Antireflection coatings become more important as the number of elements in the system increases.”); EX1008, 571 (the

“primary purpose” of antireflective coating “is to reduce the amount of reflected light from the optical surface”).

67. Thus, in addition to the above techniques of using structures to block and/or reflect/redirect light, making the structures themselves more absorptive and antireflective further helps to reduce stray light. *E.g.*, EX1008, 717 (“The key to scatter suppression is to create an opto-mechanical housing structure which maximizes the number of light absorbing surfaces that scattered light must strike before reaching the focal plane.”); *id.* (discussing “blackened” surfaces).

**D. Light Traps At The Edge Of Light-Blocking Elements
Were A Known Solution For Suppressing Stray Light,
Both Historically And In More Recent Miniature Lens Designs**

68. As reflected in my discussion in the preceding paragraphs, the use of a light trap at the edge of a light-blocking element was a well-known technique for eliminating edge reflections. As noted above, Arnoux taught using “an additional vane” at “the sharp edge of the vane” of a baffle in order “to prevent scattering at large source angle[s].” EX1014, 5; *supra* ¶¶ 59-60. Another approach, taught by Yang and CN738, includes altering the edge itself of a light-blocking element to form a light trap in the edge. *Supra* ¶¶ 61-64. By altering the inner surface of the spacer to incorporate a light trapping structure, these known approaches in a way combined the first two known methods for reducing stray light reflections (use of baffles / light traps and alteration of the shape of the inner surface).

**E. POSITAs Knew How To Calculate An
Appropriate Depth For A Given Light Trap**

69. A POSITA knew how to calculate the requisite depth of a given light trap because vane / baffle design was a well-understood practice. *See, e.g.*, EX1008, 718-721 (explaining baffle design), 722-725 (explaining how to find optical baffle geometry), 725-726 (explaining shapes of vanes), 726-728 (explaining thread profiles for baffles); EX1010, 7.10-7.17 (explaining designs for baffles and vanes).

70. POSITAs refer to the structures that form the sides of a light trap as “vanes” or “baffles.” For example, The Handbook of Optics uses the term “vanes” to describe these light trap-forming structures but notes that “[o]ther authors have used the term ‘baffles’ or ‘glare stops’ to describe these vanes.” EX1010, 7.11:16-17. This different terminology for the same structure if reflected, for example, in the figures of different lens design books. Figure 19 of the Handbook of Optics shows a light trap formed by “vane structure” whereas Fischer refers to “baffles structures.”

CONTROL OF STRAY LIGHT 7.13

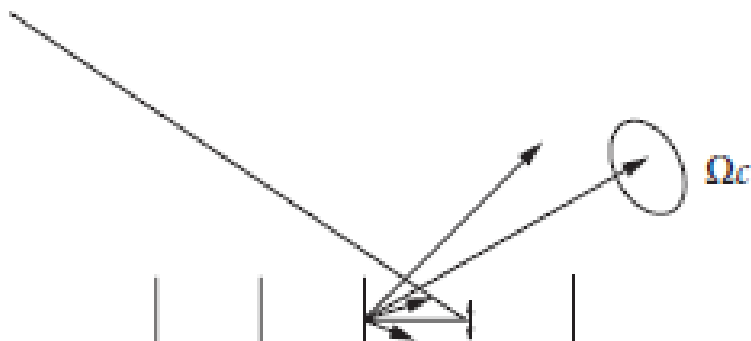


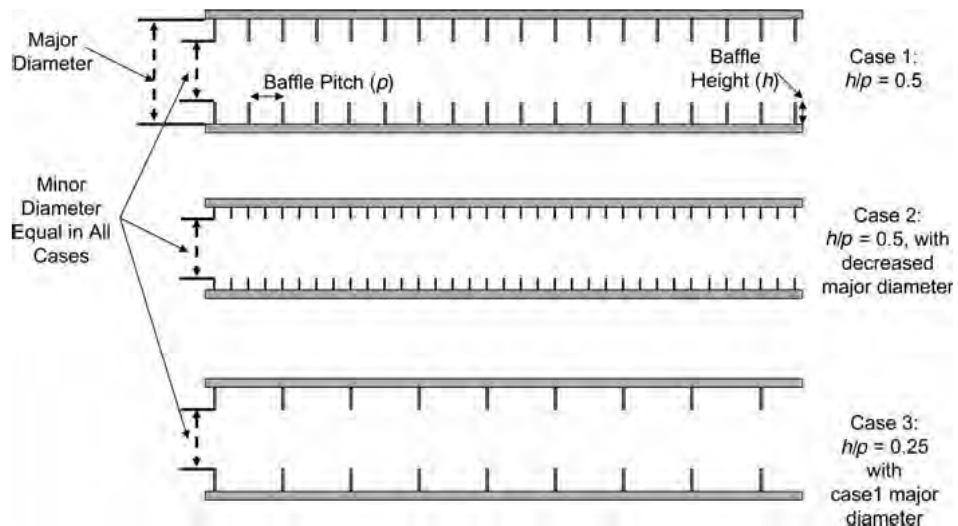
FIGURE 19 Forward scatter path highly attenuated by the vane structure. (Ref. 6, p. 92.)

EX1010, 7.13 (Figure 19)

Stray Light and Optical Scattering

719

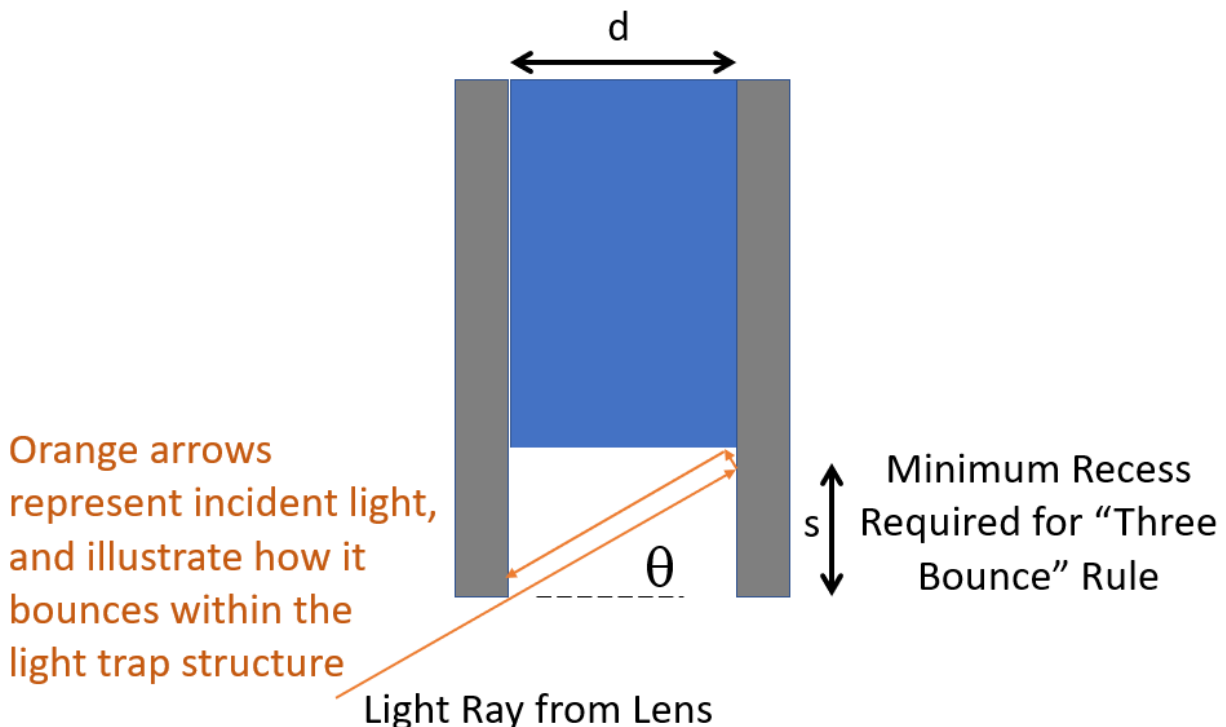
Figure 24.10
Example of Baffle
Structures in a Bore



EX1008, 719 (Figure 24.10).

71. POSITAs knew that the “three-bounce rule” helped inform light trap dimensions. As Fischer states, “[i]f there’s one rule to remember, it’s the ‘three-

bounce rule” for suppressing stray light. EX1008, 717-18. “Three bounces of a 1% reflection will reduce the amount of light to one *millionth* of the original energy. This is a great rule of thumb for most scatter suppression applications!” *Id.* (emphasis original). POSITAs knew that basic trigonometry relates the angle of the incoming light to the width of a given light trap, as depicted below, allowing for simple determination of the minimum depth or recess required to achieve three “bounces” or reflections, and thus sufficiently reduce stray light in the system. Thus, as shown by the following illustration, the minimum recess depth s for a given width d and stray light angle θ can be readily determined from the equation $s = d \cdot \tan(\theta)$:



As shown, a depth calculated from this equation will cause the stray light to bounce twice, infinitesimally close to the upper right corner, and then a third time on the left

edge (so that they may be seen by the reader, and thus better illustrate the concept, the light rays and associated bounces are not depicted infinitesimally close together in my figure above; in a “perfect” three bounce light trap for a given angle, however, the light rays would be imperceptibly close to each other). A shallower depth would allow the light to exit the trap after just two bounces; whereas a greater depth would better trap the light and thus is not strictly required, although there is nothing wrong with better trapping the light. *E.g.*, EX1010, 7.13 (“Designing the Vane Spacing and Depth”); *id.*, 7.16:9-38; EX1008, 718 (relationship between vane pitch and vane depth). The law of reflection dictates that the angle of reflection is equal to the angle of incidence (EX1030, 4), so a POSITA would thus easily calculate the bounces taken by incident light and determine the light trap depth needed to achieve *at least* three bounces for a given light trap width and stray light input angle.

72. Fischer further explains the relationship between the spacing and the depth of light trap baffles and notes a “trade-off study” that examined “the optimal spacing” or “pitch” p for a given baffle height. EX1008, 718:27-720:34. Based on this study, Fischer determined that a reasonable balance between stray light suppression and design complexity would result from a ratio of $h/p = 0.5$, or a baffle height that was $1/2$ the baffle separation. *Id.*, 718-722. Fischer concludes that “Fig. 24.13 indicates a similar trend for both specular and diffuse baffles. When the height to spacing pitch ratio (h/p) reaches approximately 0.5 little further scatter

suppression [is] achieved by the addition of more baffles.” *Id.*, 720. From this, a POSITA would understand that, for a fixed separation of the baffles, there would likely be little further benefit from making deeper light traps. While Fischer provides this analysis in the context of multiple baffles in a system, POSITAs would have known that the same basic principles and analysis applied for a single light trap formed by two baffles because, in each instance, the key factor was how many stray light bounces were created by a given light trap. In other words, the pitch and height ratio was just as applicable to a two-baffle (single light-trap) system as it was to a system with more baffles (and thus more light traps) as shown in Fischer Figure 24.10. POSITAs would have understood this as a good rule of thumb when implementing light traps to reduce stray light in an optical system. *See also* EX1010, 7.16:9-14 (discussing “vane depth considerations” and noting that at a certain point “no further improvement should be expected due to further increases in vane depth”). Thus, for example, if the two sides of a light trap were separated by 15 μm , POSITAs knew that a reasonably acceptable design would have a light trap depth of at least 7.5 μm . Such a depth would achieve a good balance between scatter suppression and design complexity, and for many applications making the light trap deeper might provide only incremental additional stray light suppression that did not warrant the additional manufacturing time or complexity. *E.g.*, EX1010, 7.16:22-23 (“Once the depth of a diffuse black vane structure is deep enough to block the single

scatter path, further increases will not improve performance.”). Of course, POSITAs knew that certain optical designs would have more exacting specifications and that a more rigorous analysis using the three-bounce rule would provide better guarantees of stray light suppression for a given angle.

VIII. OVERVIEW OF THE '660 PATENT

73. The '660 patent, titled “LIGHT BLOCKING SHEET, IMAGING LENS MODULE AND ELECTRONIC APPARATUS,” issued from U.S. Patent Application No. 15/434,163, filed on February 16, 2017, and alleges priority to Taiwan Application Serial No. 105137120, filed on November 14, 2016. EX1001, Cover.

A. The '660 Patent Describes The Alleged Invention As Use Of A Light Trap, Without Using That Term

74. The '660 patent describes a “light blocking sheet [that] includes a first outer layer, a second outer layer, an inner substrate layer and a central axis,” where the “first outer layer includes a first opening,” the “second outer layer includes a second opening,” and the “inner substrate layer includes a substrate opening,” where each of the openings is coaxial with the central axis. *Id.*, 2:22-32.

75. The '660 patent describes the prior art “conventional light blocking sheet” as a ring-shaped disc with a PET substrate layer “sandwiched by two outer layers made of a carbon-containing material.” EX1001, 1:33-41; FIG. 1. Its Fig. 1B

shows incident stray light reflecting off the inner surface of the light blocking sheet's hole:

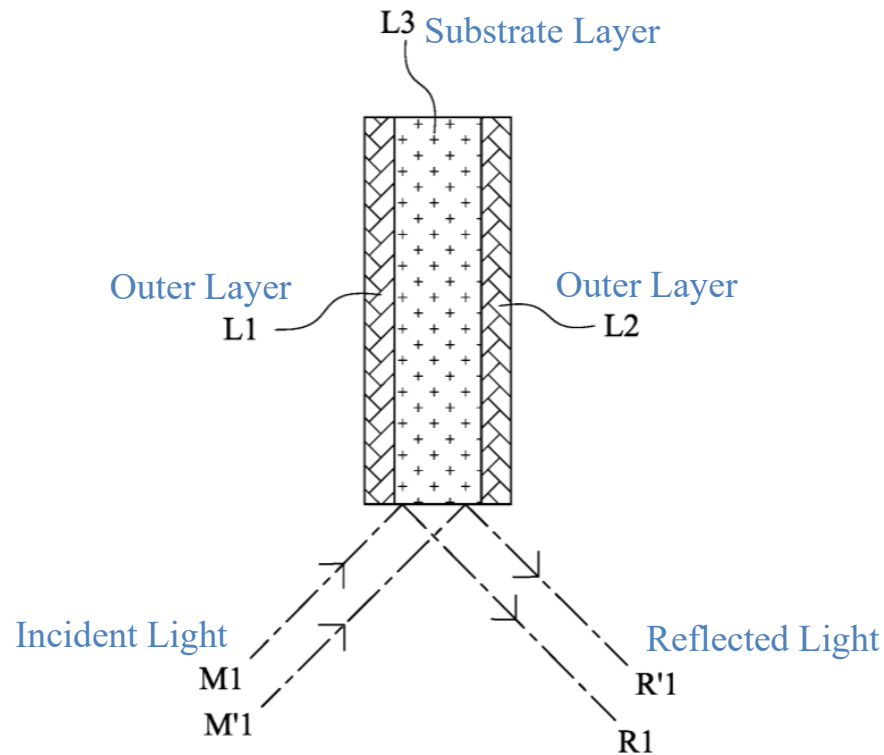


Fig. 1B (prior art)

Id., Fig. 1B (blue annotations added); *id.*, 1:55-2:14 & 2:7-14.

76. It then describes the alleged invention as a light blocking sheet of the same 3-layer structure with a minimum diameter of the substrate opening greater than the openings of the first and second carbon-containing layers. *Id.*, 2:22-39. The alleged invention is thus the addition of an “inner space” or an “air layer 140 ...

located between the first outer layer 110 and the second outer layer 120” of a conventional light blocking sheet, as shown in Fig. 2C, reproduced below. *Id.*, 5:9-17, Fig. 2C.

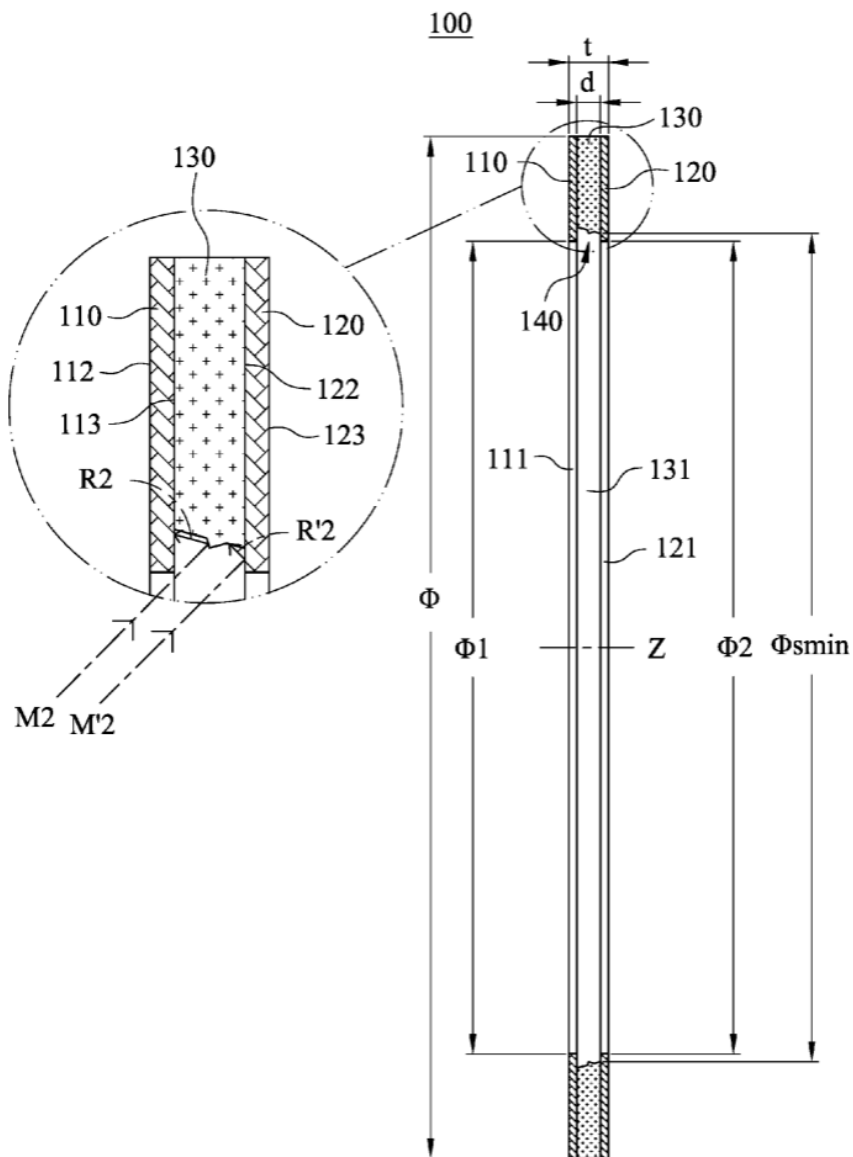
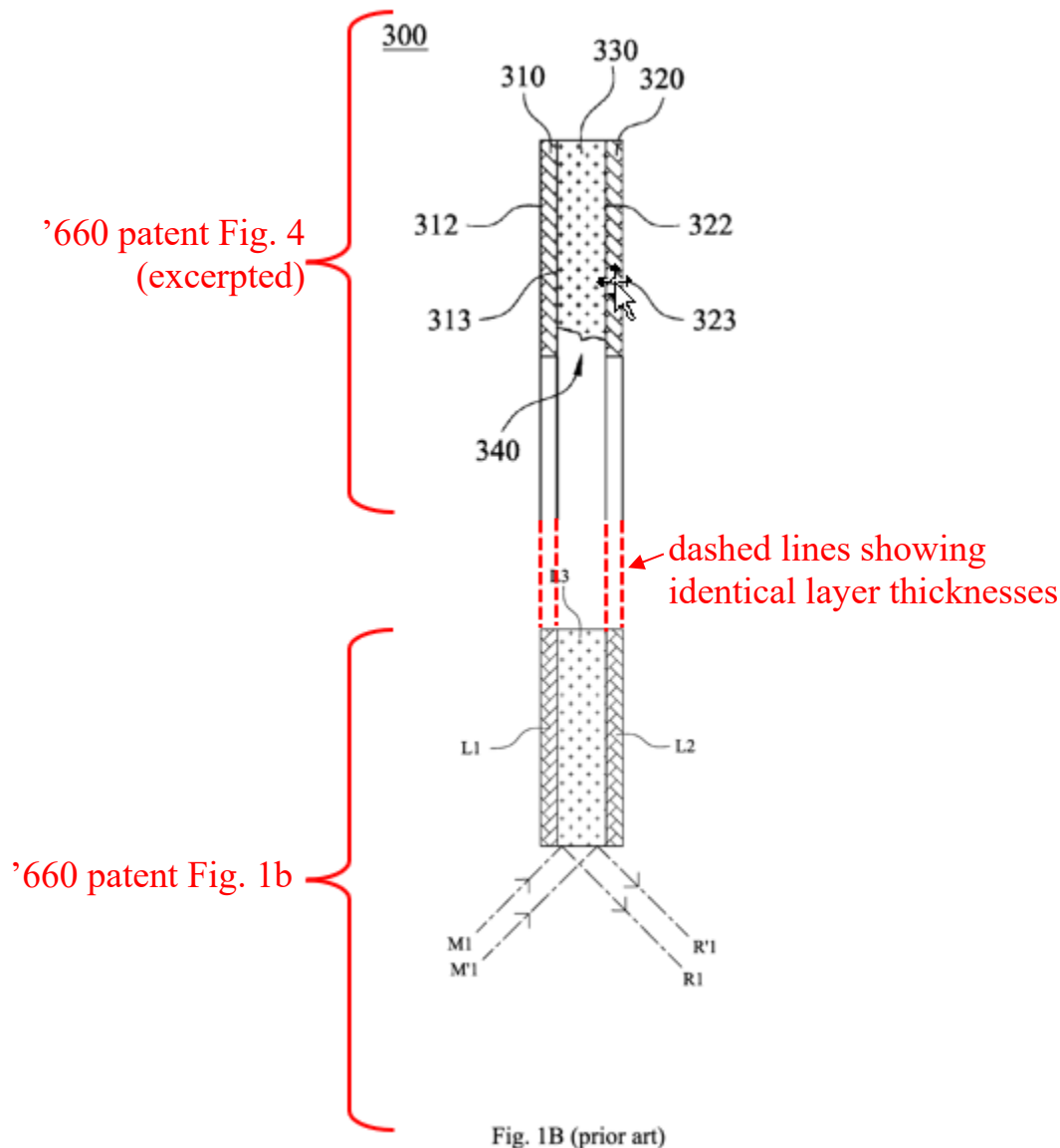


Fig. 2C

Id., Fig. 2C.

77. The '660 patent states that “when an incident light M2 and an incident light M'2 strike a surface of the inner space (air layer 140), ... a reflected light R2 and a reflected light R'2 generated thereby tend to reflect again in the inner space (air layer 140).” *Id.*, 5:24-31. This reflection of light within the inner space “can effectively attenuate an intensity of the light reflected therefrom” such that “stray lights can be effectively reduced, and the image quality can be enhanced.” *Id.*, 5:31-36; *see also id.*, 2:15-18. This describes basic light-trapping principles.

78. Confirming that the alleged invention merely adds a light trap to the same 3-layer structure as the prior art, the exemplary “prior art” light-blocking sheet shown in Fig. 1B has the same layer thicknesses as the '660 embodiment shown in Fig. 4. This is shown below by a visual comparison of the two figures:



79. Thus, without expressly using the terms for the well-known “three-bounce rule” and associated “light trap,” the ’660 patent effectively describes the alleged invention as use of a light trap to reduce stray light in the system.

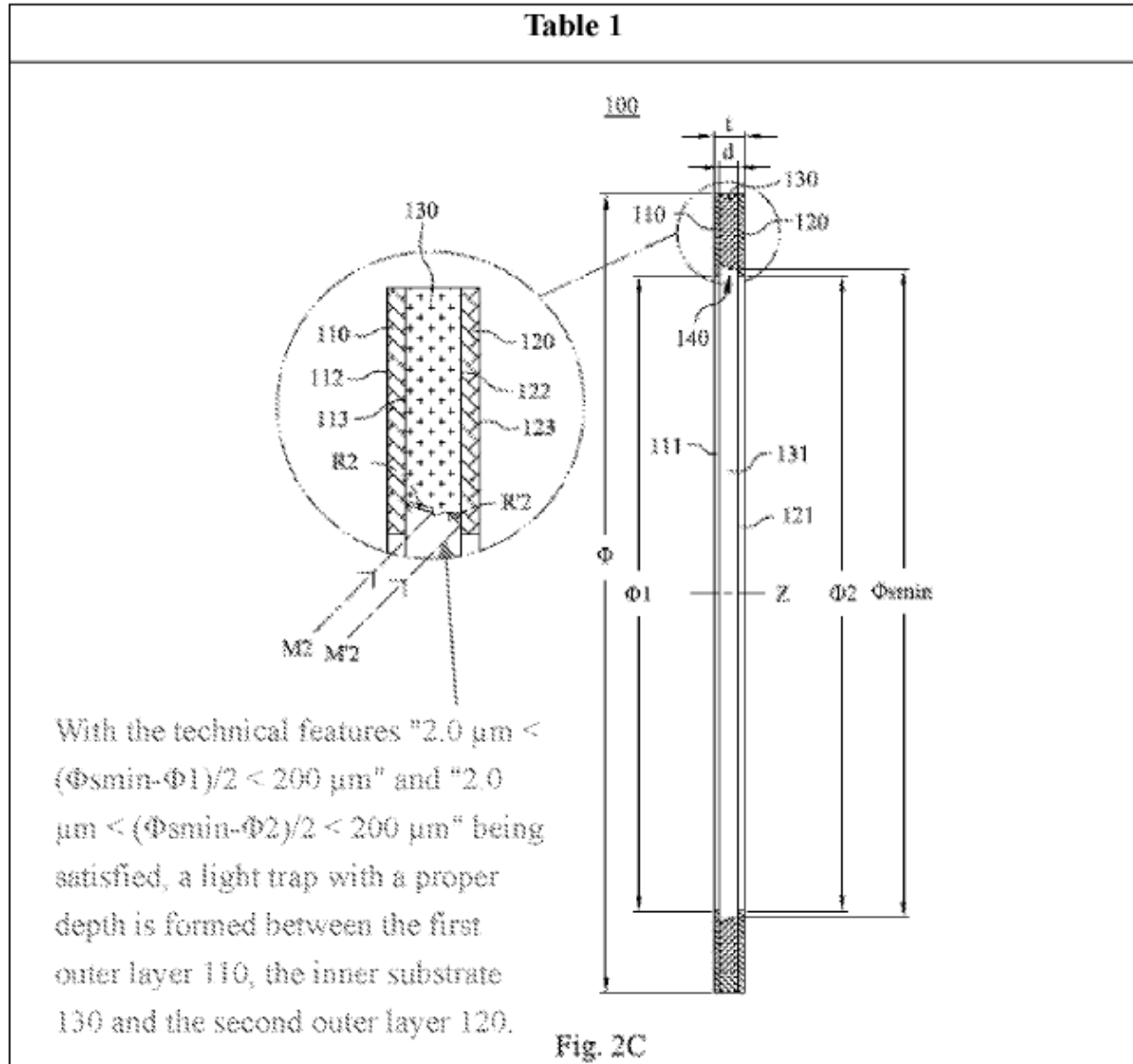
80. The ’660 patent does not describe how to manufacture or otherwise create this light trap.

B. The Prosecution History

81. An Office action rejected all claims as obvious over U.S. 2015/0022896 (to Cho et al.) in view of U.S. 2016/0349504 (Kim et al.). EX1002, 176-191/237. In response, Applicant amended the independent claims to incorporate the limitations of original claim 3 regarding the range of minimum diameter of the inner substrate to the diameter of the openings in the outer layers. *Id.*, 197-212/237. Applicant argued:

[T]he mechanism for reducing the stray light according to the present application is to form a light trap (i.e., the inner space formed between the first outer layer 110, the inner substrate layer 130 and the second outer layer 120), once the incident light strike therein, the intensity thereof is attenuated by repeated reflections.

Id., 208/237 (emphasis in original). I understand that, with no cited support, the Largan further argued that the claimed Element 1.6 dimensions led to a light trap of proper depth: “the depth of the light trap is proper, and the effect for trapping the incident light is more significant.” *Id.* In explaining these dimensions, applicant submitted an annotated copy of its Fig. 2C, which is reproduced below. This figure shows that the recited dimensions are satisfied by a light trap that is greater than 2μm deep, and less than 200μm deep, with respect to either outer layer:



EX1002, 207/237. I understand that Largan also argued that Cho and Kim “fail[ed] to disclose, teach and suggest the reduction of stray light by forming a light trap.” *Id.*, 208-211/237. Based on these arguments, the Examiner allowed the amended claims. *Id.*, 216-222/237.

C. Claims

The challenged claims are shown in their entirety in EX1023. Challenged claim 1 is provided here, with element numbering added in the lefthand column:

[1.1]	A light blocking sheet, comprising:
[1.2]	a first outer layer comprising a first opening;
[1.3]	a second outer layer comprising a second opening;
[1.4]	an inner substrate layer disposed between the first outer layer and the second outer layer, wherein the inner substrate layer connects the first outer layer to the second outer layer, and the inner substrate layer comprises a substrate opening; and
[1.5]	a central axis coaxial with the first opening, the second opening and the substrate opening;
[1.6]	wherein a minimum diameter of the substrate opening is Φ_{smin} , a diameter of the first opening is Φ_1 , a diameter of the second opening is Φ_2 , and the following conditions are satisfied: $2.0\text{ }\mu\text{m} < (\Phi_{\text{smin}} - \Phi_1)/2 < 200\text{ }\mu\text{m}$; and $2.0\text{ }\mu\text{m} < (\Phi_{\text{smin}} - \Phi_2)/2 < 200\text{ }\mu\text{m}$.

IX. CLAIM CONSTRUCTION

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

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

84. I note that claim element [1.6] recites mathematical conditions relate to relationships between the different layers of the light blocking sheet. As explained below, a plain reading of this element encompasses, and is satisfied by, a light trap on the inner surface of a three-layer light-blocking sheet, formed by recessing the middle substrate layer at least $2\mu\text{m}$ and no more than $200\mu\text{m}$, with respect to each outer layer, along the inner circumference of the sheet.

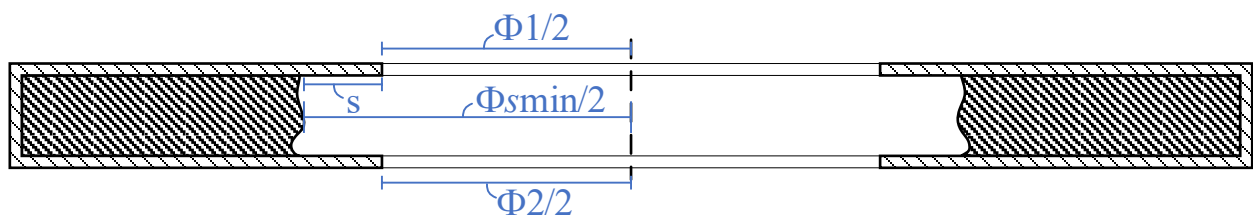
85. The claim recites:

wherein a minimum diameter of the substrate opening is Φ_{smin} , a diameter of the first opening is Φ_1 , a diameter of the second opening is Φ_2 , and the following conditions are satisfied:

$$2.0\ \mu\text{m} < (\Phi_{\text{smin}} - \Phi_1)/2 < 200\ \mu\text{m}; \text{ and}$$

$$2.0\ \mu\text{m} < (\Phi_{\text{smin}} - \Phi_2)/2 < 200\ \mu\text{m}.$$

The middle portion of the conditions can be rewritten as $(\Phi_{\text{smin}}/2) - (\Phi_1/2)$ and $(\Phi_{\text{smin}}/2) - (\Phi_2/2)$. As shown in the following figure, each of these values reflects the minimum depth that the middle layer is recessed relative to each outer layer:



86. Thus, the plain meaning of this term encompasses, and is satisfied by, a light trap on the inner surface of a three-layer light-blocking sheet, formed by recessing the middle substrate layer at least $2\mu\text{m}$ and no more than $200\mu\text{m}$, with respect to each outer layer, along the inner circumference of the sheet. A light-blocking sheet with such a light trap has a minimum substrate opening diameter Φ_{min} that is between $4\mu\text{m}$ and $400\mu\text{m}$ greater than the diameters of each of the first and second openings Φ_1 and Φ_2 .

87. This plain meaning is consistent with the prosecution history as Largan argued that Element 1.6 corresponds to “a light trap with a proper depth.” EX1002, 207/237; *supra* ¶81.

**X. GROUND 1: A POSITA WOULD HAVE FOUND
CLAIMS 1-9 AND 15-19 OBVIOUS OVER CN182**

88. As explained below, given the knowledge and skills of a POSITA, claims 1-9 and 15-19 are obvious over CN182.

A. CN182 (EX1004)

89. Chinese Patent Publication No. CN 104460182 A (EX1004, “CN182”) published March 25, 2015, and qualifies as prior art under Section 102(a)(1). EX1004, Cover. CN182 is analogous art to the ’660 patent because they are both in the same field of endeavor of blocking stray light to reduce glare in compact imaging lens modules. EX1001, 1:14-17, 1:21-32; EX1004, [0001]-[0002].

90. CN182 discloses a shading ring and a method for manufacturing the shading ring. EX1004, [0001]. CN182 explains that “[g]enerally, 3 to 5 pieces of shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to adjust the aperture of the light and to block other stray light.” *Id.*, [0002]. The shading ring disclosed in CN182 “aims to solve the existing technical problems of glare, halo and flare and other undesirable effects caused by the existing shading rings due to the reflection from the inner-wall of the through-hole.” *Id.*, [0003]. At least because it is used for light blocking, and has the same 3-layer construction as the ’660 patent invention, a POSITA would have understood the CN182 “shading ring” to be a “light blocking sheet” as that term is used in the ’660 patent. The ’660 patent acknowledges that light blocking sheets were well-known and describes its light blocking sheets as having the same use, purpose, and general structure as the “shading ring” described by CN182. Though the ’660 patent and CN182 use slightly different wording, a lens designer would understand that CN182 is directed to the same type of light blocking sheet discussed in the ’660 patent.

91. Like the ’660 patent, and as known in the art, CN182 discloses a shading ring with a three-layer structure, namely a plastic body sandwiched between layers of an antistatic coating. *Id.*, [0026]. Specifically, the shading ring uses a “polyethylene terephthalate (PET) raw material with antistatic high-shading coating on the surface,” where “the antistatic coating is a carbon powder layer.” *Id.*, [0002],

[0005]; *id.*, [0027]-[0028], [0036], [0038]. CN182 discloses the shading ring is “formed ... via direct stamping” of a sheet of material but “the stamping of the plastic material leaves a shiny cut-off section surface of the inner hole ... resulting in obvious glare, halo and flare and other undesirable effects.” *Id.*, [0002]; *id.*, [0003].

92. CN182 addresses the same problem later identified by the '660 patent: the stamping process used to form the inner hole of the shading ring leaves a shiny inner surface. *Id.*, [0002]. Stray light reflects off this shiny inner surface, which “result[s] in obvious glare, halo and flare and other undesirable effects.” *Compare id.* (“[T]he stamping of the plastic material leaves a shiny cut-off section surface of the inner hole ... resulting in obvious glare, halo and flare and other undesirable effects.”) *and id.*, [0003] (noting “undesirable effects caused by the existing shading rings due to the reflection from the inner-wall of the [shading ring’s] through-hole”) *with* EX1001, 1:49-51 (“[W]hen the inner hole is formed by stamping, the surface of the inner hole is smooth and bright and has a high reflectivity.”).

93. CN182 addresses the undesirable effects caused by the “shiny cut-off section surface” through etching away the plastic material in the middle, i.e., “forming a matte structure on the hole-wall of the through-hole by corrosion with an alkaline solution.” *Id.*, [0006]. The shading ring is placed in an alkaline solution such as sodium bicarbonate, which corrodes the PET (plastic) body but does not corrode

the “antistatic coating formed by the carbon powder layer.” *Id.*, [0028]. This process results in a non-uniform “matte structure 222 ... formed on the hole-wall” which helps “to avoid the occurrence of glare, halo and flare caused by the reflection from the hole-wall of the through-hole, thereby ensuring the capturing effect and improving the quality of the imaging products.” *Id.*, [0038], [0040], FIG. 3 (reproduced below).

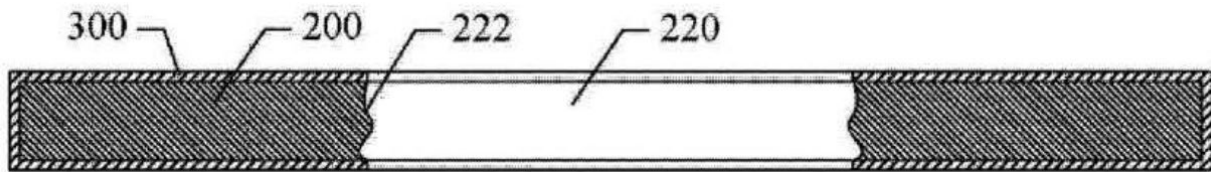
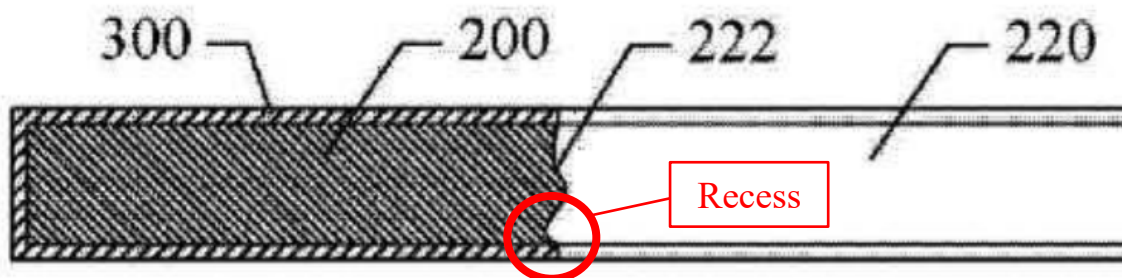


Figure 3

Id., FIG. 3.

94. After etching or corroding the PET body, the hole-wall of the shading ring is partially recessed back from the through-hole, as shown in CN182’s Figure 3, cropped and annotated below to indicate where the hole-wall partially recedes from the outer layers.



EX1004, Figure 3 (cropped and annotated).

95. The only difference between the shading ring of CN182 and the light blocking sheet of the challenged claims of the '660 patent is the requirement that a minimum diameter Φ_{min} of the PET body 200 at the through-hole 220 is slightly larger than the diameters Φ_1 and Φ_2 of the outer layers 300 sandwiching the PET body 200, such that the following conditions are satisfied: $2.0 \mu\text{m} < (\Phi_{\text{min}} - \Phi_1)/2 < 200 \mu\text{m}$, and $2.0 \mu\text{m} < (\Phi_{\text{min}} - \Phi_2)/2 < 200 \mu\text{m}$. However, as discussed further below, a POSITA would have found it obvious to intentionally etch the PET body 200 of CN182 further back relative to the outer layers, in order to efficiently trap light and thus more effectively reduce glare. This renders the claims obvious.

96. As discussed further below, the CN182 shading ring renders obvious all the elements of claims 1-9 and 15-19.

B. Claim 1

1. Element 1.1

[1.1]¹⁴ A light blocking sheet, comprising:

97. To the extent the preamble is limiting, CN182 satisfies it. CN182 discloses a “shading ring” that is “placed inside the camera of high-pixel cell phones

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

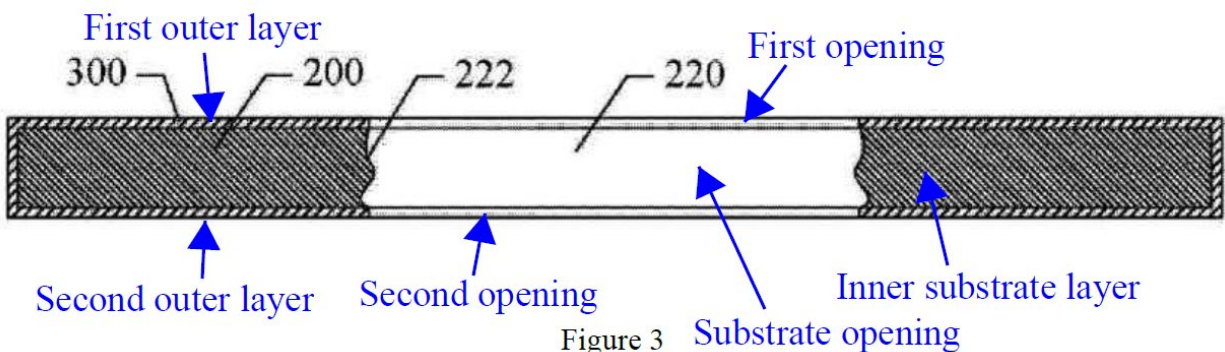
and digital cameras to adjust the aperture of the light and to *block other stray light*.” EX1004, [0002] (emphasis added). Such shading rings and spacers were historically stamped out from metal sheets, and later from plastic sheets to reduce cost. EX1004, [0002]; EX1007, 125 (explaining how a spacer or “blocking element” is “a thin disk of material” that is “stamped from sheets of material of various thicknesses”). At least because of its name, structure, and functional purpose, the CN182 shading ring would have been understood to be a “light-blocking sheet,” as claimed. *Supra* ¶ 90.

2. Elements 1.2-1.4

[1.2] a first outer layer comprising a first opening;
[1.3] a second outer layer comprising a second opening;
[1.4] an inner substrate layer disposed between the first outer layer and the second outer layer, wherein the inner substrate layer connects the first outer layer to the second outer layer, and the inner substrate layer comprises a substrate opening; and

98. CN182 discloses or renders these elements obvious. CN182 discloses first and second outer layers, with an “inner substrate layer disposed between,” as recited in Elements 1.2-1.4. For example, CN182 discloses a “body ... made of plastic material” (inner substrate layer) disposed between and connecting two outer “carbon powder layer[s]” (first and second outer layers). EX1004, [0026]; *id.*, [0005], [0014], [0027]-[0028], [0036]-[0038], Claims 1 & 6-11, Figure 3. Each of these three layers has an “opening” as claimed. *E.g., id.*, [0005], [0018], [0026]; Fig. 3.

99. CN182 discloses “a body, an antistatic coating coated on the body and a through-hole formed on the body, the body is made of plastic material, the antistatic coating is a carbon powder layer, and the through-hole is formed by stamping.” EX1004, [0026]; *id.*, [0005], [0014], [0027]-[0028], [0036]-[0038], Figure 3. As shown in CN182’s Figure 3, the antistatic coating 300 on the top side of the body 200 is a first outer layer comprising a first opening (the through-hole 220), and the antistatic coating 300 on the bottom side of the body 200 is a second outer layer comprising a second opening (the through-hole 220). EX1004, [0036], Figure 3. Further, the body 200 is an inner substrate layer disposed between the first and second outer layers, connecting the two outer layers, and comprises a substrate opening (the through-hole 220). *Id.*



EX1004, Figure 3 (blue annotations added).

100. CN182 explains how shading rings were “formed using polyethylene terephthalate (PET) raw material with antistatic high-shading coating on the surface via direct stamping.” EX1004, [0002]. This disclosure is unsurprising as the ‘660

patent itself admits that this three-layer structure was “conventional.” EX1001, 1:32-49 (“conventional light blocking sheet” features “a substrate layer made of a plastic material ... sandwiched by two outer layers made of a carbon-containing material,” where “an inner hole [is] formed by stamping”); *id.*, FIG. 1B (depicting a “conventional light blocking sheet”).

101. CN182 explains that this three-layer structure was well known at the time, as “[i]n the recent years, as the cost has dropped significantly, this type of shading ring has been replaced by a shading ring formed using polyethylene terephthalate (PET) raw material with antistatic high-shading coating on the surface via direct stamping.” EX1004, [0002]. The ’660 patent itself notes that a “conventional light blocking sheet” features this same three-layer structure, namely “a substrate layer made of a plastic material ... sandwiched by two outer layers made of a carbon-containing material,” where “an inner hole [is] formed by stamping.” EX1001, 1:32-49; *id.*, FIG. 1B (depicting a “conventional light blocking sheet”).

3. Element 1.5

[1.5] a central axis coaxial with the first opening, the second opening and the substrate opening;
--

102. CN182 discloses this element as it describes a through-hole 220 in the shading ring, formed by stamping. EX1004, [0036]. This through-hole forms the first, second, and substrate openings, and thus the central axis of the through-hole is

a central axis coaxial with the first opening, the second opening, and the substrate opening. EX1004, Figure 3.

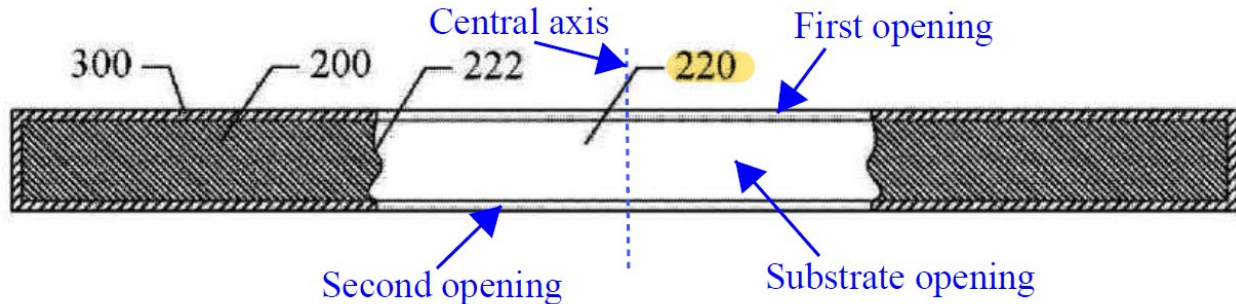


Figure 3

EX1004, Figure 3 (highlighting and annotations added).

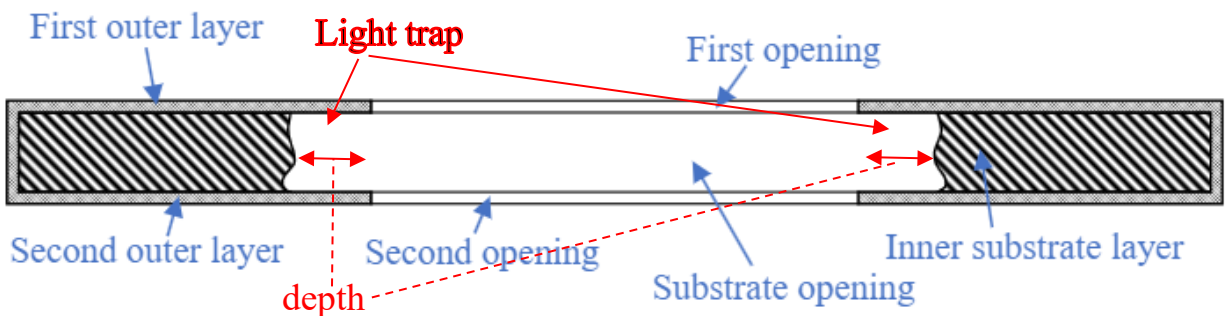
4. Element 1.6

[1.6] wherein a minimum diameter of the substrate opening is Φ_{smin} , a diameter of the first opening is Φ_1 , a diameter of the second opening is Φ_2 , and the following conditions are satisfied:
 $2.0\ \mu\text{m} < (\Phi_{smin} - \Phi_1)/2 < 200\ \mu\text{m}$; and
 $2.0\ \mu\text{m} < (\Phi_{smin} - \Phi_2)/2 < 200\ \mu\text{m}$.

103. As noted above, these conditions are satisfied by a light trap in which the substrate material is recessed by at least $2\ \mu\text{m}$ (and no more than $200\ \mu\text{m}$) with respect to each of the first and second outer layers. *Supra* ¶¶84-87. While CN182 does not expressly disclose such a light trap, it would have been obvious to implement the CN182 shading ring with a light trap having dimensions that satisfied Element 1.6.

104. Given CN182's express goal of avoiding stray light reflections off the inner surface of the through-hole, and knowledge regarding conventional stray light

suppression techniques, POSITAs would have promptly recognized the benefits of using the CN182 etching process to implement CN182's shading ring with a conventional "light trap." POSITAs thus would have naturally and predictably used CN182's etching process to further erode the inner layer of PET material relative to the outer carbon layers to a depth that efficiently trapped incident stray light. While many obvious variants would have dimensions within the claimed range and satisfy Element 1.6, exemplary obvious implementations of CN182 include **a light trap from 5.2-9.7 μ m deep** along the circumference of the inner surface, as shown here in the following cross-section:



Such a light trap satisfies the claimed conditions. *Infra* ¶¶127-128. The below subsections explain why POSITAs were motivated with a reasonable expectation of success to implement such light traps, and how near-contemporaneous development by others confirms the obviousness of the challenged claims.

105. Given that light traps had long been used to improve optical designs by reducing stray light, this obvious design simply used known light trap techniques to improve similar optical systems in a predictable way. CN182 already applies 1 of

the 3 common techniques for reducing stray light reflections, namely roughening the PET surface by etching it. *Supra* ¶¶53-67. Using that same process to further etch the middle PET layer, thus creating a light trap by altering the surface's shape, applies the other two common stray light mitigation techniques. The three techniques (roughening, light traps, and altering the shape) were complementary and regularly used together in reducing stray light reflections off the inner surface of light-blocking elements. *Supra* ¶¶53-67. Because of this, POSITAs naturally would have extended CN182's etching process to also create a light trap, thus achieving the benefit of further reducing stray light reflections.

**a) POSITAs Would Have Been Motivated To Adapt The
CN182 PET Substrate Etching Process To Create A
Light Trap Between The Two Outer Carbon Layers**

106. CN182 states a goal of minimizing reflections off the inner surface of the shading ring, thus reducing undesirable glare, i.e., “avoid the occurrence of glare, halo and flare caused by the reflection from the hole-wall of the through-hole, thereby ensuring the capturing effect and improving the quality of the imaging products.” EX1004, Abstract; *see also id.*, [0003], [0019].

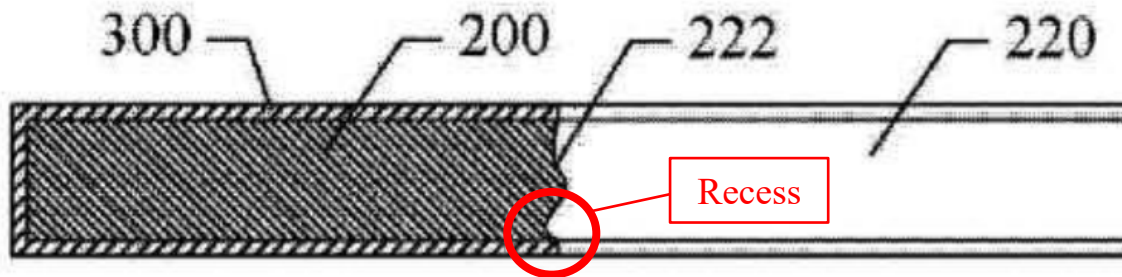
107. To further this goal, CN182 uses one of the three well-known techniques for reducing inner surface reflections within an optical system, namely *roughening* the inner PET material to create a “matte” surface. *E.g.*, EX1004, [0002] (describing “past” metal stray light blockers that achieved “complete matting”),

[0019] (describing how matte structure helps minimize glare “caused by the reflection from the hole-wall of the through-hole”), [0035] (same), [0040] (same); *supra* ¶¶53-67 (explaining the three known techniques of baffles / light traps, altering the reflecting edge surface, and surface roughening/blackening); EX1007, 120 (2009 book explaining that stray light “usually handled using *one or more of* [these] three methods”) (emphasis added).

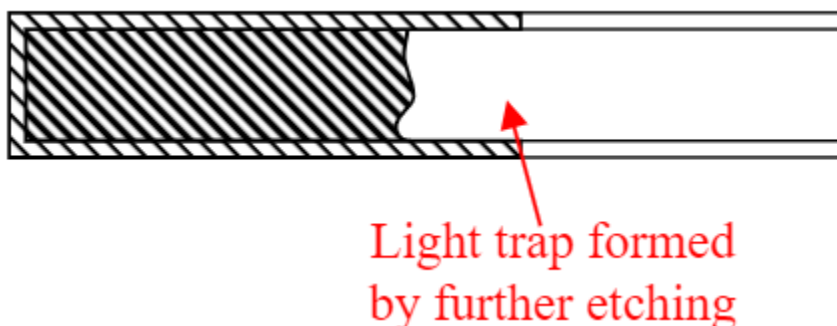
108. Given the expressly stated (and commonly known) goal of reducing reflections off the CN182 shading ring’s inner surface, a POSITA would have been motivated to use the two other established techniques that were “usually” employed for reducing those reflections: (i) baffles or light traps and (ii) altering the shape of the reflecting inner surface. *Supra* ¶¶53-64. A POSITA’s toolbox included these two other compatible methods for addressing such reflections, and often deployed them together. POSITAs would have been motivated to employ these known-compatible solutions to the same problem of reducing stray light reflections, as stray light reduction often “require[d] multiple techniques.” *E.g.*, EX1007, 121 (“[I]t may require multiple techniques to prevent unwanted reflections from reaching the image plane.”). Indeed, Schaub explains that POSITAs regularly used “one or more” of these methods to solve the stray light problem (EX1007, 120:37-38) and gives a specific example of using two in combination, altering the shape of the surface by adding a chamfer *and* roughening it (*id.*, 122:29-40). *Id.* (noting “the potential

benefits of making the effort, and taking the time, to perform stray-light analysis). Thus, POSITAs would have recognized that use of these additional techniques would have furthered CN182's goal by further reducing stray light and improving image quality. POSITAs knew that these techniques provided additional benefits, and would further improve image quality, thus motivating a POSITA to employ light trap and shape altering techniques to the inner surface of the CN182 shading ring. Especially so, because CN182 already shows that its etching process would create recesses in the middle PET layer.

109. POSITAs would have recognized that a simple, elegant extension of the CN182 etching process would beneficially create a stray light trap and reduce the inner surface area of the shading ring, thus reducing stray light reflections and glare. CN182 teaches etching the PET surface, explaining that the surrounding carbon layers are "less sensitive" to the etching solution and "basically will not be etched." *E.g.*, EX1004, [0038]. While the stated purpose of this etching is to "form a matte structure" on the inner surface of the hole wall (*e.g.*, *id.*), a POSITA knew that this process etched away the PET while leaving the carbon layers in place. Indeed, this is reflected in CN182 Figure 3, which shows portions of the middle PET layer recessed relative to the first and second outer carbon layers:



EX1004, FIG. 3 (cropped and annotated). A POSITA would have recognized that prolonging, or otherwise modifying, this etching process would have led to further etching and recessing of the middle PET layer, beneficially creating a light trap. *Supra* ¶¶53-68; EX1027, 277-283 (explaining how the micro-optics industry adopts etching techniques from semiconductor processes to achieve submicron accuracy and “allow[] manufacturing ... of high-quality micro-optics at reasonable costs”); EX1008, 736-37 (specifying to “use the three bounce rule” and to “[e]mploy threads, baffles, and fields stops where possible”); *id.*, 768 (“Always consider the possible effects of stray light, and provide suitable baffles and low-reflectivity interior system finish to attenuate it.”).



110. By *altering the surface* of the inner PET surface to *form a reflection-reducing light trap*, this natural extension of the CN182 etching process employs the other two known anti-reflection: baffled light traps and modifying the inner surface of the light-reflecting element. As explained above, adding a light trap at the edge of a baffle vane, such as a light-blocking sheet or shading ring, was a technique known for decades for addressing edge reflections. *E.g.*, EX1014, 5; *supra* ¶¶56-64, 68. And the CN182 etching process provided an elegant way to alter the inner surface of the shading ring to create the desirable light trap. *Supra* ¶¶61-64 (altering the edge shape was another known technique to reduce stray light reflections). Given this knowledge and the teachings and stated goal of CN182, a POSITA would have been motivated to create a recess in the PET body of the shading ring in CN182, thus forming a light trap and further reducing glare. Large portions of stray light incident on the hole-wall edge would reflect within the light trap recess back towards the object direction or be absorbed by the outer carbon powder layers, rather than reflect towards the image sensor. And there would be a markedly decreased surface area for reflections, only on the outer carbon layers. As implemented in the CN182 system, this light trap would thus reduce stray light by reducing the inner surface area from which stray light might reflect to just the carbon layers. Stray light that might otherwise reflect off the inner substrate layer would be trapped, thus improving image quality. For example, in a conventional design with outer carbon

layers of 6 μ m, the stray light surface would be limited to only 12 μ m, as opposed to 25 μ m in the absence of the light trap. Thus, this light trap furthered CN182's "main object" of addressing glare and other "undesirable effects caused by ... the reflection from the inner-wall of the through-hole." EX1004, [0002-0003].

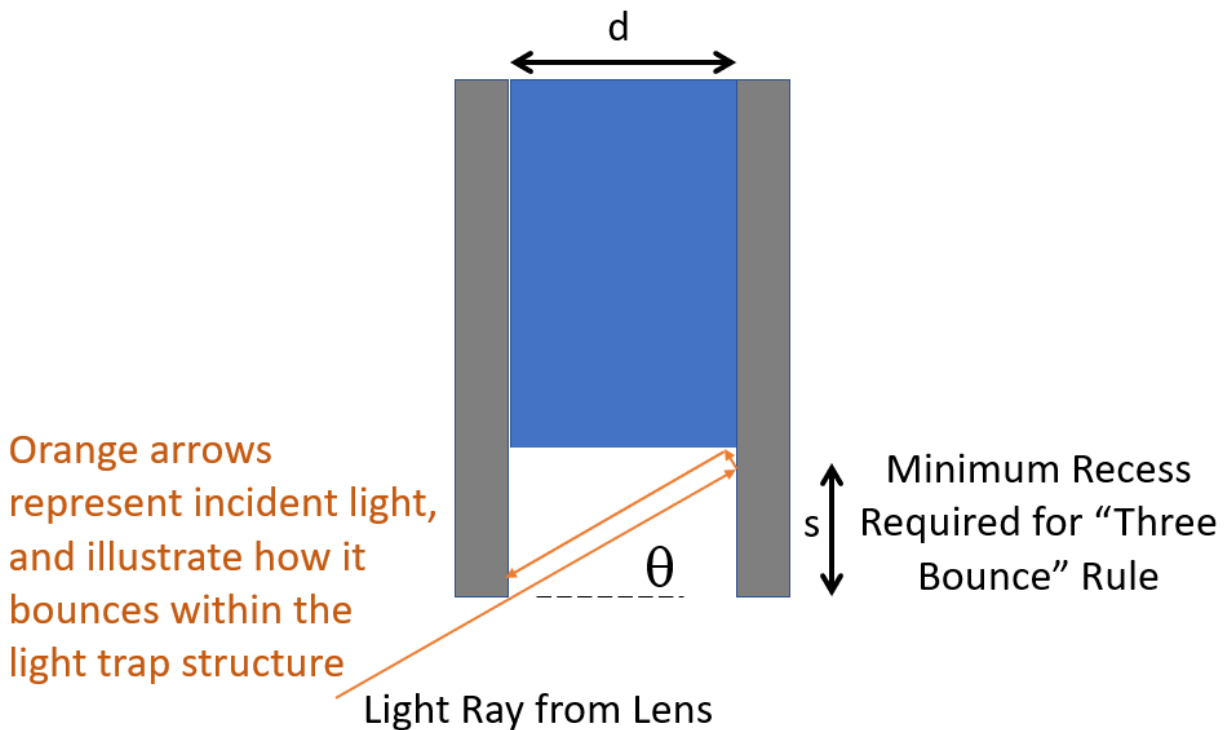
111. Thus, a POSITA would have been motivated to adapt the CN182 etching process to intentionally etch back the PET material in the three-layer structure, such that the outer carbon-containing layers form two vanes with an open space between them at the hole-wall, because this structure would efficiently trap light and more effectively reduce glare. EX1004, [0026]-[0028] (describing three-layer structure); *id.*, [0028]-[0034] (describing how to corrode the PET layer). This aligns with, and was an easily recognizable application of, known approaches that incorporated a baffle / light trapping feature in the inner surface of a light-blocking sheet / spacer. *Supra* ¶¶56-64, 68.

b) POSITAs Would Have Been Motivated To Create The Light Trap With Dimensions In The Claimed Range

112. A POSITA would have known to follow the established "three-bounce rule" in determining how deep to etch the PET layer to sufficiently "trap" and reduce the power of any incident stray light. *Supra* ¶¶69-72; EX1008, 722-725 (explaining a general approach to "Optimal Baffle Geometry" that satisfies the "Three Bounce Rule"). In this regard, a POSITA knew that the incoming angle of stray light and the

distance between the vanes (in this case the distance between the outer carbon layers) factored into the proper depth of the light trap. *Supra* Section IV.C.1; EX1005, 6, Figure 1 (depicting bounced light within baffle feature); EX1010, 7.13 (explaining the process for “Designing the Vane Spacing and Depth”); EX1008, 718 (explaining the relationship between vane pitch and vane depth). Thus, POSITAs would have used basic optical principles to calculate dimensions for the light trap.

113. Applying these optical principles, the minimum recess required to satisfy the “three bounce” rule would be readily determined by simple modeling of a light ray entering the leading edge of the light blocking sheet and calculating the minimum recess depth as $d \cdot \tan(\theta)$, where d is the thickness of the PET substrate layer and θ is the incoming angle of stray light. *Supra* ¶¶69-72; EX1008, 723-725 (explaining how baffle/vane positions obstruct light at largest incoming field angles to “retro-reflect [light] back toward the entrance aperture” or otherwise attenuate light if additional bounces direct the light toward the focal plane, satisfying the three-bounce rule).



In order to have at least three bounces, one from the second outer layer (rear inside surface), one from the inner substrate layer (PET), and one from the first outer layer, the recess must be at least $d \cdot \tan(\theta)$ deep, where d is the width of the inner substrate layer (e.g., the distance between vanes) and θ is the angle of the ray from the previous lens. Any light ray with the same θ striking the second outer layer in a different location will exhibit at least three bounces. If the recess were shorter, a light ray could bounce out of the trap with only two bounces. The POSITA knew that the largest possible incident angle dictated the desirable depth. This is because lesser angles would lead to even more bounces within the trap, thus effectively reducing reflections. Below I illustrate how shallower angles result in several bounces off the

carbon outer layers before even reaching the PET layer, thus yielding even more effective light trapping.

114. Following conventional light-blocking sheet design, a POSITA would have been motivated to implement CN182 with carbon layers having thicknesses from 4-6 μ m and thus a middle PET layer of 13-17 μ m for CN182's total thickness of 25 μ m. These thicknesses would balance ensuring structural stability with minimizing edge reflections. A POSITA would have known that the thickness of the outer carbon powder layers requires a balancing of minimizing edge reflections and maintaining structural stability and light-absorbing efficacy: outer layers that are too thick could continue to reflect light off the edge, while outer layers that are too thin may not maintain sufficient mechanical strength and shape stability after etching the PET layer to form a light trap. For example, Schaub recognizes the balance between making such edge surfaces thin to avoid reflections but also thick enough to provide sufficient structure: "[t]he thickness should be thin enough to limit potential reflections from the inner diameter of the washer but thick enough to allow for handling." EX1007, 125:20-21. Similarly, Hirata explains that the thickness of a "light shield sheet" is "necessary in terms of essential light shielding effect, mechanical strength, shape stability, reliability in environments, handling ability in assembling, and so on." EX1018, 1:37-40.

115. CN182 discloses a total shading ring thickness of 25 μ m, including the PET layer and the outer carbon powder layers. EX1004, [0013] (“a thickness of the shading ring is 0.025 mm”), [0037]. Cho discloses a similar three-layer light-blocking structure with a total thickness from 25 μ m to 80 μ m and “a thickness of each outside layer ... between 4 μ m and 15 μ m,” suggesting that each outer layer of a 25 μ m-thick shading ring would be at least 4 μ m and possibly more. EX1006, [0020]. Toshima discloses a “light-shielding material” for use in a “camera-equipped cellular phone,” where the light-shielding material includes a substrate with a black “light-shielding coat” (i.e., an outer carbon powder layer) formed on the substrate (i.e., a PET substrate). EX1031, 3:10-18, 4:43-50 (disclosing carbon black as black fine particles in the outer light-shielding coat), 10:15-20 (disclosing a PET substrate). Toshima explains that “[a] thickness of the light-shielding coat can be changed arbitrarily in accordance with a use purpose of applying the light-shielding material,” with normal ranges of “2 μ m to 15 μ m,” “2 μ m to 12 μ m,” and “2 μ m to 10 μ m,” in order of increasing preference, while noting “increasing demands for a thinner layer (for example, thinner than 6 μ m or so) particularly to the light-shielding coat in recent years.” EX1031, 3:18-25, Table 2 (evaluating light-shielding performance of light-shielding coats ranging from 3 μ m to 10 μ m thickness). This is consistent with the “conventional” Fig. 1 light-blocking sheet described in the ’660 patent with the same dimensions as its Figure 4 embodiment, which has a total

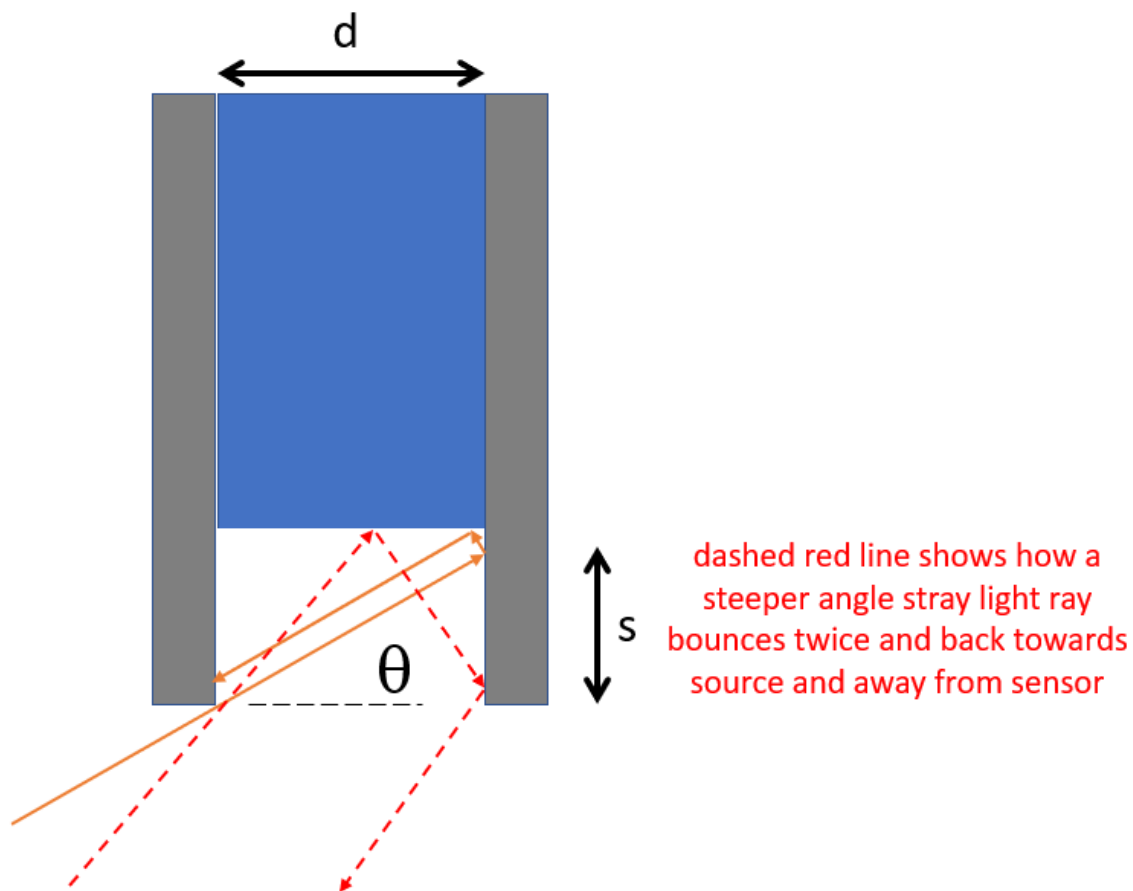
thickness (t) of $29.5\mu\text{m}$ and a substrate layer thickness (d) of $17.5\mu\text{m}$, and thus carbon layers each having a $6\mu\text{m}$ thickness. *E.g., compare* EX1001, FIG. 1B (labeled “prior art”) *with* FIG. 4 (embodiment of alleged invention with same layer thicknesses as FIG. 1B); *see also id.*, 9:36-55 (describing FIG. 4 total thickness t of $29.5\mu\text{m}$ and substrate layer d of $17.5\mu\text{m}$).

116. A POSITA would recognize that, for a shading ring with total thickness of $25\mu\text{m}$, the thickness of a conventional carbon outer layer would range from a floor of $4\mu\text{m}$ (as suggested by Cho) up to $6\mu\text{m}$ (as taught by Toshima and admitted as conventional by the '660 patent). For a total thickness of $25\mu\text{m}$, as CN182 discloses, outer layer thicknesses of $4\text{-}6\mu\text{m}$ would provide a PET layer thickness of $13\text{-}17\mu\text{m}$. POSITAs would have understood that carbon layers of $4\text{-}6\mu\text{m}$ thickness reduced the light-reflecting surface area and yet would provide structural support for most applications. After etching the PET layer of CN182's shading ring, there would be no substrate between the outer layers in the light trap, so retaining shape stability and mechanical strength of the outer layers at the light trap is an important consideration. A POSITA would have been motivated with a reasonable expectation of success to select a larger thickness in this range, such as $6\mu\text{m}$, for deeper light traps, to minimize edge reflections and maintain structural stability.

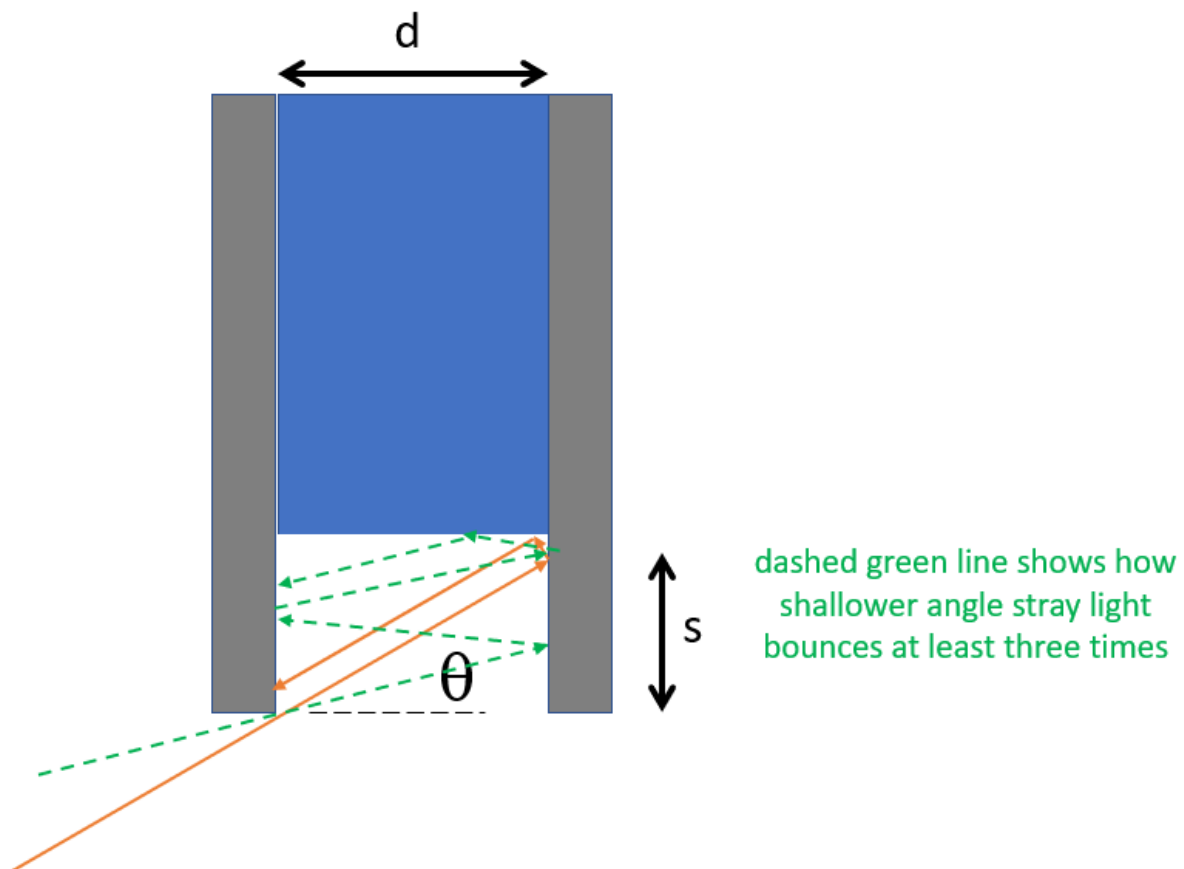
117. While a given light trap implementation would depend on the associated optical design, POSITAs understood that designing a trap for stray light

at a 30-degree angle of incidence would provide satisfactory stray light attenuation for most designs.

118. While stray light might arrive at incidence angles even greater than 30 degrees in some designs, POSITAs understood that this would be less common and that such stray light would be more likely to bounce off additional structures and thus would be sufficiently otherwise weakened prior to reaching the sensor. The POSITA also knew that light at a range of higher incidence angles would still bounce at least twice within the trap and, ultimately, often exit in a desirable direction away from the image sensor.



And light incident at less than 30 degrees would be adequately “trapped” because it would reflect at least three times within the trap and likely even more—this is because the shallower/smaller the incidence angle, the more the light tends to bounce within the trap (and thus the more it tends to be “trapped”). This is illustrated by a basic diagram showing how a light trap designed to capture light incident at roughly 30 degrees will also capture light incident at shallower angles, such as roughly 15 degrees:



As shown, the smaller the angle, the greater the number of bounces.

119. Thus, a light trap designed to create three bounces for stray light at incidence angles up to 30 degrees would be a reasonably good choice for a system. While certain designs might allow for a shallower angle, and others might benefit from a steeper angle, a trap that provided three bounces for 30 degrees of incident light would markedly reduce stray light reflections and associated downsides such as glare, and be sufficient for most designs. If a particular design required better trapping, then POSITAs knew how to easily adjust the dimensions accordingly using the basic $s = d \cdot \tan(\theta)$ equation.

120. Thus, given a conventional substrate thickness of $13\mu\text{m}$, POSITAs would have been motivated to use the CN182 etching process to etch back the substrate layer by $13\mu\text{m} \cdot (\tan 30^\circ) = \mathbf{7.5\mu\text{m}}$. Were the substrate thickness $17\mu\text{m}$, then the equation would yield $17\mu\text{m} \cdot (\tan 30^\circ) = \mathbf{9.8\mu\text{m}}$. For slightly thicker carbon layers of $8\mu\text{m}$, and a resulting substrate thickness of $9\mu\text{m}$, the etch depth would be $9\mu\text{m} \cdot (\tan 30^\circ) = \mathbf{5.2\mu\text{m}}$.

121. Confirming that these were appropriate depths, the Fischer optical design book rule of thumb (make the trap depth $\frac{1}{2}$ the trap width, *supra* ¶¶69-72; EX1008, 718) yields comparable depths of $6.5\mu\text{m}$, $8.5\mu\text{m}$, and $4.5\mu\text{m}$. Moreover, as the ray angle increases, so does the minimum recess. Thus, if a design needed to handle steeper angles of incident light, it would result in deeper recesses. The following table provides dimensions for other exemplary light traps that would have

been obvious and also satisfy the claims, with light trap depth in the right-hand column, for a given PET middle layer thickness d and incidence angle θ :

PET = 13μm thick	θ	θ (radians)	$\tan \theta$	$d * \tan \theta$
	15	0.26	0.27	3.48
	30	0.52	0.58	7.51
	45	0.79	1	13
	60	1.05	1.73	22.52
	75	1.31	3.73	48.52
PET = 17μm thick	θ	θ (radians)	$\tan \theta$	$d * \tan \theta$
	15	0.26	0.27	4.56
	30	0.52	0.58	9.81
	45	0.79	1	17
	60	1.05	1.73	29.44
	75	1.31	3.73	63.44

To account for process variations and possible uneven etching across the surface, an ideal recess would be slightly larger than the minimum.

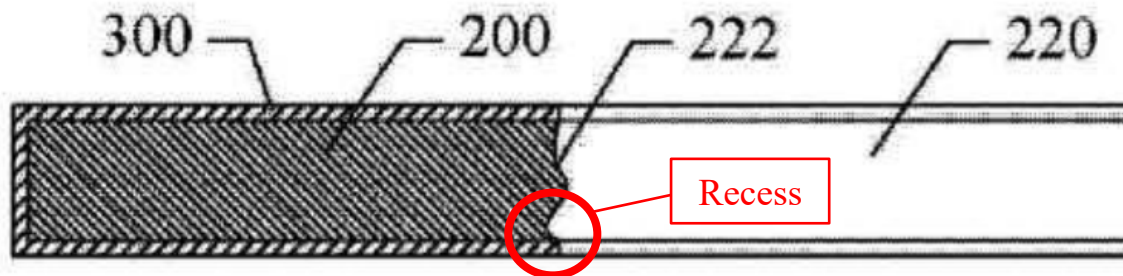
122. Thus, using basic optical principles and at most simple trigonometric math, POSITAs would have been motivated to use the CN182 process to etch back the PET material to form an inner surface light trap with a depth that satisfied the claimed range. *E.g.*, EX1004, [0028]-[0034] (describing how to corrode the PET layer). While the specific depths of **5.2-9.8 μ m** are discussed in detail above, other designs with depths in the claimed range also would have been obvious choices.

**c) A POSITA Would Have Expected Success In
Implementing Such A Light Trap Using The
Known Etching Processes Described In CN182**

123. In addition to the above-explained motivation, POSITAs would have reasonably expected to succeed in implementing the CN182 shading ring with a light trap of the noted dimensions, using the CN182 etching process. CN182 already explains how to create a recess in the PET layer of the shading ring and the POSITA would have immediately recognized that—without any additional steps—adaptation of the existing etching step would further improve the design by creating a light trap. POSITAs knew that additional etching of the PET layer with the alkali solution as taught by CN182 would remove PET to a desired depth, because the etch rate of the PET layer is much higher than the etch rate of the outer carbon powder layers, thereby allowing selective etching of the PET layer. EX1004, [0006], [0028], [0038] (explaining that the carbon powder layer “basically will not be etched with the alkali solution”); EX1016, 609 (“Etch selectivity is the ratio of the etch rates of the different materials in an etch process.”); *id.*, 613 (“Most wet chemical etchants etch isotropically.”); EX1027, 277-78 (explaining how the micro-optics industry commonly uses equipment and techniques optimized by the semiconductor industry to achieve submicron accuracy in manufacturing), 278-79 (explaining how etching processes including “a standard wet-chemical developing process” were applicable

to micro-optics systems and how changing etch rates helps control precise shaping during the process).

124. The method of etching the PET body disclosed in CN182 is also known as wet etching or chemical etching, which “involves the use of liquid etchants” where material is “immersed in the etchant solution and the exposed material is etched mostly by chemical processes.” EX1016, 609. A POSITA would have recognized that the wet-etching process taught by CN182 already creates a partial recess within the hole-wall, as shown in CN182’s Figure 3, cropped and annotated below to indicate where the PET layer partially recedes from the outer carbon layers:



EX1004, FIG. 3 (cropped and annotated). A POSITA would have immediately recognized that further etching of the shading ring would lead to the PET layer being etched deeper across the opening. And CN182 also explains what POSITAs knew, namely that temperature and movement increased the etch rate and thus predictably facilitated further etching. EX1004, [0034] (“Heating and stirring further guarantee the etching effect; at the same time, the etching time is shortened and the processing

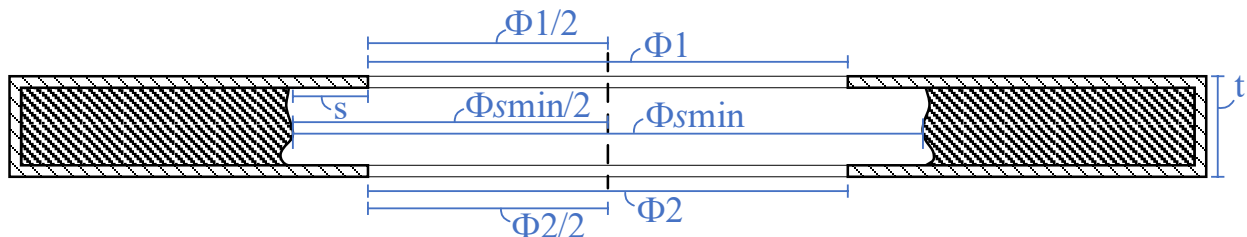
efficiency is improved.”); *id.*, [0039]. The ’660 patent’s own lack of description on the process used to create its preferred embodiments confirms that POSITAs knew how to selectively etch back the PET layer in conventional Carbon-PET-Carbon light-blocking elements.

125. As further confirmation, Dr. Bentley, a Largan expert in a proceeding on the Indian counterpart to the ’660 patent, explained that “the process of chemical etching (also for spacers) was already known.” EX1028, ¶42 (parentheses original). For a desired depth, “the process parameters can be varied to yield the desired outcome” and, “if product details are known or understood, an average skilled or skilled person can work backwards to formulate process parameters to achieve that product.” *Id.* This is because the chemical etching process, as taught by CN182 for light-blocking elements, is predictable and “can be controlled with a great degree of precision and accuracy.” *Id.*, ¶18. Otherwise, “it would not be the preferred process for manufacturing high end and sophisticated products requiring dimensional characteristics at miniscule level such as chipsets in the semiconductor industry, or light blocking sheets in miniature camera lenses for smartphones.” *Id.*; *see also id.*, ¶7. Finally, the ’660 patent’s lack of any description on how its allegedly inventive light-blocking sheet is created is consistent with my opinion that POSITAs knew that etching processes would create a light trap of the desired depth.

126. Thus, a POSITA would have been motivated with a reasonable expectation of success to implement the shading ring of CN182 with a light trap of a depth that fell within the claimed range.

d) These Obvious Light Traps Satisfy Element 1.6

127. As I explained in the preceding sections, POSITAs would have been motivated with a reasonable expectation of success to implement the CN182 shading ring with a light trap, including light traps at least $5.2\text{-}9.8\mu\text{m}$ deep at any given point around the inner circumference of the shading ring. As a matter of claim construction, Element 1.6 encompasses light traps of these depths. *Supra* ¶¶82-87. Here, I also explain how such light traps satisfy the mathematical conditions of Element 1.6. The following labeled figure helps illustrate these conditions in the context of obvious CN182 implementations:



128. For an exemplary light trap depth of $5.2\mu\text{m}$, at any given point the PET layer is etched back at least $5.2\mu\text{m}$ with respect to each of the first and second carbon outer layers. Thus, because the recited Φ values represent diameters of a cross-section and the PET layer is etched back on either side of that cross-section and

because each of the carbon outer layers has the same diameter, each of $\Phi_{\text{min}}-\Phi_1$ and $\Phi_{\text{min}}-\Phi_2$ is $10.4\mu\text{m}$. Plugging these values into the recited conditions yields:

$$2.0\mu\text{m} < (10.4\mu\text{m})/2 < 200\mu\text{m}$$

$$2.0\mu\text{m} < (10.4\mu\text{m})/2 < 200\mu\text{m}$$

Applying the divisor of 2 in the middle portion of the equation yields:

$$2.0\mu\text{m} < (5.2\mu\text{m}) < 200\mu\text{m}$$

$$2.0\mu\text{m} < (5.2\mu\text{m}) < 200\mu\text{m}$$

Similarly, light traps of $7.5\mu\text{m}$ and $9.8\mu\text{m}$ would also each result in the conditions being satisfied, with $\Phi_{\text{min}}-\Phi_1$ and $\Phi_{\text{min}}-\Phi_2$ of $15\mu\text{m}$ and $19.6\mu\text{m}$, for each respective light trap. Again, applying the divisor of 2 to these values results in values of $7.5\mu\text{m}$ and $9.8\mu\text{m}$, each of which is greater than $2.0\mu\text{m}$ and less than $200\mu\text{m}$. Thus, the obvious light trap depths of at least $5.2\text{-}9.8\mu\text{m}$ results in shading rings that satisfy the claimed ranges. Other obvious light traps, including those with dimensions indicated in the table above in paragraph 121, also would have satisfied the claim elements.

**e) Another Contemporaneous Patent
Confirms My Opinions On Obviousness**

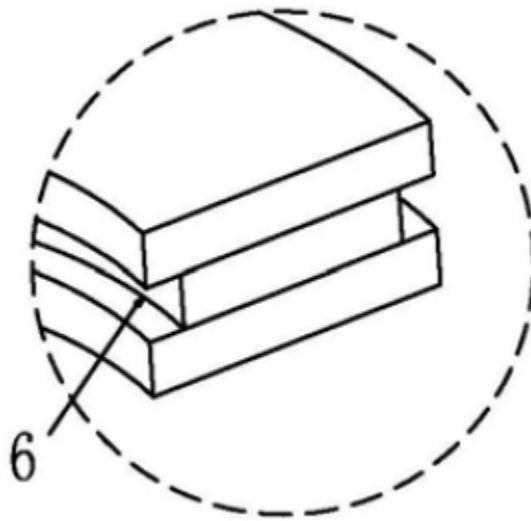
129. Another patent confirms that POSITAs would have immediately recognized the benefits and feasibility of adapting CN182 to include a light trap on the inner surface of a light-blocking sheets, thus further establishing the motivation

to combine and reasonable expectation of success. Chinese Patent Application Publication No. CN 107045249B (EX1015, “CN249”) was filed March 6, 2017, less than one month after the U.S. filing date of the ’660 patent and less than 4 months after the November 14, 2016, filing date of the ’660 patent’s alleged Taiwanese priority application.

130. CN249 refers expressly to the processing method and shading ring of CN182 and discusses how CN182’s shading ring “can reduce the reflection or diffusion of stray light to a certain extent,” but observes that “there is still an obvious phenomenon of stray light.” EX1015, [0004]-[0005]. To further reduce this stray light, CN249 teaches using the same approach of CN182, namely wet etching a light-shielding sheet comprising a base material made of PET and coated with carbon layers with a light hole “made by a [punching] process.” EX1015, [0030]-[0037]. CN249 discloses “etch[ing] the [base material] 4 on a [hole] wall [surrounding] the light-through hole 2 to form a depression 6, [thereby] suppress[ing] the stray light in an optical lens from diffusing or reflecting to an imaging surface, thereby ensuring a shooting effect and improv[e] the quality of [] camera product[s].” *Id.*, [0032].

131. CN249 shows the light trap created from this etching process in its FIG. 3 (reproduced below), noting that the “depth of the depression 6 of the [base material] 4 is equal to a thickness of the [base material] 4.” *Id.*, [0038]. A POSITA would recognize that this is a light trap that creates three bounces for light entering

at 45 degrees or less, as $\tan(45^\circ) = 1$, and thus applying the equation $s = d \cdot \tan(\theta)$ would yield a depth s equal to the width d .



EX1015, FIG. 3. This disclosure in CN249 corresponds exactly to how POSITAs would have applied CN182's teachings on stray light reduction to create a light trap and achieve additional reductions in glare.

C. Claim 2

2. The light blocking sheet of claim 1, wherein the inner substrate layer is made of a plastic material, and each of the first outer layer and the second outer layer is made of a black carbon-containing material.

132. CN182 renders obvious the light blocking sheet of claim 1, as discussed *supra* ¶¶97-131. CN182 further discloses the inner substrate layer is made of a plastic material, and each of the first outer layer and the second outer layer is made of a black carbon-containing material. Specifically, CN182 discloses “a body” (inner

substrate layer) and “an antistatic coating coated on the body” (the first outer layer and the second outer layer), where “the body is made of plastic material, [and] the antistatic coating is a carbon powder layer.” EX1004, [0026]. A POSITA would have known that the carbon powder layer is black, and thus a “black carbon-containing material,” because carbon powder, also referred to as “carbon black,” is a well-known material for creating light-absorbant black surfaces. *E.g.*, EX1011, 6.15 (discussing “tools ... available to the black surface designer to tailor the optical properties” such as “absorbing compounds” including “carbon black particles”); *id.*, 6.35 (discussing paints used as “standards for black coatings” that “consisted of pigments with approximately 20 percent carbon black and 80 percent silicon dioxide”).

D. Claim 3

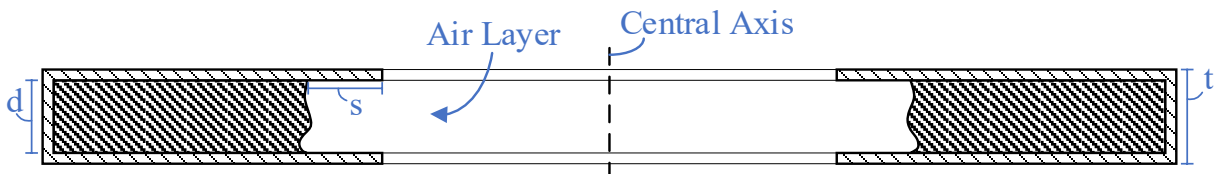
3. The light blocking sheet of claim 1, wherein the minimum diameter of the substrate opening is Φ_{min} , the diameter of the first opening is Φ_1 , the diameter of the second opening is Φ_2 , and the following conditions are satisfied:
 $3.0\ \mu\text{m} < (\Phi_{\text{min}} - \Phi_1)/2 < 85\ \mu\text{m}$; and
 $3.0\ \mu\text{m} < (\Phi_{\text{min}} - \Phi_2)/2 < 85\ \mu\text{m}$.

133. CN182 renders obvious claim 3, as the obvious light traps discussed above satisfy the recited conditions, which merely narrow the Element 1.6 conditions. Obvious implementations of CN182 had light traps with minimum depths between $3\ \mu\text{m}$ and $85\ \mu\text{m}$, relative to each outer carbon layer, thus rendering claim 3 obvious. *Supra* ¶¶82-87 (claim construction), 103-131 (element 1.6).

E. Claim 4

4. The light blocking sheet of claim 1, further comprising:
an air layer located between the first outer layer and the second outer layer,
wherein the air layer is close to the first opening and the second opening.

134. CN182 renders this claim obvious, as the obvious light trap discussed above forms an air layer located between the first outer layer and the second outer layer, wherein the air layer is close to the first opening and the second opening. *Supra* ¶¶103-131 (element 1.6). The light trap is an “air layer” because there is no material within the recess.



F. Claim 5

5. The light blocking sheet of claim 4, wherein a length parallel to the central axis of the air layer is d , and the following condition is satisfied:
 $5\text{ }\mu\text{m} < d < 49\text{ }\mu\text{m}$.

135. CN182 renders this claim obvious. The claimed condition relates to the thickness of the air layer, which is equal to the thickness or width of the inner substrate layer. As explained above, obvious implementations of the CN182 shading ring had air/substrate layer thicknesses of 13-17 μm , which fall within the claimed range. *Supra* ¶¶103-131 (element 1.6).

G. Claim 6

6. The light blocking sheet of claim 4, wherein a thickness of the light blocking sheet is t , and the following condition is satisfied:
 $5\text{ }\mu\text{m} < t < 49\text{ }\mu\text{m}$.

136. CN182 renders this claim obvious because it discloses a shading ring (light blocking sheet) thickness of $25\text{ }\mu\text{m}$, which is within the claimed range of $5\text{ }\mu\text{m} < t < 49\text{ }\mu\text{m}$. EX1004, [0013] (disclosing a preferable thickness of 0.025 mm , which is $25\text{ }\mu\text{m}$), [0018] (same), [0027] (same), [0037] (same).

H. Claim 7

7. The light blocking sheet of claim 4, wherein a length parallel to the central axis of the air layer is d , a thickness of the light blocking sheet is t , and the following condition is satisfied:
 $0.12 < d/t < 0.67$.

137. CN182 renders this claim obvious. The claimed condition relates to the ratio of the thickness of the air layer (which is the same as the thickness of the substrate) to the thickness of the entire light-blocking sheet. CN182 discloses a total thickness of $25\text{ }\mu\text{m}$ (*supra* claim 6) and renders obvious PET substrate layer / air layer thicknesses of $13\text{-}17\text{ }\mu\text{m}$ (*supra* claim 5). Those designs with thicknesses from $13\text{-}16.74\text{ }\mu\text{m}$ fall within the claimed range, thus rendering this claim obvious. *Supra* ¶¶114-116, 135.

I. Claim 8

8. The light blocking sheet of claim 1, wherein the diameter of the first opening is $\Phi 1$, the diameter of the second opening is $\Phi 2$, and the following condition is satisfied:

$$0.93 < \Phi 1 / \Phi 2 < 1.07.$$

138. CN182 renders this claim obvious because the diameter of the through-hole is the same for both outer carbon layers, such that the diameter of the first opening $\Phi 1$ is the same as the diameter of the second opening $\Phi 2$. EX1004, [0026] (“the through-hole is formed by stamping”), [0027] (“the diameter of the through-hole is 2.14 mm”). As a result, $\Phi 1 / \Phi 2 = 1$, which is within the claimed range.

J. Claim 9

9. The light blocking sheet of claim 1, wherein a maximum outer diameter of the light blocking sheet is Φ , a thickness of the light blocking sheet is t , and the following condition is satisfied:

$$1 < 1000t / \Phi < 50.$$

139. CN182 renders this claim obvious. CN182 does not explicitly disclose a maximum outer diameter of the shading ring (light blocking sheet), but the thickness t of the CN182 shading ring (light blocking sheet) is 0.025 mm. EX1004, [0027]. The minimum outer diameter of the CN182 shading ring (light blocking sheet) is *at least* the diameter of the through-hole (2.14mm) plus the light trap recess (e.g., 0.0098mm times two) for a minimum outer diameter of 2.160mm. EX1004, [0027] (“the diameter of the through-hole is 2.14 mm”); *supra* ¶¶118-120 (example light-trap depth of 9.8 μ m). This minimum boundary for the maximum outer

diameter satisfies the condition because $1000 \cdot (0.025 \text{ mm}) / 2.160 \text{ mm}$ is 11.57, which is within the claimed range.

140. POSITAs knew that elements in cell phone camera systems, which includes shading rings/spacers, had “diameters in the 3-5mm range” as of 2006. EX1017, 1. Thus, when implemented in cell phone camera systems as prescribed (e.g., EX1004, [0002]), the maximum outer diameter of the CN182 shading ring would be within this 3-5 mm range. A maximum outer diameter of 3 mm, for example, satisfies the condition because $1000 \cdot (0.025 \text{ mm}) / 3 \text{ mm}$ is 8.33, while a maximum outer diameter of 5 mm satisfies the condition because $1000 \cdot (0.025 \text{ mm}) / 5 \text{ mm}$ is 5.

141. Considering the boundaries of the condition $1 < 1000t/\Phi < 50$ and a thickness $t = 0.025 \text{ mm}$, the lower bound equates to a maximum outer diameter of 25 mm, while the upper bound equates to a maximum outer diameter of 0.5 mm. This comes from multiplying each group by Φ , yielding $\Phi < 1000t < 50\Phi$. Applying a thickness of 0.025mm, and solving for both aspects of this equations yields $\Phi < 25\text{mm}$ and $\Phi > 0.5\text{mm}$. A shading ring with a through-hole diameter of 2.14 mm cannot have a maximum outer diameter of 0.5 mm, and a POSITA would not expect a cell phone camera system to have an unreasonably large 25 mm diameter.

K. Claim 15

1. Element 15.1

[15.1] A light blocking sheet, comprising:

142. To the extent the preamble is limiting, CN182 discloses it for the same reasons discussed for claim 1. *Supra* ¶¶97 (element 1.1).

2. Element 15.2

[15.2] a first outer layer comprising a first opening;

143. CN182 renders this element obvious for the same reasons discussed with regard to claim 1. *Supra* ¶¶98-101 (element 1.2).

3. Element 15.3

[15.3] a second outer layer comprising a second opening;

144. CN182 renders this element obvious for the same reasons discussed with regard to claim 1. *Supra* ¶¶98-101 (element 1.3).

4. Element 15.4

[15.4] an inner substrate layer disposed between the first outer layer and the second outer layer, wherein the inner substrate layer connects the first outer layer to the second outer layer, and the inner substrate layer comprises a substrate opening;

145. CN182 renders this element obvious for the same reasons discussed with regard to claim 1. *Supra* ¶¶98-101 (element 1.4).

5. Element 15.5

[15.5] an air layer located between the first outer layer and the second outer layer, wherein the air layer is close to the first opening and the second opening; and

146. CN182 renders this element obvious for the same reasons discussed with regard to claim 4. *Supra* ¶134 (claim 4).

6. Element 15.6

[15.6] a central axis coaxial with the first opening, the second opening and the substrate opening;

147. CN182 renders this element obvious for the same reasons discussed with regard to claim 1. *Supra* ¶102 (element 1.5).

7. Element 15.7

[15.7] wherein a length parallel to the central axis of the air layer is d , a minimum diameter of the substrate opening is Φ_{smin} , a diameter of the first opening is Φ_1 , a diameter of the second opening is Φ_2 , and the following conditions are satisfied:

$5\ \mu\text{m} < d < 50\ \mu\text{m}$;
 $2.0\ \mu\text{m} < (\Phi_{smin} - \Phi_1)/2 < 200\ \mu\text{m}$; and
 $2.0\ \mu\text{m} < (\Phi_{smin} - \Phi_2)/2 < 200\ \mu\text{m}$.

148. CN182 renders this element obvious for the same reasons discussed with regard to claims 1 and 5. *Supra* ¶¶103-131 (element 1.6), 135 (claim 5).

L. Claim 16

16. The light blocking sheet of claim 15, wherein the inner substrate layer is made of a plastic material, and each of the first outer layer and the second outer layer is made of a black carbon-containing material.

149. CN182 renders this claim obvious for the same reasons discussed with regard to claims 15 and 2. *Supra* ¶¶142-148 (claim 15), 132 (claim 2).

M. Claim 17

17. The light blocking sheet of claim 16, wherein a thickness of each of the inner substrate layer, the first outer layer and the second outer layer is uniform.

150. CN182 renders this claim obvious for the same reasons discussed with regard to claim 16 and element 1.6. *Supra* ¶¶149 (claim 16), 103-131 (element 1.6). Further, CN182 depicts each layer, namely the body 200 and the antistatic coating 300 coated on both sides of the body 200, with a uniform thickness:

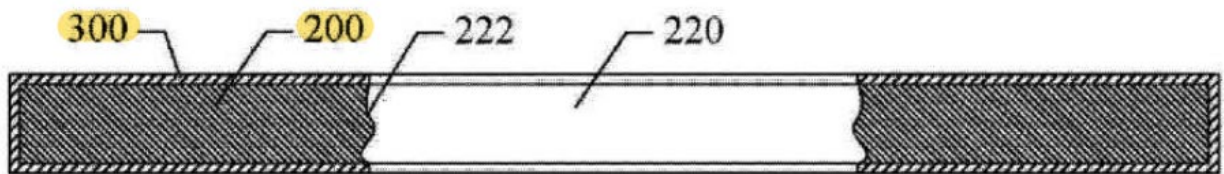


Figure 3

EX1004, FIG. 3 (highlighting added), [0036]. CN182 further discloses “the thickness of the shading ring is 0.025 mm,” indicating that the thickness is uniform across the shading ring. EX1004, [0037]. To achieve a uniform total thickness of the

shading ring, a POSITA would understand that each layer of the shading ring would be uniform.

151. CN182 renders this claim obvious for the same reasons discussed with regard to claims 1 and 16. *Supra* ¶¶149 (claim 16), 103-131 (element 1.6). Further, CN182 depicts each layer, namely the body 200 and the antistatic coating 300 coated on both sides of the body 200, with a uniform thickness:

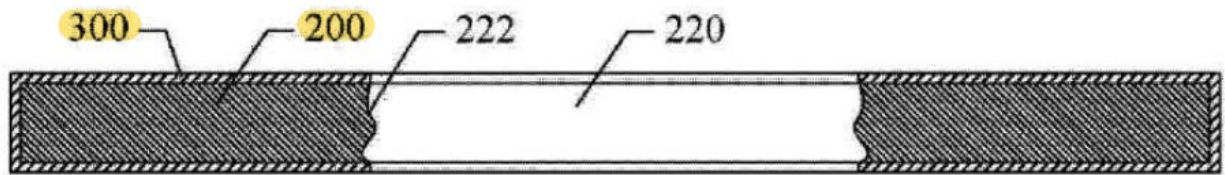
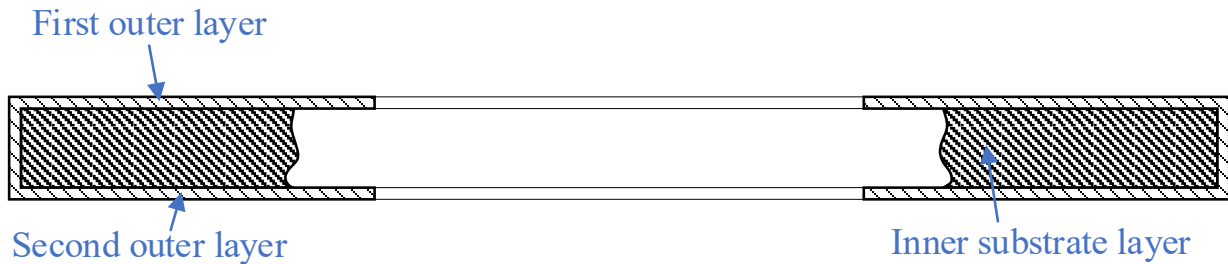


Figure 3

EX1004, Figure 3 (highlighting added), [0036]. CN182 further discloses “the thickness of the shading ring is 0.025 mm,” indicating that the thickness is uniform across the shading ring. EX1004, [0037]. To achieve a uniform total thickness of the shading ring, a POSITA would understand that each layer of the shading ring would be uniform.

152. Further, each layer of the CN182 shading ring has a uniform thickness across the shading ring:



A POSITA would expect a uniform thickness of each layer of the CN182 shading ring because the carbon powder layers (first and second outer layers) are “less sensitive to alkali solution and basically will not be [corroded] with the alkali solution,” while the PET body (inner substrate layer) is etched isotropically from the through-hole, which would not alter the uniform thickness of the PET body. EX1004, [0028], [0038]; *supra* ¶¶103-131 (element 1.6).

153. Therefore, CN182 renders obvious the “light blocking sheet of claim 16, wherein a thickness of each of the inner substrate layer, the first outer layer and the second outer layer is uniform.”

N. Claim 18

18. The light blocking sheet of claim 16, wherein the minimum diameter of the substrate opening is Φ_{smin} , the diameter of the first opening is Φ_1 , the diameter of the second opening is Φ_2 , and the following conditions are satisfied:
 $3.0\text{ }\mu\text{m} < (\Phi_{smin} - \Phi_1)/2 < 85\text{ }\mu\text{m}$; and
 $3.0\text{ }\mu\text{m} < (\Phi_{smin} - \Phi_2)/2 < 85\text{ }\mu\text{m}$.

154. CN182 renders this claim obvious for the same reasons discussed with regard to claims 1, 3, and 16. *Supra* ¶¶97-130 (claim 1), 133 (claim 3), 149 (claim 16).

O. Claim 19

19. The light blocking sheet of claim 16, wherein the length parallel to the central axis of the air layer is d , a thickness of the light blocking sheet is t , and the following condition is satisfied:
 $0.12 < d/t < 0.67$.

155. CN182 renders this claim obvious for the same reasons discussed with regard to claims 1, 7, and 16. *Supra* ¶¶97-131 (claim 1), 137 (claim 7), 149 (claim 16).

XI. GROUND 2: A POSITA WOULD HAVE FOUND CLAIMS 5, 7, 10, 14, 19, 20, AND 22 OBVIOUS OVER CN182 AND CHO

156. As explained below, claims 5, 7, 10, 14, 19, 20, and 22 are obvious over CN182 in view of Cho.

A. Cho (EX1006)

157. U.S. Patent Publication No. 2015/0022896 (EX1006, “Cho”) was filed October 31, 2013, published January 22, 2015, and qualifies as prior art under Sections 102(a)(1-2). EX1006, Cover. Cho is analogous art to the ’660 patent because they are both in the same field of endeavor of blocking stray light to reduce glare in compact imaging lens modules. EX1001, 1:14-17, 1:21-32; EX1006, [0002], [0004]-[0005].

158. Cho discloses a “spacer” used to block stray light in a “camera module of a portable electronic device (e.g. mobile phone, tablet computer, notebook computer, etc.).” EX1006, [0004], [0018], [0027]. Cho notes the same problem later

identified by CN182 and then the '660 patent and: “since the spacer has a specific thickness, stray light may be reflected by an inner periphery of the spacer and then received by the imaging plane, such that flare or ghost phenomenon may occur. *Id.*, [0004]. The Cho spacer “restrain[s] the light from being reflected by the inner periphery of the spacer effectively, so as to avoid the occurrence of flare or ghost phenomenon.” *Id.*, [0008].

159. A POSITA would have understood the Cho light-blocking “spacer,” with its carbon-PET-carbon structure, to be a “light blocking sheet” as that term is used in the '660 patent, as well as a “shading ring” as used in CN182. Like the '660 patent and CN182, and as known in the art, Cho discloses a basic three-layer structure for its spacer, with a plastic body (“inside layer”) sandwiched between two carbon-containing outside layers. EX1006, [0019]-[0020], FIG. 2. Cho specifically describes an inside layer “made of a polymer material” such as “polyethylene terephthalate (PET)” and outer layers made of a “carbon material (e.g. carbon leather).” *Id.*, [0020]. And like the '660 patent and CN182, Cho also describes the conventional use of a “stamping process” to form an inner ring-shaped surface of the three-layer spacer. *Id.*, [0019], [0024], [0025]. Cho discloses “a total thickness of the spacer 14a may be between 25 μm and 80 μm , and a thickness of each outside layer 142, 144 may be between 4 μm and 15 μm .” *Id.*, [0020].

160. Cho discloses an “imaging lens 1 compris[ing] a lens barrel 10, a plurality of lens elements 12a, 12b, 12c and a plurality of spacers 14a, 14b, 14c,” where the spacer is “disposed between the lens barrel 10 and one of the lens elements 12a, 12b, 12c or between two adjacent lens elements 12a, 12b, 12c.” EX1006, [0017], FIG. 1. Light “enters the lens barrel 10 along the optical axis L” and then “forms an image on the imaging plane 3 ... after passing through the lens elements 12a, 12b, 12c.” *Id.*, [0018].

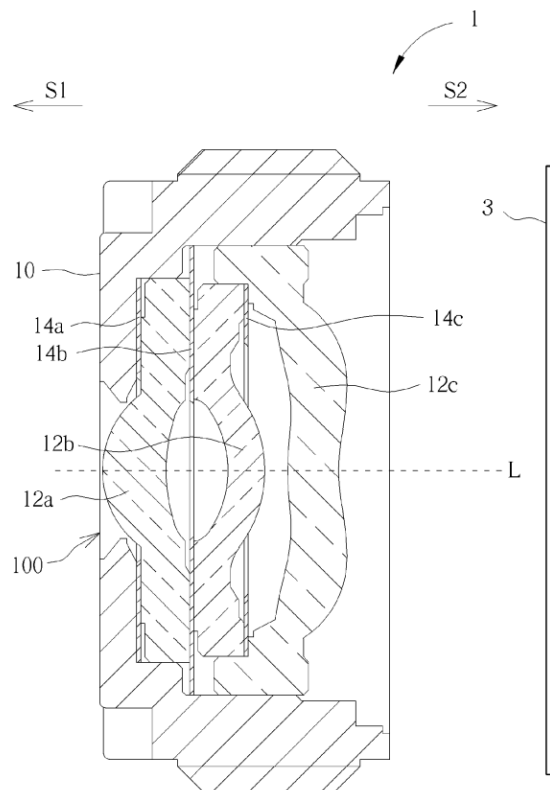


FIG. 1

Id., FIG. 1.

B. Implementing CN182's Shading Ring In Cho

161. With regards to its “shading ring” light-blocking sheet, CN182 notes that “3 to 5 pieces of shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to adjust the aperture of the light and to block other stray light.” EX1004, [0002]. Cho, in turn, discloses an example camera and imaging lens system that includes a plurality of light-blocking spacers with a same three-layer structure and dimensions as the CN182 shading ring. EX1006, [0017]-[0020], FIG. 1. Thus, a POSITA would have readily recognized that shading rings as taught by CN182 were intended for use in camera lens systems like those disclosed by Cho. Indeed, CN182 discloses a total sheet thickness of 25 μ m (EX1004, [00013]) and Cho describes that its light-blocking spacers of same structure were from 25-80 μ m thick (EX1006, [0020]). Moreover, CN182 and Cho both address the same problem of reducing stray light reflections off of the inner surfaces of light-blocking elements. *E.g.*, EX1006, [0004]; EX1004, [0002]. Thus, POSITAs implementing systems like those disclosed by Cho would have been motivated to seek out and implement alternative approaches to the same problem.

162. As discussed *supra* ¶¶103-130, a POSITA would have been motivated, with a reasonable expectation of success, to implement CN182's shading ring with a recessed inner layer in order to efficiently trap light, thus reducing glare caused by stray light reflections. The benefits of this modified CN182 light-blocking sheet

would have motivated a POSITA to use the same light trap implementation in Cho. Each of Cho's spacers could be simply substituted with the improved CN182 shading ring to obtain the predictable result of improved stray-light reduction. A POSITA would have been motivated to do so to achieve the benefits of trapping light incident on the inner periphery of the shading ring, rather than simply redirecting it via an oblique surface as taught by Cho. *Id.* Additionally, the CN182 implementation would provide the further benefit of a roughened PET surface created by the CN182 etching process. The POSITA would have had a reasonable expectation of success for reasons explained above as to Ground 1 and because the CN182 shading ring had similar dimensions and served the same purpose as the light-blocking spacers in Cho. For at least these reasons, a POSITA would have implemented the improved CN182 shading ring in place of the light-blocking spacers of the Cho lens system.

C. Claim 5

5. The light blocking sheet of claim 4, wherein a length parallel to the central axis of the air layer is d , and the following condition is satisfied:
 $5\text{ }\mu\text{m} < d < 49\text{ }\mu\text{m}$.

163. CN182 discloses a total thickness of $25\text{ }\mu\text{m}$ for the shading ring. EX1004, [0013], [0018], [0027], [0037]. Cho similarly discloses a similar three-layer spacer with a total thickness between $25\text{ }\mu\text{m}$ and $80\text{ }\mu\text{m}$, where "a thickness of each outside layer" is "between $4\text{ }\mu\text{m}$ and $15\text{ }\mu\text{m}$." EX1006, [0020]. A POSITA

would therefore recognize that for a shading ring or spacer with 25 μm total thickness, as taught by CN182, the outer layers would each have a thickness of at least 4 μm , as taught by Cho, such that the length parallel to the central axis of the air layer is at most $d = 17 \mu\text{m}$. This is within the claimed range of $5 \mu\text{m} < d < 49 \mu\text{m}$.

D. Claim 7

7. The light blocking sheet of claim 4, wherein a length parallel to the central axis of the air layer is d , a thickness of the light blocking sheet is t , and the following condition is satisfied:
 $0.12 < d/t < 0.67$.

164. CN182 and Cho render this claim obvious. The thickness of the CN182 shading ring (light blocking sheet) is $t=25 \mu\text{m}$. *E.g.*, EX1004, [0013]. Cho teaches outer layers at least 4 μm thick, and up to 15 μm thick, and a POSITA would have been motivated to use carbon layers 4-6 μm thick. EX1006, [0020] (“a thickness of each outside layer ... may be between 4 μm and 15 μm ”); *supra* ¶¶113-115. A POSITA would have been motivated with a reasonable expectation of success to use 4-6 μm outer carbon layers, to balance sufficient thickness for structural integrity with minimal surface area for reduced edge reflections. *Supra* ¶¶113-115; EX1018, 1:34-40 (explaining that the thickness of a light blocking sheet “is necessary in terms of essential light shielding effect, mechanical strength, shape stability, reliability in environments, handling ability in assembling, and so on”). This renders obvious

CN182 implementations with a middle PET layer of 13-17 μ m thickness, and a PET layer of 13-16.74 μ m satisfies the recited condition, thus rendering the claim obvious.

E. Claim 10

1. Element 10.1

[10.1] An imaging lens module, comprising:

165. To the extent the preamble is limiting, Cho discloses it. Cho discloses “an imaging lens comprises a lens barrel, a plurality of lens elements and a spacer,” where such imaging lens “may be applied to a camera module of a portable electronic device” such as a mobile phone. EX1006, [0006], [0017]-[0018]. Further, CN182 teaches that “shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to adjust the aperture of the light and to block other stray light.” EX1004, [0002]. CN182 and Cho therefore render obvious an imaging lens module.

2. Element 10.2

[10.2] a barrel;

166. Cho discloses “a lens barrel.” EX1006, [0004] (“the imaging lens essentially comprises a lens barrel”), [0006], [0008], [0017]-[0018], [0021], [0027], FIG. 1.

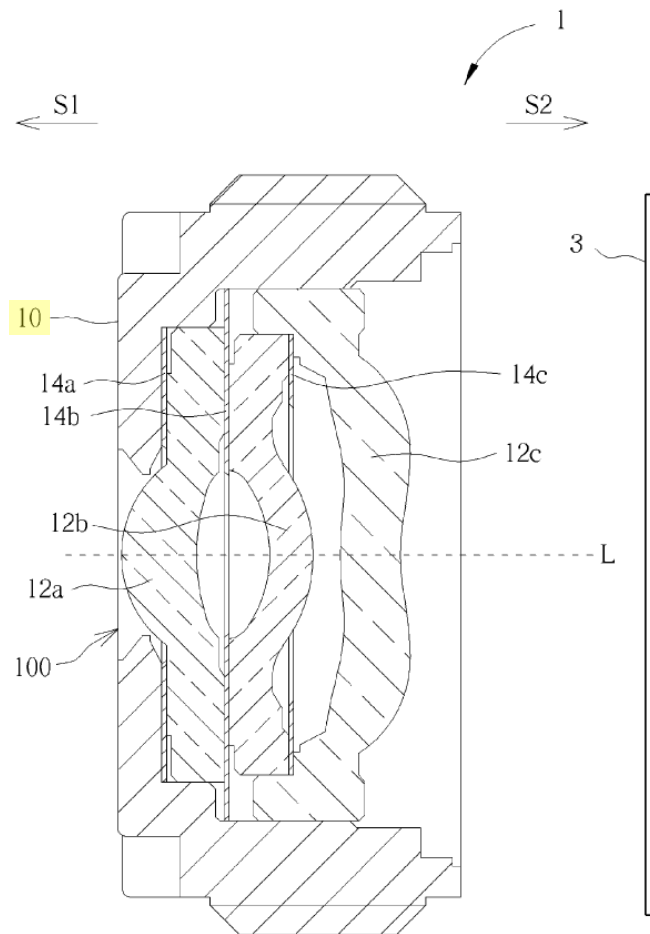


FIG. 1

EX1006, FIG. 1 (highlighting added).

3. Element 10.3

[10.3] an optical lens assembly disposed in the barrel; and

167. Cho discloses “lens elements ... disposed in the lens barrel.” EX1006, [0004], [0006], [0017], FIG. 1. A POSITA would understand that the lens elements of Cho comprise an “optical lens assembly” because light that “enters the lens barrel

10 along the optical axis L” and “forms an image on the imaging plane ... after passing through the lens elements 12a, 12b, 12c.” *Id.*, [0018], FIG. 1.

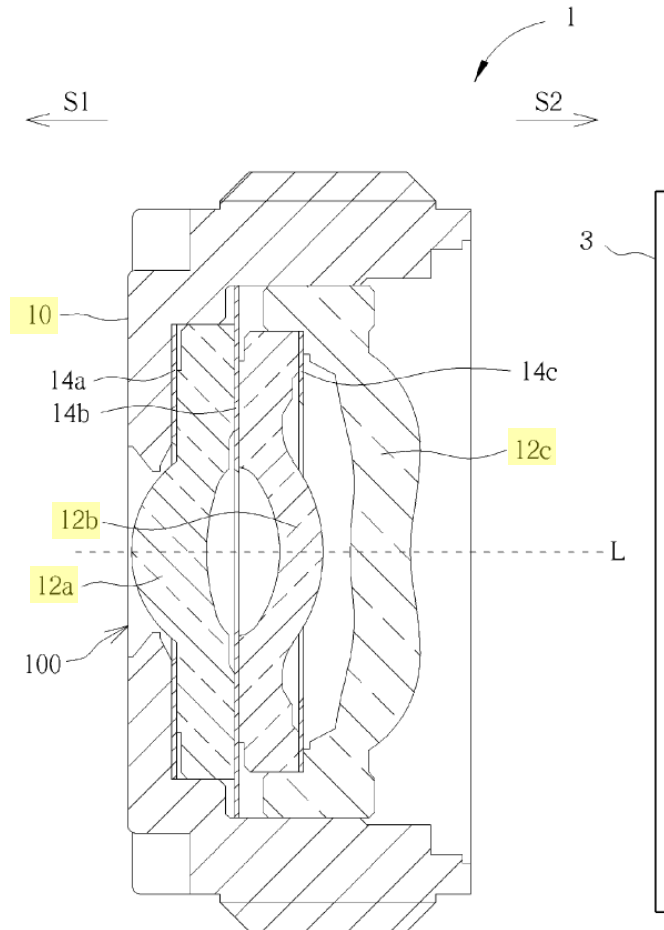


FIG. 1

EX1006, FIG. 1 (highlighting added).

4. Element 10.4

[10.4] the light blocking sheet of claim 1 disposed in the barrel.

168. CN182 renders obvious the light blocking sheet of claim 1. *Supra* ¶¶97-131 (claim 1). Cho discloses a “plurality of spacers” that “are disposed in the lens barrel 10.” EX1006, [0017], FIG. 1. CN182 teaches that “shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to adjust the aperture of the light and to block other stray light.” EX1004, [0002]. A POSITA therefore would have found it obvious to implement the CN182 shading ring (light blocking sheet) within a barrel such as Cho’s lens barrel 10 in order “to adjust the aperture of the light and to block other stray light” as taught by CN182, because doing so would reduce “glare, halo and flare and other undesirable effects caused by the existing shading rings due to the reflection from the inner-wall of the through-hole.” *Id.*, [0002]-[0003].

F. Claim 14

1. Element 14.1

[14.1] An electronic apparatus, comprising:

169. CN182 and Cho render this element obvious. Cho teaches that an “imaging [lens] is a quite important optical component in a mobile electronic device or a camera and the optical property of the imaging lens determines the quality of an image.” EX1006, [0004]; *see also* EX1004, [0002] (teaching that “shading rings need to be placed inside the camera of high-pixel cell phones and digital cameras to

adjust the aperture of the light and to block other stray light”). A “mobile electronic device or a camera” is an electronic apparatus.

2. Element 14.2

[14.2] the imaging lens module of claim 10; and

170. CN182 and Cho render obvious the imaging lens module of claim 10. *Supra* ¶¶165-168 (claim 10).

3. Element 14.3

[14.3] an image sensor disposed on an image surface of the imaging lens module.

171. CN182 and Cho render this element obvious. Cho discloses an “imaging plane 3 ... disposed at the image side S2” of the “imaging lens 1 ... applied to a camera module of a portable electronic device” such as a “mobile phone.” EX1006, [0018]. Light “forms an image on the imaging plane 3 at the image side S2 of the imaging lens 1 after passing through the lens elements 12a, 12b, 12c.” *Id.* Cho discloses that “the image plane 3 may be a charge-coupled device (CCD) sensor or a complementary metal-oxide semiconductor (CMOS) sensor.” *Id.* The “imaging plane” of Cho is therefore “an image sensor disposed on an image surface of the imaging lens module.”

G. Claim 19

19. The light blocking sheet of claim 16, wherein the length parallel to the central axis of the air layer is d , a thickness of the light blocking sheet is t , and the following condition is satisfied:
 $0.12 < d/t < 0.67$.

172. CN182 and Cho render this claim obvious for the same reasons discussed with regard to claims 7 and 16. *Supra* ¶¶149 (claim 16), 164 (claim 7).

H. Claim 20

1. Element 20.1

[20.1] An imaging lens module, comprising:

173. CN182 and Cho render this element obvious for the same reasons discussed with regard to claim 10. *Supra* ¶165 (element 10.1).

2. Element 20.2

[20.2] a barrel;

174. CN182 and Cho render this element obvious for the same reasons discussed with regard to claim 10. *Supra* ¶166 (element 10.2).

3. Element 20.3

[20.3] an optical lens assembly disposed in the barrel; and

175. CN182 and Cho render this element obvious for the same reasons discussed with regard to claim 10. *Supra* ¶167 (element 10.3).

4. Element 20.4

[20.4] the light blocking sheet of claim 15 disposed in the barrel.

176. CN182 renders obvious the light blocking sheet of claim 15. *Supra* ¶¶142-148 (claim 15). A POSITA would have understood that the light blocking sheet is disposed in the barrel to block stray light within the barrel. *Supra* ¶168 (element 10.4).

I. Claim 22

1. Element 22.1

[22.1] An electronic apparatus, comprising:

177. CN182 and Cho render this element obvious for the same reasons discussed regarding claim 14. *Supra* ¶169 (element 14.1);

2. Element 22.2

[22.2] the imaging lens module of claim 20, and

178. CN182 and Cho render obvious the imaging lens module of claim 20. *Supra* ¶¶173-176 (claim 20).

3. Element 22.3

[22.3] an image sensor disposed on an image surface of the imaging lens module.

179. CN182 and Cho renders this element obvious for the same reasons discussed regarding claim 14. *Supra* ¶171 (element 14.3).

**XII. GROUND 3: A POSITA WOULD HAVE
FOUND CLAIMS 11-13 AND 21 OBVIOUS
OVER CN182 IN VIEW OF CHO AND TAKAHASHI**

180. As explained below, claims 11-13 and 21 are obvious over CN182 in view of Cho and Takahashi.

A. Takahashi (EX1025)

181. U.S. Patent Publication No. 2015/0103226 (EX1025, “Takahashi”) was filed October 14, 2014, published April 16, 2015, and qualifies as prior art under Sections 102(a)(1-2). EX1025, Cover. Takahashi is analogous art to the ’660 patent because they are both in the same field of endeavor of blocking stray light to reduce glare in compact imaging lens modules. EX1001, 1:14-17, 1:21-32; EX1025, [0003]-[0015].

182. Takahashi discloses an “optical element” used in a multi-lens assembly in “an electronic apparatus such as a digital camera [o]r a mobile phone.” *Id.*, [0003], [0010]-[0015], FIG. 1. This “optical element ... can prevent the occurrence of stray light by minimizing reflection of light at a surface of a light blocking layer.” *Id.*, [0010]. Specifically, a “light blocking portion” is formed by a “light blocking layer 16” and an “antireflection layer 17,” where the light blocking layer 16 is positioned at a surface of an optical lens to “prevent[] light ... from being incident to the” lens. *Id.*, [0035]-[0038]. The light blocking layer 16 contains “light blocking substances such as black pigments or dyes.” *Id.*, [0039]-[0040]. “The antireflection layer 17

prevents reflection of light at the surface of the light blocking layer 16.” *Id.*, [0041]. Takahashi explains that, by providing this antireflection layer on a surface of the light blocking layer, issues caused by oblique light, such as flare and ghosting, is minimized. *Id.*, [0042]-[0049].

B. Claim 11

11. The imaging lens module of claim 10, wherein the first outer layer of the light blocking sheet further comprises a first surface corresponding to an object-side surface of the imaging lens module, the second outer layer of the light blocking sheet further comprises a second surface corresponding to an image-side surface of the imaging lens module, and at least one of the first surface and the second surface comprises an anti-reflection film coated thereon.

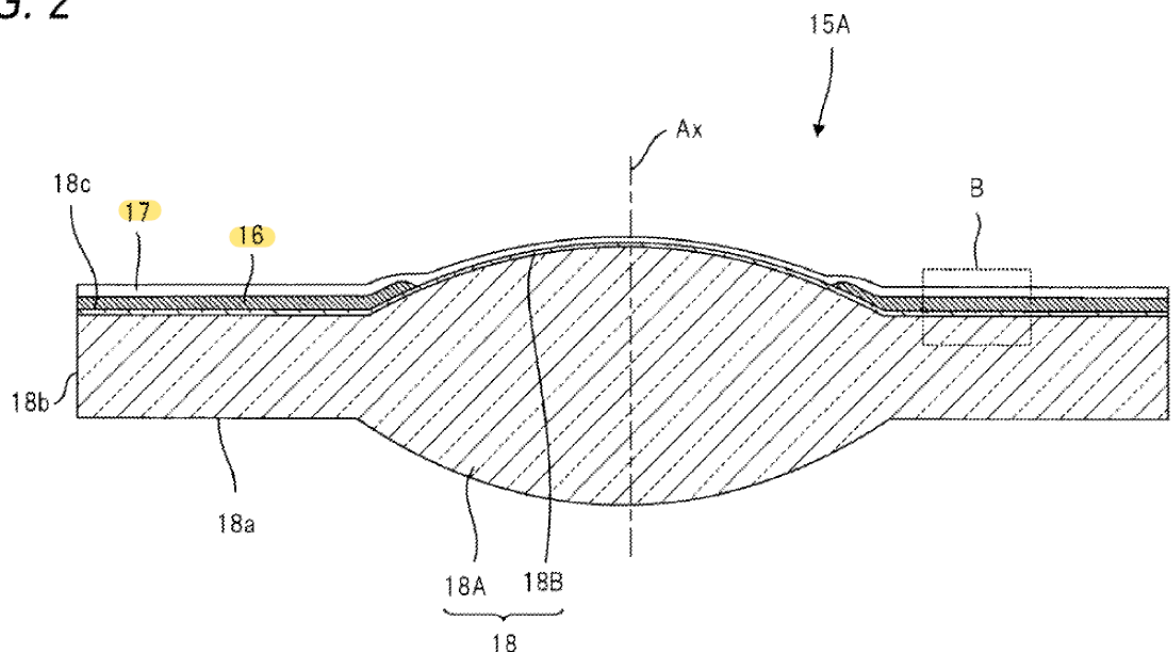
183. CN182, Cho, and Takahashi render this claim obvious. CN182 and Cho render obvious the imaging lens module of claim 10. *Supra* ¶¶165-168. The first outer layer of the CN182 shading ring is a first surface corresponding to an object-side surface of the imaging lens module, and the second outer layer of the CN182 shading ring is a second surface corresponding to an image-side surface of the imaging lens module.

184. A POSITA would have been motivated to coat at least one of the first surface and the second surface with an anti-reflection film because doing so would help with “reducing the surface reflectance” of the outer surface, further aiding in the suppression of stray light. EX1007, 110; *supra* ¶¶65-67. It was well known that “an antireflection (AR) coating” is a “commonly used coating for plastic optics,”

and multiple coatings are often used. EX1007, 111; EX1011, 3.17 (“Antireflection coatings are frequently utilized on polymer substrates, and may consist of a single layer or a rudimentary multilayer stack yielding better reflection-suppression performance.”).

185. Further, the placement of an anti-reflection film on the outer surface of a light-blocking sheet was well known to a POSITA. For example, Takahashi discloses an “antireflection layer 17” on a surface of a “light blocking layer 16,” such that a “light blocking portion is constituted by the light blocking layer 16 and the antireflection layer 17.” EX1025, [0035], FIG. 2.

FIG. 2



EX1025, FIG. 2 (highlighting added). Takahashi teaches that the “antireflection layer 17 prevents reflection of light at the surface of the light blocking layer 16.”

EX1025, [0041]. The “antireflection layer 17 is not particularly limited in materials used as long as the condition regarding refractive indexes is satisfied.” *Id.*, [0043]. As guidance, “a refractive index of the light blocking layer 16 is higher than a refractive index of the antireflection layer 17 in order to prevent reflection of light at the surface of the light blocking layer 16.” *Id.*, [0042].

186. Thus, a POSITA would have been motivated to coat at least one of the first surface and the second surface of the CN182 shading ring with an anti-reflection film, as taught by Takahashi and generally a well-known technique, in order to further suppress reflections and “more reliably prevent the occurrence of flare or ghosting in the entire lens unit.” EX1025, [0041], [0043]-[0047], [0049]; EX1007, 110-11; EX1011, 3.17; EX1025, [0041].

187. CN182, Cho, and Takahashi thus renders obvious “wherein the first outer layer of the light blocking sheet further comprises a first surface corresponding to an object-side surface of the imaging lens module, the second outer layer of the light blocking sheet further comprises a second surface corresponding to an image-side surface of the imaging lens module, and at least one of the first surface and the second surface comprises an anti-reflection film coated thereon.”

C. Claim 12

12. The imaging lens module of claim 11, wherein the anti-reflection film comprises a silicon dioxide material layer.

188. CN182, Cho, and Takahashi renders this claim obvious because silicon dioxide was a well-known material often used as an anti-reflection coating or film in optical systems. EX1024, [0073] (disclosing a “protective layer ... such as SiO₂,” silicon dioxide, as “an antireflection coating”); EX1026, [0014]-[0015] (disclosing silicon dioxide (SiO₂) as a layer of an anti-reflection film “coated on the object-side surface” of a lens to significantly reduce reflections on that surface); EX1011, 6.35 (discussing paints used as “standards for black coatings” that “consisted of pigments with approximately 20 percent carbon black and 80 percent silicon dioxide”); EX1027, 337 (listing SiO₂ as a coating material for anti-reflection coatings), 321-358 (discussing different processes for applying SiO₂ as an anti-reflection coating / film).

189. It would have been obvious to a POSITA to use a silicon dioxide material layer as an anti-reflection film coating to the at least one of the outer layers of the CN182 shading ring because silicon dioxide is a well-known and common material for anti-reflection film, and using silicon dioxide as the anti-reflection film would further help reduce flare. *E.g.*, EX1011, 7.23 (illustrating silicon dioxide as a typical anti-reflection coating), 7.31-32 (same).

D. Claim 13

13. The imaging lens module of claim 11, wherein only one of the first surface and the second surface comprises the anti-reflection film coated thereon.

190. CN182, Cho, and Takahashi renders this claim obvious. A POSITA would have found it obvious to implement the CN182 shading ring with an anti-reflection film coated on at least one of the first surface and the second surface. *Supra* ¶¶183-187 (claim 11). A POSITA would have been motivated to coat only one of the first surface and the second surface with the anti-reflection film because doing so would reduce cost, compared to coating both surfaces with the anti-reflection film. EX1007, 113 (explaining that the “primary downside to the use of coatings is their cost” and that “[i]n order to reduce cost, as many pieces as possible should be coated in a single run”). Further, it was well known that elements in a lens system may have different coatings on different surfaces, depending on their position and orientation relative to the object side and the image side of the lens module. *E.g.*, EX1007, 139 (discussing how coatings “such as antireflection (AR) coatings” may have different requirements on either surface); Further, Takahashi discloses providing the “antireflection layer 17” on only one side of the “light blocking layer 16.” EX1025, [0038], FIGS. 1-2.

E. Claim 21

21. The imaging lens module of claim 20, wherein the first outer layer of the light blocking sheet further comprises a first surface corresponding to an object-side surface of the imaging lens module, the second outer layer of the light blocking sheet further comprises a second surface corresponding to an image-side surface of the imaging lens module, and at least one of the first surface and the second surface comprises an anti-reflection film coated thereon.

191. CN182, Cho, and Takahashi renders this claim obvious for the same reasons discussed with regard to claims 11 and 20. *Supra* ¶¶183-187 (claim 11), 173-176 (claim 20).

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

Dated: March 29th, 2024



Tom D. Milster

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CURRICULUM VITAE

TOM D. MILSTER

3/29/2024

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CHRONOLOGY OF EDUCATION

Colleges and universities attended:

University of Arizona	(Optical Sciences)	1981-1987
University of Missouri-Rolla	(Electrical Engineering)	1979-1981
Southwest Mo. State University	(Math)	1977-1979
Rochester Institute of Tech.	(Photographic Science)	1976-1977

Institutions, degrees and dates awarded:

University of Arizona	Ph.D. Optical Sciences	1987
University of Missouri	B.S. Electrical Engineering	1981

Title of doctoral dissertation and name of advisor:

“Design and construction of a modular gamma camera”
Advisor: Dr. Harrison Barrett

Major Fields:

Optical Sciences and Electrical Engineering

CHRONOLOGY OF EMPLOYMENT

University of Arizona College of Optical Sciences	Professor	2007-date
University of Arizona Optical Sciences Center	Research Professor	2000-2007
University of Arizona Optical Sciences Center	Assoc. Research Professor	1995-2000
University of Arizona Optical Sciences Center	Assist. Professor	1989-1995
Lawrence Livermore National Laboratory	Optical Engineer	1989(summer)
IBM General Products Division	Staff Engineer, Optical Storage	1986-1989
University of Arizona Optical Sciences Center	Graduate Research Assoc.	1982-1986
University of Arizona Electrical Engineering	Graduate Teaching Assist.	1981
University of Missouri Electrical Engineering	Undergrad Research Assist.	1980-1981
Argonne National Laboratory	Summer Research Assist.	1980

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HONORS AND AWARDS

- Paper “High-harmonic diffractive lens color compensation,” *Appl. Opt.* 2021, selected as *Editor’s Pick* and *Top Download* for the month of July 2021.
- Paper “Design aspects of large-aperture MODE lenses,” *OSA Continuum* 2021, selected as *Editor’s Pick* and *Top Download* for the month of July 2021.
- Paper “Multiple-order diffractive engineered surface lenses,” *Appl. Opt.* 2020, selected as *Editor’s Choice* and *Top Download* for three consecutive months in October-December, 2020.
- National Academy of Inventors (NAI) Elected Senior Member 2020
- Paper “Highly efficient near-field probes,” *Appl. Opt.*, 2000, selected for Optics in 2001 as published in *Optics and Photonics News*, **12**(12), p. 38 (2001)
- Society of Photo-Optical Instrumentation Engineers (SPIE) – Elected Fellow (2001)
- Optical Society of America – Elected Fellow (1999)
- Paper “Linear behavior of a near-field optical scanning system,” *JOSA- A*, 1995, selected by SPIE as a landmark paper in near-field optics.
- Paper “Objective lens design for multiple-layer optical data storage,” *Opt. Eng.* (1997) selected by SPIE as one of 300 most influential papers in lens design (1999).

SERVICE AND OUTREACH

Departmental committees:

Multiple years in each position: Admissions Committee (Chair); Comprehensive Exam Committee (Chair); Graduate Curriculum Committee (Chair 2014-2016); ABET Undergraduate Academic Accreditation Committee (Chair 2014-2016); In addition, too many oral defense exams to list, including comprehensive examinations, master’s defenses, and Ph.D. defenses.

Profession:

- Co-Chair, Topical Meeting on Optical Data Storage, SPIE Optics and Photonics, Optical Engineering and Applications, Conference OP233, San Diego Convention Center, San Diego, California, 2014-2016.
- Advisory Committee Member, Topical Meeting on Optical Data Storage, 2006-2023
- Program Committee Member, International Symposium on Optical Memory, 2006-2023

PUBLICATIONS

Chapters in scholarly books:

1. T. Milster, “The Gerchberg-Saxton Phase Retrieval Algorithm and Related Variations.” In Optical Holography-Materials, Theory and Applications (Elsevier, 2020) pp. 61-72.
2. T. Milster, “Superresolution Microscopy,” in Springer Handbook of Nanotechnology (Springer, Berlin, Heidelberg 2017) pp. 845-865.
3. T. Milster and T. Tkaczyk, "Miniature and Micro Optics," Chapter 22, Handbook of Optics, 3rd Ed. Optical Society of America 2010.
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5. E. P. Walker and T.D. Milster, “Beam Shaping for Optical Data Storage,” in Laser Beam Shaping Applications, F. M. Dickey, S. C. Holswade and D. L. Shealy, eds. (Marcel Dekker, New York, 2005, 2014 and 2017).
 6. T. D. Milster, “Optical Data Storage,” in The Optics Encyclopedia: Basic Foundations and Practical Applications, Volume 1 T. G. Brown, K. Creath, H. Kogelnik, M. A. Kriss, J. Schmit and M. J. Weber, eds. (Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2003), pp. 227-274 (2003).
 7. T. D. Milster and G. T. Sincerbox, “Future of Optical Data Storage,” in McGraw-Hill 2002 Yearbook of Science and Technology, pp. 252-255 (2002).
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 11. T. D. Milster, “Miniature and Micro-optics,” in Handbook of Optics, Volume 2, B. Wolfe, ed. (McGraw-Hill, New York, 1995), ch. 7 (1995).

Peer-Reviewed Papers 2020s:

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3. Milster, Tom D., Zichan Wang, and Young Sik Kim. "Design aspects of large-aperture MODE lenses." *OSA Continuum* 4, no. 1 (2021): 171-181.
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1. Eguchi, Akira, and Tom D. Milster. "Single-shot phase retrieval with complex diversity."

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2. Apai, Dániel, Tom D. Milster, Dae Wook Kim, Alex Bixel, Glenn Schneider, Rongguang Liang, and Jonathan Arenberg. "A thousand earths: a very large aperture, ultralight space telescope array for atmospheric biosignature surveys." *The Astronomical Journal* 158, no. 2 (2019): 83.
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12. Fukutake, Naoki, and Tom D. Milster. "Proposal of three-dimensional phase contrast holographic microscopy." *Optics Express* 15, no. 20 (2007): 12662-12679.
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14. Choi, Narak, Seongbo Shim, Tom D. Milster, and Jaisoon Kim. "Optical design for the optimum solid immersion lens with high numerical aperture and large tolerance." *Japanese journal of applied physics* 46, no. 6S (2007): 3724.
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18. Park, Sang-Ki, Tom D. Milster, Tim M. Miller, John Butz, and Warren Bletscher. "Master and slave beam servo technique for volumetric bit-wise optical data storage." *Japanese journal of applied physics* 44, no. 5S (2005): 3442.
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21. Beaudry, Neil A., and Tom D. Milster. "Imaging properties of a patterned rough surface: effects of defocus." *Optical Engineering* 44, no. 6 (2005): 063201-063201.
22. Lang, Matthew, Tom D. Milster, Takahisa Minamitani, Gregg Borek, and David Brown. "Fabrication and characterization of sub-100 μ m diameter gallium phosphide solid

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- immersion lens arrays." Japanese journal of applied physics 44, no. 5S (2005): 3385.
23. Zhang, Yan, Tom D. Milster, Jai Soon Kim, and Sang-Ki Park. "Advanced lens design for bit-wise volumetric optical data storage." Japanese journal of applied physics 43, no. 7S (2004): 4929.
 24. Khoh, Andrew, Ganesh S. Samudra, Yihong Wu, Tom Milster, and Byoung-Il Choi. "Image formation by use of the geometrical theory of diffraction." JOSA A 21, no. 6 (2004): 959-967.
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PhD Students (30)

Joshua Jo, Robert Upton, Yan Zhang, Edwin Walker, Hong Tang, Fred Froehlich, Donis Flagello, Joshua Kann, Mark Wang, Craig Curtis, Neil Beaudry, Yan Zhang, Dongyel Kang, Jun Zhang, Matthew Lang, Tao Chen, Seung-Hune Yang, Sang Ki Park, Taeyoung Choi, Shu Guo Tang, Akira Eguchi, Weichuan Gao, Emily Finan, Phat Lu, Anoop George, John Tamkin, Zichan Wang, Nicholas Brar, Priyanka Jillella, Kent Wallace

MS Students (29)

Wolfgang Schlichting, Weiquan Li, Chris Campillo, Jeffrey Treptau, Jen Nan Wong, Kei Shimura, Rochan Shetty, Eric Aspnes, Andrew Khoh, David Felix, Timothy Miller, Sashi Kasanavesi, John Brewer, Lee Johnson, Justin Sierchio, Melissa Zaverton, Victor Densmore, Derek Keys, Erin Ford, Dolaphine Kwok, Alex Felli, Ridley Gatlin, Kira Purvin, Sanja Dmitrovic, Genevieve Allouche, Cory Stinson, David Hill, Kai Hu, Stephanie Barns

Issued Patents

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1. Milster, Thomas D., Lee C. Johnson, and Daniel Apai. "Optical device comprising a multi-order diffractive Fresnel lens (MOD-DFL) and an achromatizing compensation mechanism, and a method for enhancing images captured using the MOD-DFL." U.S. Patent 11,671,706, issued June 6, 2023.
2. Singer, Kenneth D., Irina Shiyanovskaya, Asher Sussman, Thomas Milster, and Young Sik Kim. "Systems and methods for increasing data rate and storage density in multilayer optical discs." U.S. Patent 11,456,010, issued September 27, 2022.
3. E. Finan, E. Bendek and T. Milster, "Active coating apparatus, methods and applications," USP 10,866,406 (2020).
4. Matsubara, Y. Unno, W. Dallas, and T. D. Milster, "Hologram with cells to control phase in two polarization directions and exposure apparatus," USP 9,116,303 (2015).
5. B. Gelernt, T. D. Milster and T. Jota, "Interferometric systems and methods," USP 9,081,193 (2015).
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7. T. D. Milster and J. Km, "Alignment feature for near-field transducers," USP 8,737,178 (2014).
8. B. Gelernt and T. D. Milster, "Apparatus and method for deep ultraviolet optical microscopy," USP 8,472,111 (2013).
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10. T. D. Milster and S. Kannan, "Application of wavelet transform filtering for processing data signals from optical data storage devices," USP 7,974,170 (2011).
11. T. D. Milster, P. K. Khulbe, and B. Gelernt, "Apparatus and method for spectroscopy," USP 7,916,291 (2011).
12. P. B. Chu, M. I. Lutwyche, T. Rausch, W. A. Challener, and T. D. Milster, "Optical system for data storage devices," USP 7,796,487 (2010).
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14. T. D. Milster and Kei Shimura, "Method and apparatus for detecting light from a multilayerd object," USP 6,577,584 (2003).
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17. Y. D. Milster and S. Yao, "Detector for magnetooptic recorders," USP 4,823,220 (1989).

Classes

1. OPTI 380A *Intermediate Optics Lab I* (Junior Undergraduate, 1 credit hour): The main objectives for this lab are to understand the basics of physical optics, interference, diffraction, detectors, laser cavities, and the electro-optical properties of gas and semiconductor lasers. A variety of optical lab techniques is also taught.
2. OPTI505R *Diffraction and Interferometry* (Core PhD Graduate Class, 3 credit hours): Waves and Polarization, Interference and interferometry; diffraction theory; Fraunhofer and Fresnel

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diffraction; concepts of coherence; optical transfer function (Holography and Speckle are presented in optional lectures).

3. OPTI505L *Physical Optics Laboratory* (Graduate Laboratory Course, 1 credit hour): Gaussian beams, polarization, basic interference, Mach-Zehnder interferometer, diffraction, shearing interferometry, coherence, white-light profilometry
4. OPTI600D *Diffraction Optical Elements – Theory and Design* (Advanced Graduate Course, 1 credit hour): This course includes a physical optics approach to understanding computer-generated diffractive optical elements (DOEs) and their differences with respect to refractive lens elements. Included in the discussion are gratings, focusing elements, aberration compensators, servo-signal generators, axicons, computer-generated holograms (CGHs) and other elements. Design techniques using Zemax ray-tracing software are demonstrated, and an open-source Matlab program called OptiScan is used for project assignments.
5. OPTI600E *Diffraction Optical Elements – Fabrication and Testing* (Advanced Graduate Course, 1 credit hour): This course is a hands-on fabrication and testing course in which students learn characteristics of fabricating and testing different types of computer-generated diffractive optical elements (DOEs).

Other Classes

1. Workshops: Computer generated holography, lithography, adaptive optics.
2. Short courses: Bit-wise volumetric storage, microlithography, miniature optics for diode lasers and beam shaping, near-field solid immersion lenses, hands-on physical optics, near-field technologies

Research Funding

- Average yearly total budget ~ \$1M
- Present and past sponsors include: NASA, NSF, Department of Defense, AFOSR, Sandia National Laboratories, BKA (German Federal Police), IBM, Eastman Kodak, Phillips, Samsung, Intel, Raytheon, Canon, Nikon, Seagate, ASML-Zeiss, LG, II-VI Foundation, The Gordon and Betty Moore Foundation, and many small companies.

Other Presentations, Digest Papers and Articles

2020s

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2. Esparza, Marcos, Heejoo Choi, Nicholas Brar, Zichan Wang, Youngsik Kim, Chuck Fellows, Mingab Bog et al. "Kinematically engaged yoke system for segmented lens-based space telescope integration and testing." *Journal of the European Optical Society-Rapid Publications* 19, no. 1 (2023): 2023016.

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5. Milster, Tom D., Zichan Wang, and Youngsik Kim. "Theory of color correction in high-harmonic diffractive lenses." In *International Optical Design Conference*, p. 120780Y. Optica Publishing Group, 2021.
6. Choi, Heejoo, Marcos A. Esparza, Ariel Lamdan, Yi-Ting Feng, Tom Milster, Daniel Apai, and Dae Wook Kim. "In-process metrology for segmented optics UV curing control." In *Optical Manufacturing and Testing XIII*, vol. 11487, pp. 115-121. SPIE, 2020.
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12. Kim, Youngsik, Marcos Esparza, Zichan Wang, Nicholas Brar, Heejoo Choi, Daewook Kim, Daniel Apai, and Tom D. Milster. "Stray light analysis and testing of a MODE lens telescope." In *Optical Manufacturing and Testing XIV*, vol. 12221, pp. 90-94. SPIE, 2022.
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17. Kim, Youngsik, Zichan Wang, and Tom Milster. "Optical design and analysis of ultralight, large aperture transmissive lenses for space telescopes." In *Frontiers in Optics*, pp. JTU7A-1. Optica

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20. Esparza, Marcos A., Ryan Luu, Heejoo Choi, Tom D. Milster, Daniel Apai, and Daewook Kim. "Progress towards alignment of Multi-Order Diffractive Engineered (MODE) lens segments using the Kinetically-Engaged Yoke System (KEYS) for optical performance testing." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 115-121. SPIE, 2022.
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20. Bendek, Eduardo A., Ruslan Belikov, Eugene Pluzhnik, Olivier Guyon, Thomas Milster, Lee Johnson, Emily Finan, Justin Knight, and Alexander Rodack. "Results of the astrometry and direct imaging testbed for exoplanet detection." In Techniques and Instrumentation for Detection of Exoplanets VIII, vol. 10400, pp. 393-406. SPIE, 2017.
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