

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO. LTD., AND
SAMSUNG ELECTRONICS AMERICA, INC.
Petitioner

v.

SINOTECHNIX, LLC.

Patent Owner

Case IPR2025-00333
U.S. Patent No. 7,748,873

**DECLARATION OF TOM D. MILSTER, PH.D.
ON BEHALF OF PETITIONER**

CLAIMS 1-8 and 10-13

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Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,748,873

I, Tom D. Milster, declare as follows.

I. Introduction

1. My Name is Tom D. Milster.
2. 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 have studied and worked in the field of optical engineering for over 43 years.
3. 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 on optical storage using miniature optical systems, 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. I have been teaching and researching at the University of Arizona for about 35 years.
4. I have authored over 100 publications in peer-reviewed academic journals, transactions and books in the field of optics. Several publications related

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to lens design and measurement for miniature optical systems include “Practical measurement of cell-phone camera lens focal length,” Optical System Alignment, Tolerancing, and Verification XIII, vol. 11488, pp. 39-48. SPIE, 2020, “Advanced lens design for bit-wise volumetric optical data storage,” Japanese Journal of Applied Physics 43, no. 7S (2004): 4929, “Objective lens design for multiple-layer optical data storage,” Optical Engineering 38 (1999): 295-301, “Compensation of chromatic errors in high NA molded objective lenses,” Applied Optics 34, no. 34 (1995): 8079-8080, “Technique for simultaneous alignment and collimation of a laser diode in an optical data storage head,” Applied Optics 30, no. 31 (1991): 4481-4483.

5. 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.

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6. I am a named inventor in 18 issued U.S. patents concerning various advanced optical systems, like data detectors and systems for optical data storage that include miniature optics.

7. I am a Fellow 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.

8. A copy of my curriculum vitae (“CV”) is attached as Appendix A. It provides a description of my professional experience, including my academic and employment history, publications, conference participation, awards and honors, and more.

9. I have been asked to provide my opinion whether the claims of the U.S. Patent No. 7,748,873 (the “’873 patent”) are valid.

10. I understand that the ’873 Patent was filed on April 6, 2007 as U.S. Patent Application No. 11/576,882, claiming priority to four Korean Patent Applications (10-2004-0079909, filed October 7, 2004; 10-2005-0000269, filed January 3, 2005; 10-2005-0056436, filed June 28, 2005, and 10-2005-0083743, filed September 8, 2005). *See* EX1001, Cover.

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11. I have reviewed and considered the following exhibits, and all other documents mentioned in my Declaration. Additionally, my opinions are based on my technical education, training and experience in the field.

Exhibit No.	DESCRIPTION
1001	U.S. Patent No. 7,748,873 ('873 Patent)
1003	File History of U.S. Patent No. 7,748,873
1004	Certified Translation of JP 2002-344027 ("Odawara")
1005	U.S. Patent No. 6,598,998 ("West")
1006	U.S. Patent No. 6,674,096 ("Sommers")
1007	U.S. Patent Publication No. 2004/0140543 ("Elpedes")
1008	U.S. Patent No. 3,774,021 ("Johnson")
1009	J. Strong "Evaporated Aluminum Films For Astronomical Mirrors" 1934 <i>PASP</i> 46 18
1013	U.S. Patent No. 6,274,924 ("Carey")
1014	Certificate of Translation Accuracy of JP 2002-344027 ("Odawara")
1015	U.S. Patent No. 7,170,151 ("Elpedes Patent")

12. I have been retained to serve as an expert for Samsung Electronics Co. Ltd. and Samsung Electronics America, Inc. in the field of optical engineering, such as lenses utilized for illumination.

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

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14. I do not have any financial interest in the outcome of this case nor do I have any financial interest in Samsung Electronics Co. Ltd., Samsung Electronics America, Inc., or Sinotechnix LLC.

15. I do not personally know the named inventors of the '873 Patent and have never had any personal contact with them.

II. Relevant Law

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

A. Person of Ordinary Skill in the Art

17. I have been informed and understand that a patent should be analyzed from the perspective of a person of ordinary skill in the art ("POSITA"). I understand that a POSITA is a hypothetical individual with ordinary creativity who would have been familiar with the prior art as of the patent's priority date.

18. I have been informed and understand that there are multiple factors that are relevant to determining the level of a person of ordinary skill in the art. These include (i) the level of education and experience of the inventors named on the '873 Patent, (ii) the types of problems encountered in the field, (iii) the

solutions to these problems present in the prior art, (iv) the speed at which innovations are made in that field, (v) the sophistication of technology, and (vi) education level of the people who work in the field.

B. Claim Construction

19. I have been informed that to determine the meaning of the terms in the claims of the '873 Patent for the purposes of the *inter partes* review, one should generally use the ordinary and customary meaning as understood by a POSITA at the time of the claimed priority date, taking into consideration the claim language and patent specification.

20. I have been informed that a patentee can include a definition of a claim term in the specification. In such instances, I understand that the claim should generally be interpreted according to that definition provided in the patent.

21. I have been informed that the patent's claims, specification, and the file history (EX1003) should be analyzed to arrive at the proper interpretation of a claim term. As such, I have reviewed the claims, specification, and file history of the '873 Patent.

22. I also understand that while a claim should be read in light of the specification, one must generally avoid importing limitations into the claim from

the specification. However, I also understand that interpreting a claim term to exclude a preferred embodiment is rarely correct. 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.

C. Anticipation

23. I have been informed and 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.*, although implied, it is necessarily present).

24. I have also been informed and understand that patent drawings can teach a claim limitation if they reasonably teach to a POSITA the claimed structure or function.

D. Obviousness

25. I have been informed and understand a claim is unpatentable if it had 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 may be found to be obvious from a single prior art reference, including a combination of multiple embodiments from a single prior art reference, or from a combination of embodiments from two or more prior art references.

26. I understand that evaluating obviousness involves considering several factors, such as the scope and content of the prior art, the differences between the claimed invention and the prior art, and the level of a POSITA in the relevant field of technology.

27. I further understand that a claim would have been obvious if it combines old elements with no change to their respective functions, or simply 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 technique has been used to improve one device and a POSITA would recognize that applying the same technique would have similarly improved similar devices in the same way, then it

would have been obvious to use that technique in such applications. I understand that a claim would have been obvious if common sense directs one to combine multiple prior art references or add missing features. I also understand that a claim would have been obvious if a POSITA had recognized that a combination of elements from a single or multiple references could be made with a reasonable expectation of success.

28. I have been informed and understand that a determination of obviousness must avoid hindsight bias derived from the patent under consideration. Accordingly, the patent's claims or its description of the claimed subject matter cannot serve as a roadmap when evaluating combinations of prior art references.

E. Multiple Dependent Claims

29. I understand that claims 4 and 5 have been drafted in a format that is called a multiple dependent claim because it recites "[t]he lens as claimed in any one of claims 1 to 3." I understand that claims 4 and 5 can each be thought of as three separate claims. For example, claim 4 has three claims that depend on claims 1, 2 and 3. Similarly, claim 5 has three claims that depend on claims 1, 2, and 3. As such, I have added square brackets next to claims 4 and 5 to identify the version of claims that it depends from throughout my declaration.

F. Antecedent Basis

30. I understand that any claim element first addressed in the claims should normally begin with “a” or “an.” Then, if the same claim element is later identified in the claims, the antecedent “the” should be utilized to avoid any ambiguity.

III. Summary of Opinions

31. For the reasons explained below, I conclude that claims 1-8 and 10-13 of the '873 Patent are unpatentable as being anticipated and/or rendered obvious by the prior art references identified below.

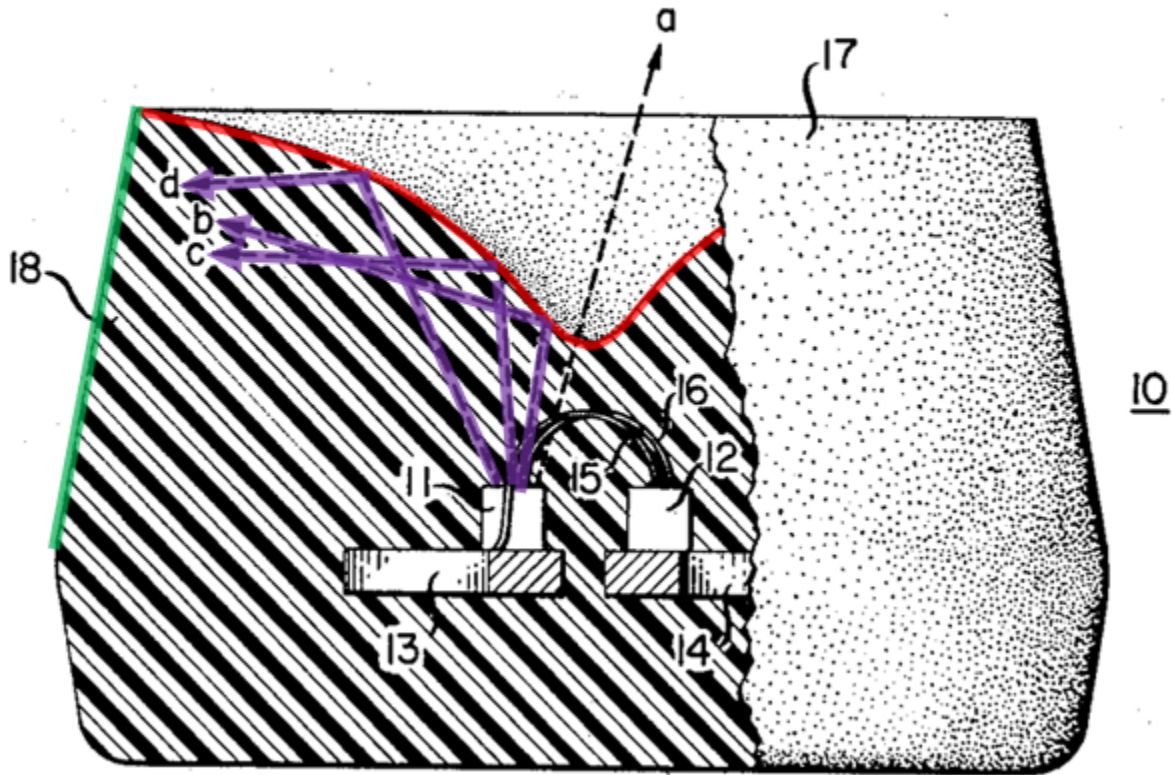
Grounds	Claims	Statutory Ground	Prior Art Reference(s)
I, II	1, 2, 4[1], 4[2], 5[1], 5[2], 7	35 U.S.C. §102/103	Odawara
III	1, 2, 4[1], 4[2], 5[1], 5[2], 6, 7	35 U.S.C. §103	Odawara in view of West
IV, V	1, 3, 4[1], 4[3], 7	35 U.S.C. §102/103	Sommers
VI	1, 3, 4[1], 4[3], 5[1], 5[3], 6, 7	35 U.S.C. §103	Sommers in view of West
VII	8, 10-13	35 U.S.C. §103	Elpedes in view of Odawara
VIII	8, 10-13	35 U.S.C. §103	Elpedes, in view of Odawara, and West
IX	8, 10-13	35 U.S.C. §103	Elpedes in view of Sommers
X	8, 10-13	35 U.S.C. §103	Elpedes in view of Sommers, and West

IV. Technology Background

A. General Overview of Technology

32. Side illumination lenses were well-known long before the alleged priority date of the '873 Patent. For instance, as shown below, U.S. Patent No. 3,774,021, issued on November 20, 1973, demonstrates a side illumination lens that has **a total internal reflection (TIR) surface** combined with **refractive side surfaces** on the side.

FIG. 1



EX1008, Figure 1.

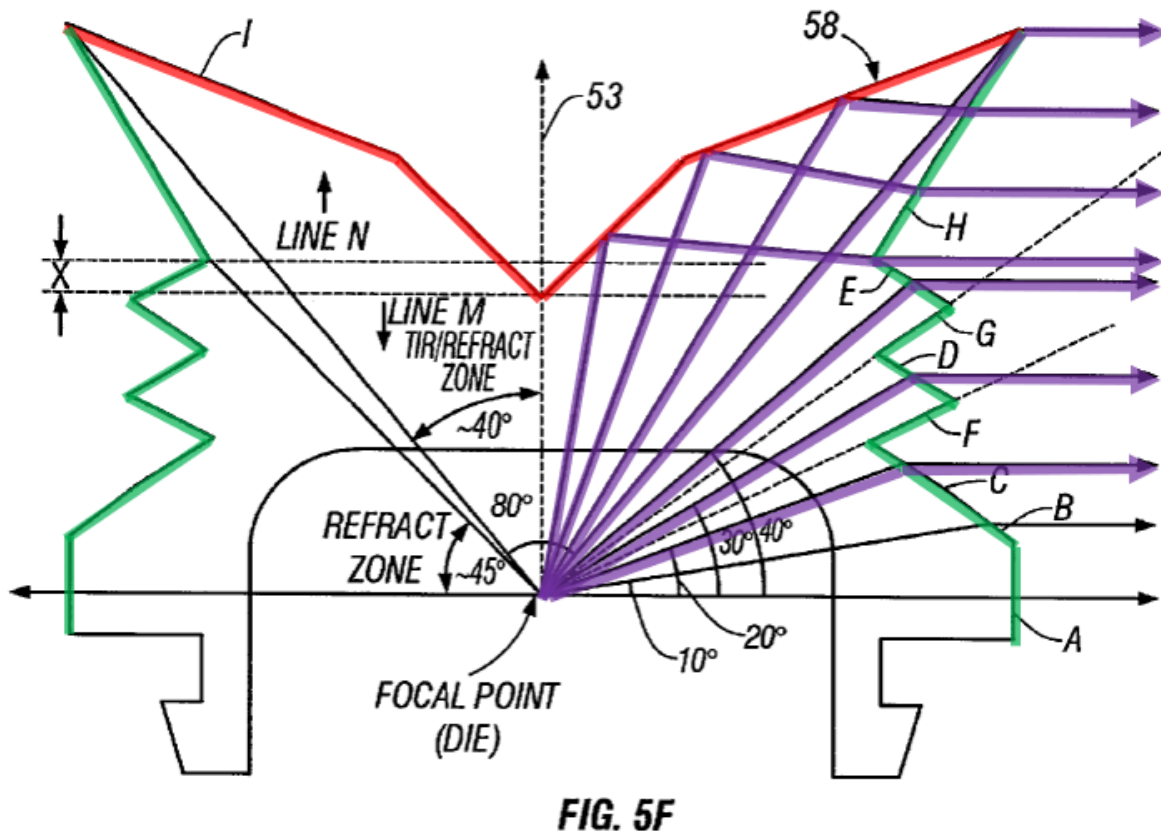
33. The design principles behind the above lens, are described as follows:
“[t]he light emitting devices are designed according to principles of internal reflection so that the predominant portion of the light produced in each diode is emitted in a confined plane and with a uniform flux over 360°.” EX1008, 1:23-27.

“Light reflected from this surface has a high probability of exiting the dome through the sidewall 18, the ultimate goal.” EX1008, 2:24-29.

34. The reasons for the industry developing such side illumination lenses are described in the Background section of the '873 Patent itself. Light sources, such as light-emitting diodes (LEDs) that emit light in random directions, often benefit from lenses that are able direct light in desired directions. Specifically, the '873 Patent notes that “since the direction of light emitted by a light emitting diode is random, the light should be induced in a desired direction to be used as an illumination device and a backlight.” EX1001, 1:28-41. The '873 Patent further acknowledges that lenses designed to emit light in side directions were already well-known. See, EX1001, 1:38-45 (“studies on development of a device capable of emitting light in side directions of a lens have been actively conducted using the total internal reflection (TIR) property of light.”).

35. One such example provided in the '873 Patent is a reference called West. As the '873 Patent states, one “[c]onventional lens[] using [total internal reflection] TIR [is] disclosed in U.S. Pat. No[. ... 6,598,998 [West].” EX1001, 1:45-46. Figure 5F of West, reproduced below, shows a design where light emitted

from the die is totally reflected using **TIR surface** 58 and exits sideways through **refractive surfaces** on the sides of the lens.



EX1005, Figure 5F.

36. However, the '873 Patent criticizes these “conventional lens[es]” for their complexity and cost of fabrication. It explains that lenses with “a plurality of **refractive surfaces** formed on right and left sides of the **total reflection surface**”

require molds with multiple parts or casting/grinding methods that are difficult to implement. Specifically, it notes, “if a lens is fabricated using a mold, upper and lower mold parts and right and left mold parts are required; and if a lens is fabricated by means of a casting or grinding method, it cannot be easily fabricated in view of its shape.” EX1001, 1:51-59.

V. Overview of the '873 Patent

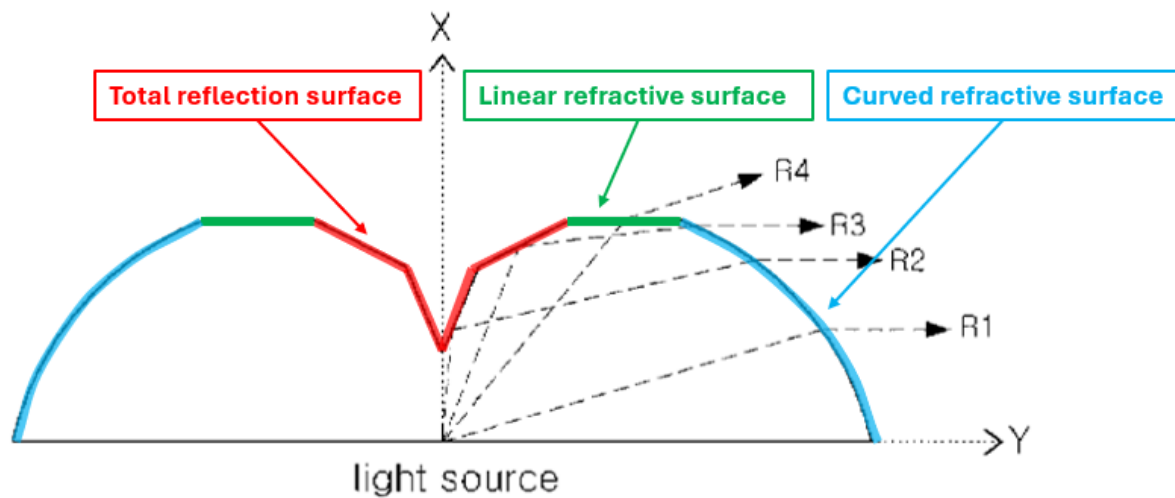
A. Summary of the '873 Patent

37. The '873 Patent describes “a side illumination lens and a device using the same.” EX1001, Abstract. The lens described in the '873 Patent includes a **total reflection surface** and at least one of a **linear refractive surface**, a **curved refractive surface**, or both, which “extend away from the central axis and beyond the periphery of the total reflection surface,” which I understand was alleged to be a novel feature of the independent claims, as more fully explained below in Paragraphs 42-43, and 45-46. *See* EX1001, claim 1; EX1003, 415-421, 431.

38. Figure 31 provides an example of this type of lens, depicting a **total reflection surface**, a **linear refractive surface**, and a **curved refractive surface**. As illustrated, light incident on the total reflection surface is reflected toward the linear and curved refractive surfaces. These surfaces then direct the light rays

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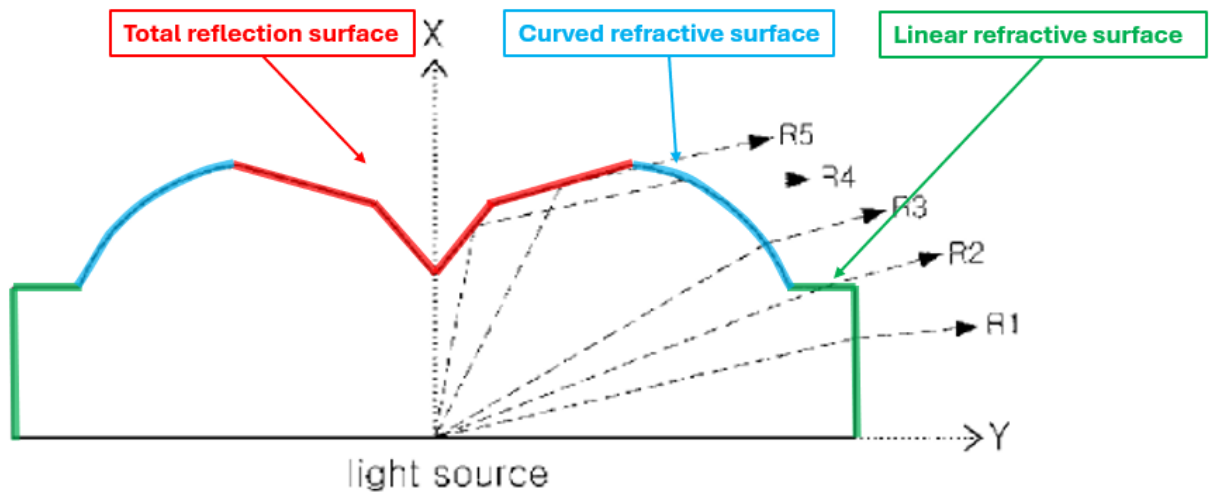
outward from the lens, primarily along the horizontal y-axis direction. *See*
EX1001, 17:12-19.



EX1001, Figure 31.

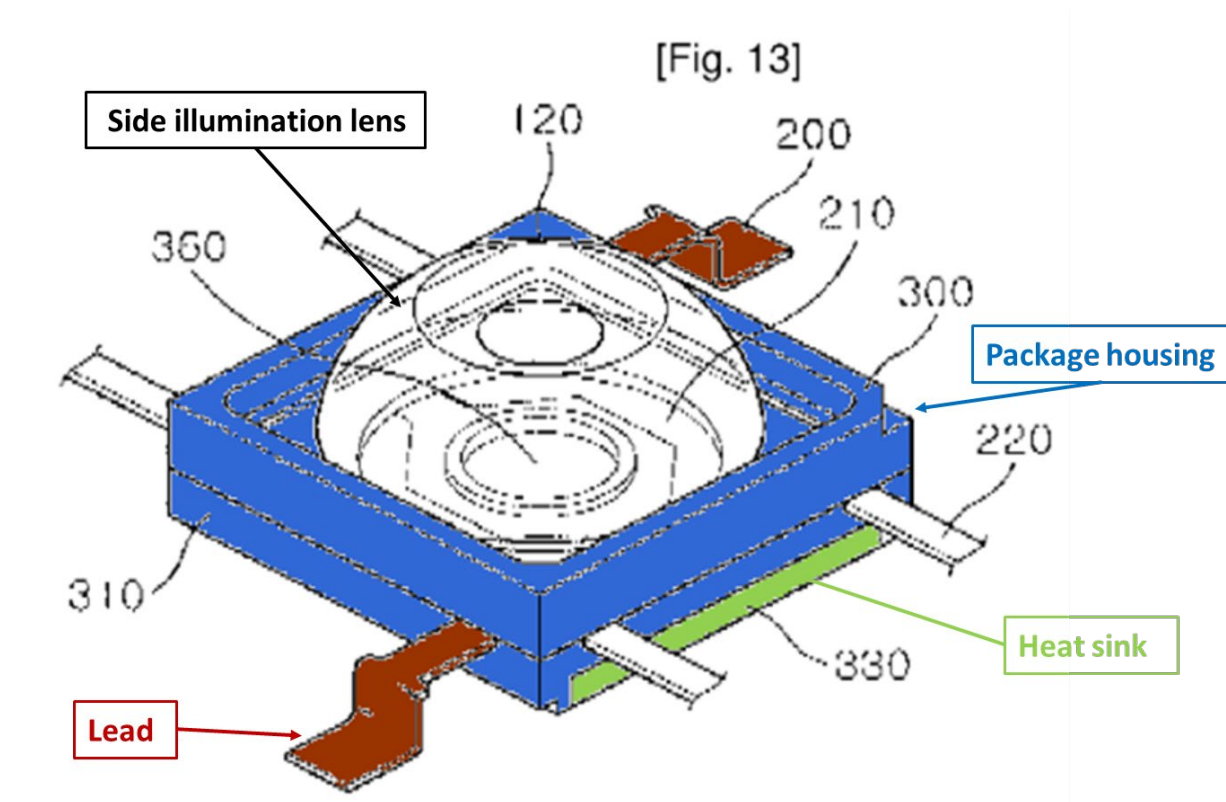
39. Another example of the claimed lens is depicted in Figure 35 below. Similar to the lens shown in Figure 31, light striking the **total reflection surface** is reflected toward both the **curved refractive surface** and the **linear refractive surface**. These surfaces then redirect the light rays, again causing them to exit the lens primarily along the horizontal y-axis direction. *See* EX1001, 18:22-42.

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EX1001, Figure 35.

40. The '873 Patent also explains that these side illumination lenses can be integrated into a luminescent device. This device may also include additional components, such as a **package housing 300**, **lead terminals 200**, and **heat sink 330**. See EX1001, 8:10-17; 8:36-41.



EX1001, Figure 13.

B. Summary of the Prosecution History of the '873 Patent

41. The application for the '873 Patent was filed on April 6, 2007.

EX1001, Cover. The application that was issued as the '873 Patent claims priority to four Korean Patent Applications: 10-2004-0079909 (filed October 7, 2004), 10-2005-0000269 (filed January 3, 2005), 10-2005-0056436 (filed June 28, 2005), and 10-2005-0083743 (filed September 8, 2005). EX1001, Cover.

42. The Examiner rejected all pending claims 1-15 in a Non-Final Office Action mailed on June 1, 2009. EX1003, 390-399. Specifically, the Examiner rejected claims 1-7 under 35 U.S.C. §102(b) as being anticipated by West (EX1005). EX1003, 392-394. Additionally, claims 8-15 were rejected under 35 U.S.C. §103(a) as obvious over U.S. Patent No. 6,274,924 (“Carey”) in view of West. EX1003, 394-398.

43. In response to this Non-Final Office Action, the Applicant amended independent claim 1 to include the limitation “a linear and/or curved refractive surface(s) formed to extend away from the central axis and beyond a periphery of the total reflection surface.” EX1003, 415. Similarly, independent claims 8 and 12 were amended to include the limitation “a refractive surface formed to extend away from the central axis and beyond a periphery edge of the total reflection surface.” EX1003, 416-418. Applicant explicitly argued that these amendments differentiate the claimed lens from that of West, because “West’s refractive portion 56 does not extend away from the central axis and beyond a periphery of the total internal reflection funnel portion 58.” EX1003, 420. The Applicant did not provide additional arguments regarding the dependent claims 2-7, merely

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arguing that these claims are allowable because they depend from claim 1.

EX1003, 420.

44. On December 9, 2009, the Examiner issued another Office Action rejecting claim 1 under 35 U.S.C. §112, second paragraph as indefinite because it was unclear whether “the refractive surfaces are linear, curved, or linear and curved.” EX1003, 426-428.

45. In response, the Application for the '873 Patent amended the independent claim 1 to recite the following: “at least one of a linear refractive surface and[[/or]] a curved refractive surface[[s]] formed to extend away from the central axis and beyond a periphery of the total reflection surface.” EX1003, 431.

46. The Examiner issued a Notice of Allowance on April 29, 2010. EX1003, 1436-1441. In the Reasons for Allowance the Examiner stated that the reason for allowance was that the prior art failed to teach and/or show a lens “having a body with a total reflection surface and a linear refractive surface and a curved refractive surface formed to extend away from a central axis and beyond a periphery of the total reflection surface.” EX1003, 1440.

47. The '873 Patent issued on July 6, 2010. EX1003, 1475, EX1001, Cover.

VI. Level of Ordinary Skill in the Art

48. As I noted above in Paragraphs 17-18, I have been informed that a patent and the prior art should be analyzed from the perspective of a POSITA.

49. I considered the factors I noted in the Paragraphs 17-18. I have been unable to locate any information regarding the education level of the inventors. Nevertheless, based on the nature of the art and the claimed solutions, it is reasonable to infer that the inventors likely possessed at least a bachelor's degree with a foundation in engineering and/or optics. Often, such optical engineers would have a few years of experience in the industry working in these lens design, working on problems such as the design of lens shapes based on reflection and/or refraction of light rays to achieve desired light output characteristics. The references applied by the Examiner in rejecting the claims during the prosecution of the '873 Patent are consistent with my understanding discussed above. In my opinion, the field of lens design was a relatively mature field by 2004, and the field was not recognized to be developing groundbreaking and truly novel inventions by 2004.

50. Accordingly, based on my analysis, a POSITA as of the earliest claimed priority date of the '873 Patent (i.e., October 7, 2004) would have at least

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a bachelor's degree in engineering (e.g., optical engineering), physics, or a related field, and a minimum of two years of experience in designing optical systems. A POSITA would have readily known how to design lens shapes applying the well-known principles of how light rays reflect and refract off different material surfaces. A POSITA would also know how such lenses would be incorporated in various light-emitting devices. I note that a higher level of education or specific skills in the industry may make up for less experience and vice versa.

51. I met and/or exceeded these requirements for POSITA for at least the reasons provided above in Paragraphs 2-8.

VII. Overview Of The Prior Art References

A. Overview of Odawara

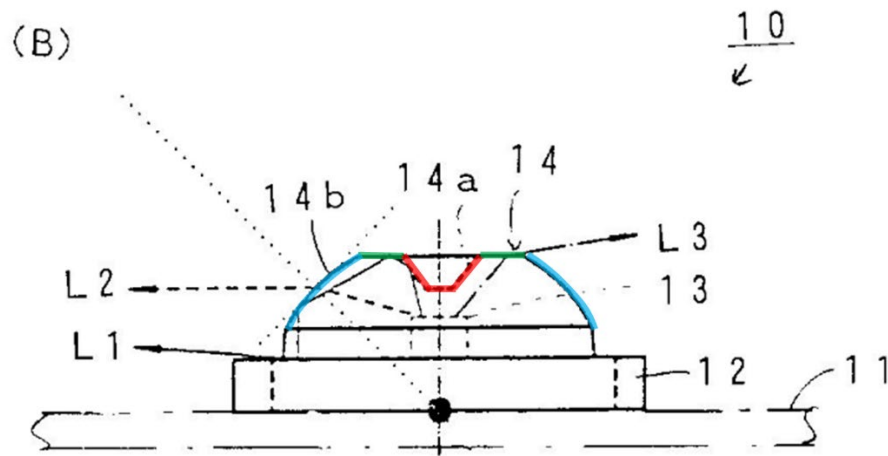
52. Odawara is a Japanese Patent Publication No. 2002-344027, which published on November 29, 2002. EX1004, Cover. I have been informed that Odawara is prior art to the '873 Patent. I have reviewed a certified translation of Odawara and have relied on the certified translation in forming my opinions.

53. Odawara describes a lens where "the light that is emitted from the LED chip ... travels in an almost horizontal direction." EX1004, [0018]. As illustrated in Figure 1 below, the lens includes three primary features: a **cone-**

shaped recessed part 14a, a **linear upper surface**, and a **curved side surface 14b**, which extends outward from the central axis and beyond the periphery of the **recessed part 14a**. The **recessed part 14a** is centrally located on the upper surface of the lens and is specifically designed to reflect light emitted from the LED chip upwards in the optical axis direction. This reflection redirects the light laterally around the entire periphery. EX1004, [0016], [0029], [0034].

54. The **curved side surface 14b** extends outward from the central axis and beyond the periphery of the **recessed part 14a**. The **side surface** can take various shapes, including spherical or truncated cone forms, depending on the desired light distribution. EX1004, [0018], [0033].

55. Additionally, Odawara emphasizes that the **recessed part 14a** and **side surface 14b** work together to achieve wide directivity. Light striking the **recessed part** is first reflected laterally and subsequently directed through the **refractive side surface**, enabling the lens to emit light evenly along a horizontal plane. These combined features allow the lens to achieve a wide emission pattern with high efficiency, making it suitable for applications like backlighting or key illumination. EX1004, [0029], [0032], [0034].



EX1004, Figure 1.

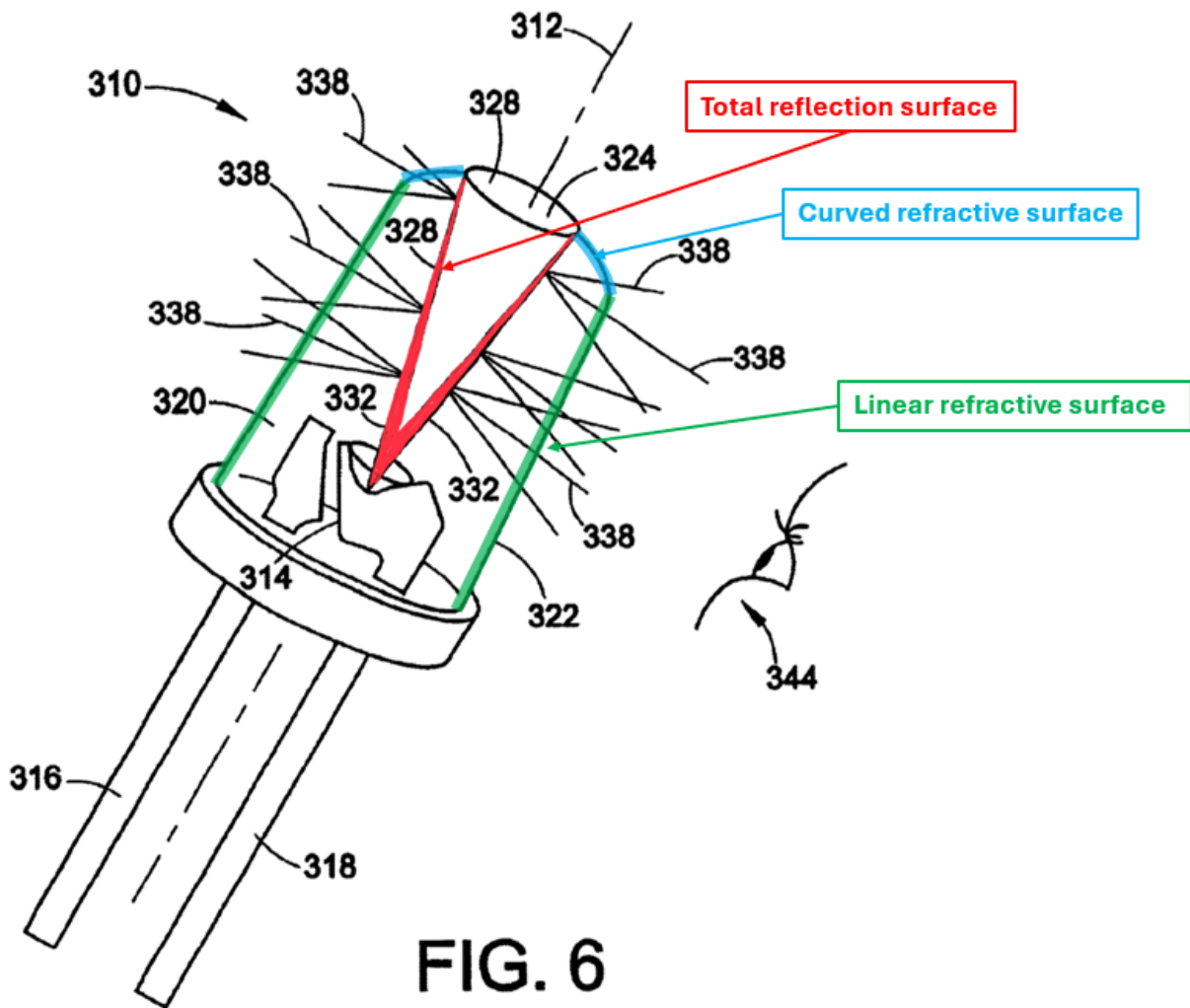
B. Overview of Sommers

56. Sommers is a U.S. Patent No. 6,674,096 issued on January 6, 2004.

EX1006, Cover. I have been informed that Sommers is prior art to the '873 Patent.

57. Sommers teaches a number of side-emitting lenses, one of which is shown in Figure 6 below. See, EX1006, 5:63-66 (“[A]nd this is indicated in FIG. 6 by a plurality of rays 338 emanating from each point where an incident ray 332 scatters off inner surface 328.”). The lens includes a **depression 324 with surface 328**, which is described as having a reflective coating. Specifically, Sommers at 6:6-10, states: “For example, the scattering strength may be increased either by coating the outer surface 328 with a reflective coating, or by filling depression 324

with a metal or other reflective filling material which is pressed against outer surface 328 and conforms to the roughness of that surface.”



EX1006, Figure 6.

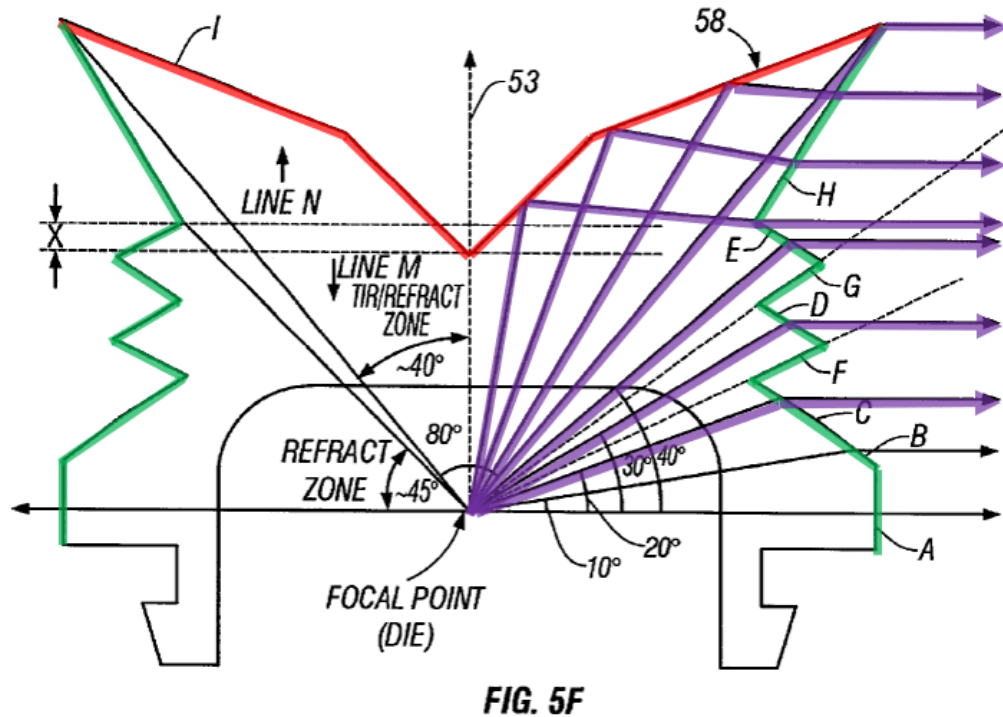
58. Furthermore, Figure 6 of Sommers illustrates a side surface 322 that incorporates both a **curved refractive surface** portion and a **linear refractive**

surface portion. See, e.g., EX1006, 6:26-29 (“Additionally, because the light is scattered diffusely, any refraction occurring at side surface 322 will not significantly change the intensity distribution, and so the detailed curvature of the side surfaces is also not critical.”)

C. Overview of West

59. West is a U.S. Patent No. 6,598,998 issued on July 29, 2003. EX1005, Cover. I have been informed that West is prior art to the '873 Patent.

60. West is directed to a “side emitting light emitting device.” EX1005, Title. As illustrated in Figure 5F below, West describes a lens featuring a “[f]unnel **portion 58** [that] is designed as a TIR surface. The TIR surface reflects light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.” EX1005, 4:12-15. Additionally, West includes a “**sawtooth portion 56** [that] is designed to refract and bend light so that the **light exits** from the lens 44 as close to 90 degrees to the longitudinal package axis 43 as possible.” EX1005, 4:2-9.



EX1005, Figure 5F.

61. As I noted above in Paragraphs 42-43, the Examiner cited West during prosecution and the Applicant for the '873 Patent overcame this rejection by amending the independent claim 1 to recite that “at least one of a linear refractive surface and[[/or]] a curved refractive surface[[s]] formed to extend away from the central axis and beyond a periphery of the total reflection surface.”

EX1003, 415-418, 431. And as I noted, each of independent claims 8 and 12 was

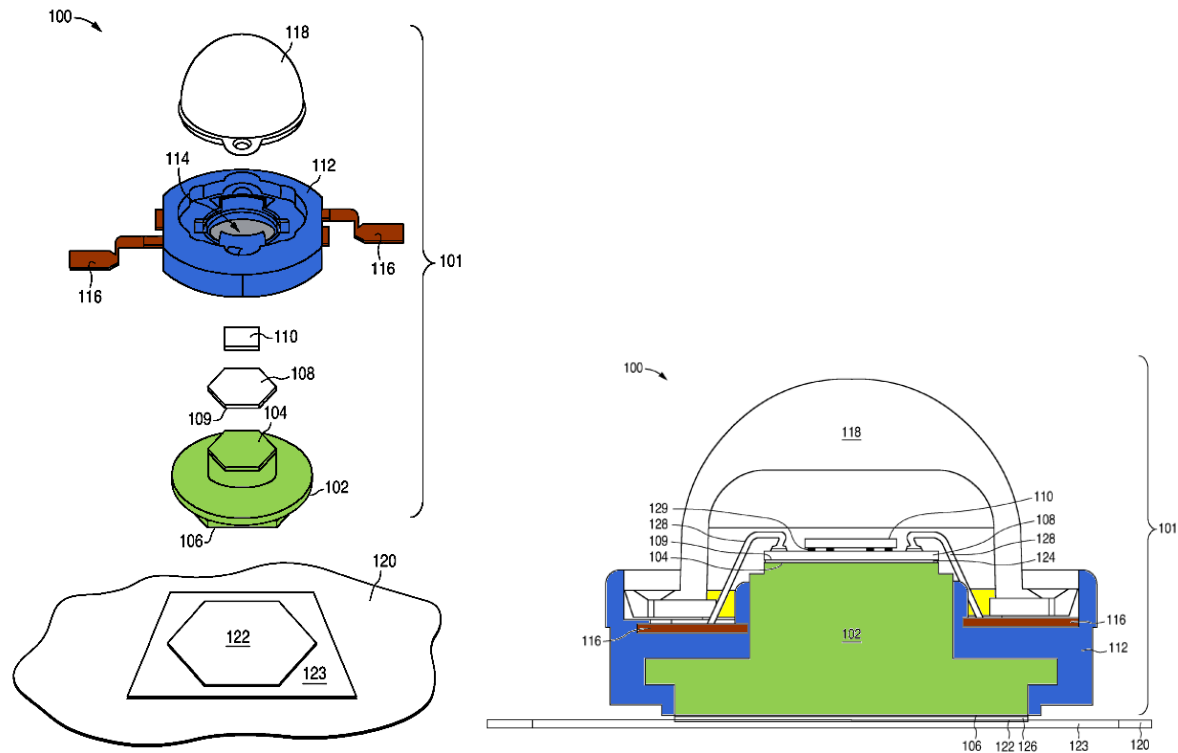
amended similarly. EX1003, 415-418, 431. I note that in the Paragraphs below, I do not rely on West for these limitations.

D. Overview of Elpedes

62. Elpedes is a U.S. Patent Publication No. 2004/0140543, which published on July 22, 2004. EX1007, Cover. I have been informed that Elpedes is prior art to the '873 Patent. To illustrate the features of Elpedes, I have used figures from U.S. Patent No. 7,170,151 (EX1015), which is the issued patent for Elpedes. I chose figures from EX1015 because they are of higher quality. I found no other substantial differences between the figures in Elpedes (EX1007) and EX1015. I understand that EX1015 is also prior art to the '873 Patent.

63. Elpedes teaches an LED assembly. See, EX1007, Abstract (“An LED assembly includes a heat sink and a submount... The LED assembly may further include a substrate having a top mating surface, and the heat sink may further include a bottom mating surface.”). As illustrated in Figure 1A below, the LED assembly comprises a lens 118, **body 112**, **leads 116**, and **heat sink 102**. Elpedes further teaches that the “[s]ubmount 108 is mounted on a **heat sink 102** (also called a ‘**slug**’).” EX1007, [0010]; *see also* EX1007, [0013 (“LED package 100 further includes a **body 112** that defines a cavity 114 (FIGS. 1A and 1B). ... **Body**

112 includes **leads 116** that pass electrical signals between LED package 100 and other components. ... **Body 112** further includes a lens 118 fitted on **body 112**.”)



EX1007, Figures 1A and 2.

VIII. Claim Construction

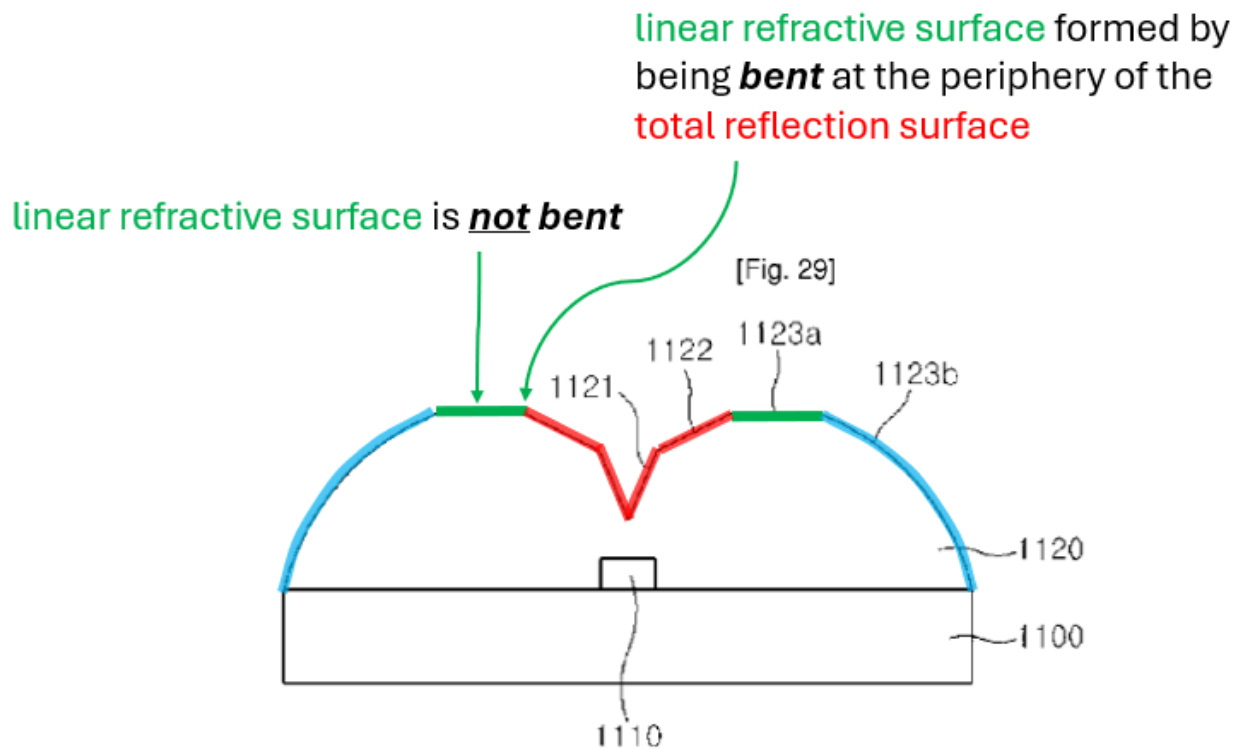
64. I analyzed whether any particular claim terms should be construed. First, I have not seen any terms that were defined in the patent specification. I have also analyzed the claims, the patent’s specification, the prosecution history, and the prior art considered during prosecution and believe that the claim terms should be

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,748,873

interpreted by applying the ordinary and customary meaning as understood by a POSITA as of October 7, 2004.

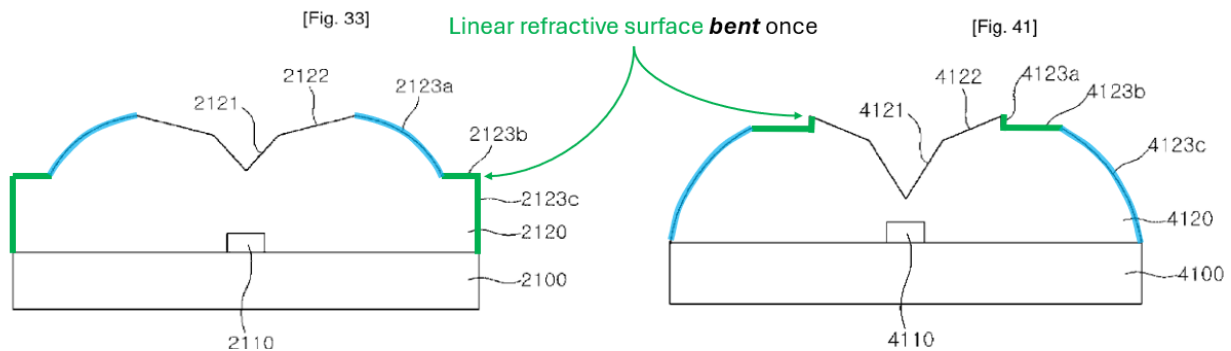
65. I note that claim 5 of the '873 Patent recites a limitation “wherein the **linear refractive surface** is bent more than once.” In my opinion, under a proper construction, this term requires that the claimed “**linear refractive surface**” to include at least two bends.

66. I first note that this term does not encompass bends that occur at the junctions between (1) the **total reflection surface** and the **linear refractive surface**, or (2) the **linear refractive surface** and the **curved refractive surface**. For example, as depicted in Figure 29 below, the **linear refractive surface** may begin at a bend where it connects to the **total reflection surface**, but the **linear refractive surface** itself remains unbent along its length.



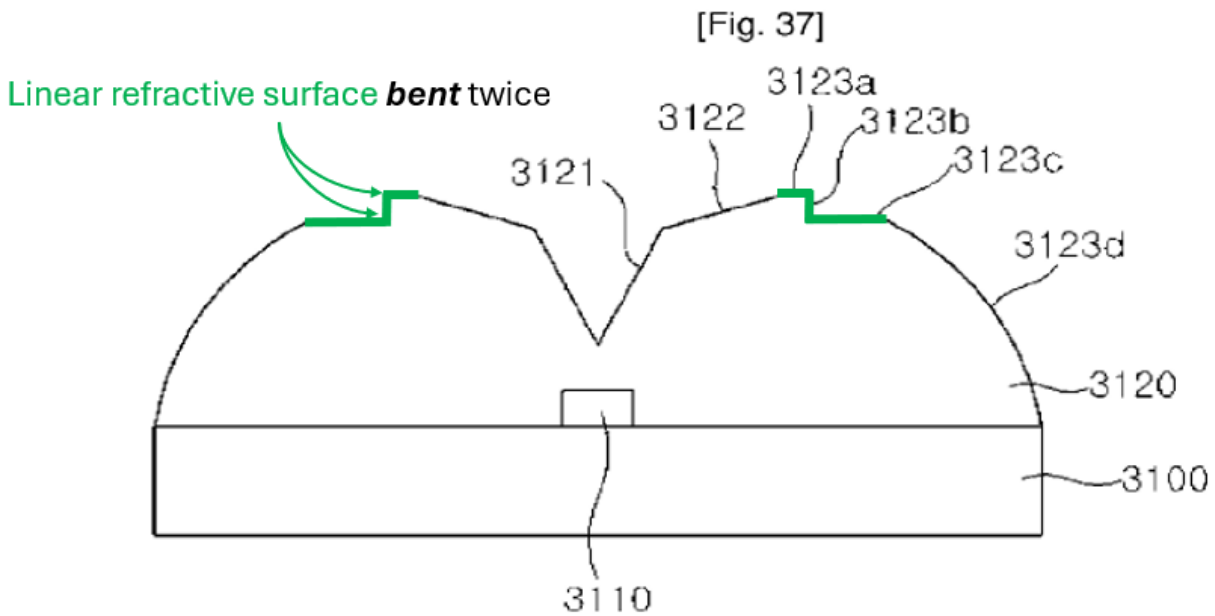
EX1001, Figure 29.

67. The term also does not include a **linear refractive surface** that is bent only once. For instance, Figure 33 illustrates a lens “with a **linear surface** extending from a **curved surface** and bent once” (EX1001, 18:10-12), as seen between the **linear refractive surfaces 2123b** and **2123c**. Likewise, Figure 41 depicts a “side illumination lens with a **linear surface** bent once” (EX1001, 20:61-64), demonstrated by the **surfaces 4123a** and **4123b**.



EX1001, Figures 33 and 41.

68. In contrast, Figure 37 illustrates a lens “with a **linear surface bent twice**” (EX1001, 19:35-38). This is evident from the segments labeled **3123a**, **3123b**, and **3123c**, which together form the linear refractive surface with two distinct bends.



EX1001, Figure 37.

69. Thus, based on the disclosures in the '873 Patent and consistent with its plain and ordinary meaning, the term “wherein the **linear refractive surface** is bent more than once” means that the **linear refractive surface** includes at least two bends.

IX. Specific Grounds

70. As I explained in Paragraph 31, I conclude that claims 1-8 and 10-13 of the '873 Patent are anticipated and/or rendered obvious by the prior art. In the sections below, I explain in detail how claims 1-8 and 10-13 of the '873 Patent are not patentable over prior art.

A. Grounds I and II: Odawara Anticipates Or Renders Obvious Claims 1, 2, 4[1], 4[2], 5[1], 5[2], And 7.

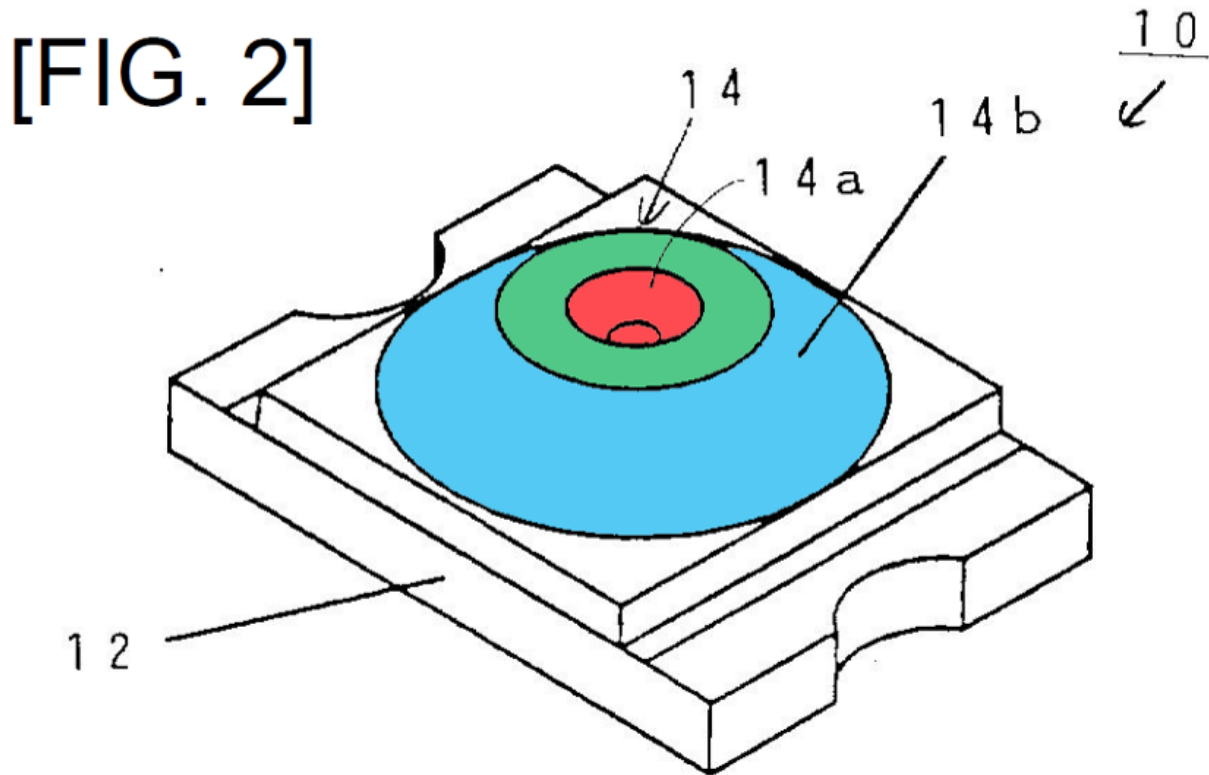
71. In my opinion, claims 1, 2, 4[1], 4[2], 5[1], 5[2], and 7 are all anticipated or rendered obvious by Odawara.

1. Independent Claim 1 And Dependent Claim 2

i. [1pre] A lens, comprising:

72. I understand that the preamble may not limit the claims. Regardless, in my opinion, Odawara teaches [1Pre].

73. Odawara discloses a “**lens.**” For instance, Odawara discloses a “surface mounted LED 10 [which] includes a chip substrate 12 having a surface mounted terminal part, an LED chip 13 mounted on the chip substrate, and a ***lens part 14...***”). EX1004, Abstract. *See also* EX1004, [0024] (“The ***lens part 14*** is made of a transparent or translucent material, such as a thermosetting epoxy resin, and is formed by a transfer molding process. The ***lens part 14*** functions as a light emitting part by emitting light from the LED chip 13 from the front surface.”); Figures 1-3.



EX1004, Figure 2.

ii. [1a] a body;

74. In my opinion, Odawara teaches [1a].

75. Odawara discloses that “a lens part formed [is] of a transparent or translucent resin on the chip substrate so as to surround the LED chip.” EX1009, [0009], Abstract, claim 1, [0024]. This lens part is designed to be positioned on the chip substrate, and thereby it surrounds the LED chip and is made from a material that allows light to pass through.

76. Odawara also provides additional information about the shape and structure of the lens part. It states that “the lens part 14 has a cone shaped recessed part 14a in the center of the upper surface, and the surrounding side surface 14b is formed so as to taper upward.” EX1004, [0025]; *see also* EX1004, claims 1 and 3, [0009]-[0011], [0016], [0029], [0034].

iii. [1b] a **total reflection surface** with a total reflection slope with respect to a central axis of the body; and

77. In my opinion, Odawara teaches [1b].

78. As a preliminary matter, the '873 Patent provides three different examples of what constitutes a “**total reflection surface**.”

79. The *first example* involves a surface that reflects light by relying on the principle of total internal reflection (TIR). For instance, the specification states: “Conventional lenses using [total internal reflection] TIR are disclosed in U.S. Patent Nos. 6,679,621, 6,607,286, and 6,598,998. In the patents, a lens comprises a total reflection surface...” EX1001, 1:45-51. As another example, the specification states, “An object of the present invention is to provide a side illumination lens, which comprises a total internal reflection surface with a total reflection slope...” EX1001, 2:14-20. While the '873 Patent frequently refers to “total internal

reflection” in its description, the claims omit the term “internal” in “**total reflection surface.**”

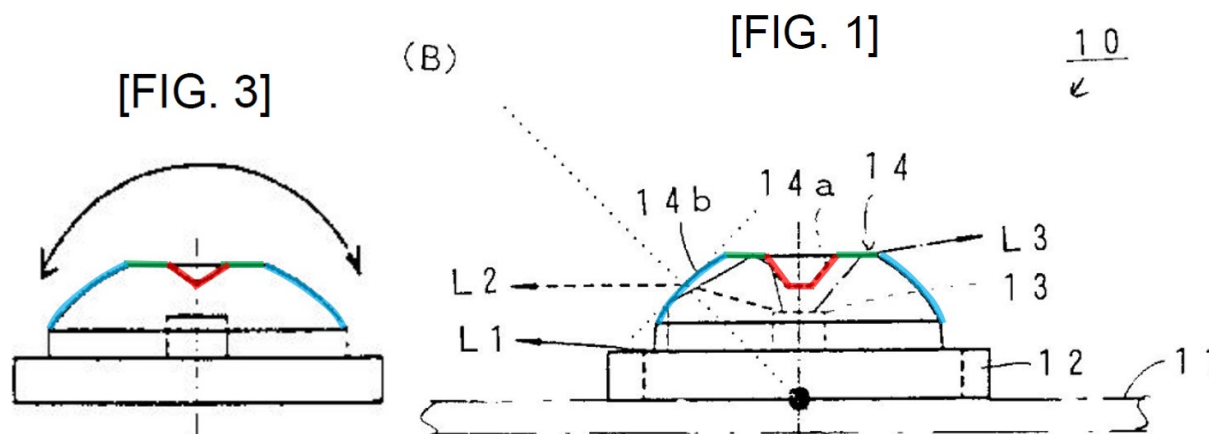
80. The *second example* describes a surface that achieves total reflection through the application of a reflective material. This can involve a surface lined or coated to reflect light fully. The '873 Patent discusses this in the context of lens 12, which is lined with “reflection cups 14” to achieve light reflection. See EX1001, 1:28-41.

81. The *third example* combines aspects of the first two. It describes a total internal reflection surface that is additionally lined or coated with a reflective material to ensure total light reflection. The '873 Patent refers to U.S. Patent No. 6,598,998 (West), which states: “[i]n the patent[], a lens comprises a **total reflection surface** which is formed on the lens and has a predetermined slope.” EX1001, 1:42-47. West provides further explanation, noting that **funnel portion 58** [that] is designed as a [total internal reflection] TIR surface.” EX1005, 4:12. Additionally, West explains that a “metallization layer (e.g., aluminum) may be placed on top of **funnel portion 58** to prevent light transmission through the TIR surface.” EX1005, 17-19.

82. Thus, the '873 Patent encompasses a variety of surfaces that can achieve total reflection. These include surfaces that reflect light through total internal reflection, those coated with reflective materials, and surfaces that combine total internal reflection with metallization.

83. As such, I apply the plain and ordinary meaning of the term “**total reflection surface**” that can include any one of these exemplary surfaces that totally reflect light. Under the plain and ordinary meaning of the term “**total reflection surface**,” Odawara teaches or at minimum renders [1b] obvious. This is evident in Figures 1 and 3, where Odawara describes a **recessed part**. Specifically, Odawara explains that “light emitted from the LED chip upward in the optical axis direction is *totally reflected* by the inner surface of the **recessed part** and travels along the entire periphery in the lateral direction.” EX1004, [0034]; *see also* EX1004, [0014], [0017], [0029].

84. Odawara further describes that this *total reflection* occurs “along the entire periphery in the lateral direction,” producing “an approximately uniform reflection around the entire periphery.” EX1004, [0016], [0017]; *see also* EX1004., [0007], [0020], [0029], [0034].



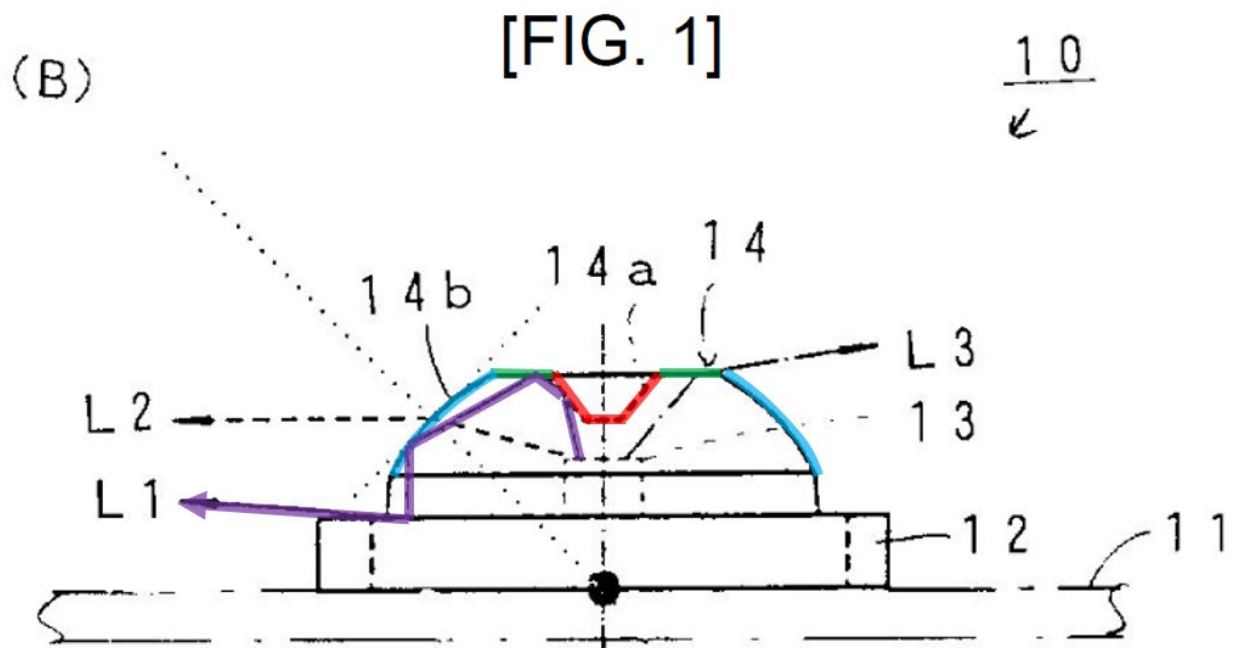
EX1004, Figures 3 and 1B

85. In addition, the **recessed part** includes a slope relative to the optical axis, which runs vertically through the center of the lens. Odawara describes the **recessed part** as being “cone shaped,” with examples provided in Figures 1B and 3. See EX1004, Abstract, claims 1, 2, [0009], [0016]-[0018], [0020], [0025], [0034]. According to Odawara, the “center axis substantially coincides with the optical axis perpendicular to the LED chip 13 and the chip substrate 12.” EX1004, [0026].

86. It is unclear whether Figures 1 and 3 are directed to the same or different embodiments. But even assuming Figures 1 and 3 describe different embodiments, it is my opinion that a POSITA would have found it obvious to replace the **recessed part** in Figure 1 (having a flat bottom) with the **recessed part**

illustrated in Figure 3 (with a pointy cone shape). I provide my reasons why these two embodiments are combinable further below in Paragraphs 101-105.

87. In fact, a POSITA would likely understand that Odawara teaches that **recessed part 14a** totally reflects light using total internal reflection. For instance, as shown in Figure 1B, Odawara describes that “**light L1** incident on the **recessed part 14a** of the lens part 14 is *totally reflected*, as depicted in FIG. 1(B), and travels laterally, and is *totally reflected* again by the **side surface 14b** of the lens part 14, and is incident on the surface of the chip substrate 12.” EX1004, [0029].



EX1004, Figure 1B.

88. In my opinion, a POSITA would understand that the “totally reflected” **light L1** at the **side surface 14b** is the result of total internal reflection. This interpretation is supported by the behavior of other light rays, such as light L2, which approach the **side surface 14b** at angles smaller than the critical angle required for total internal reflection and simply refract through the surface instead. In contrast, **light L1** is “*totally reflected*” because it reaches the **side surface 14b** at an angle greater than the critical angle necessary for total internal reflection.

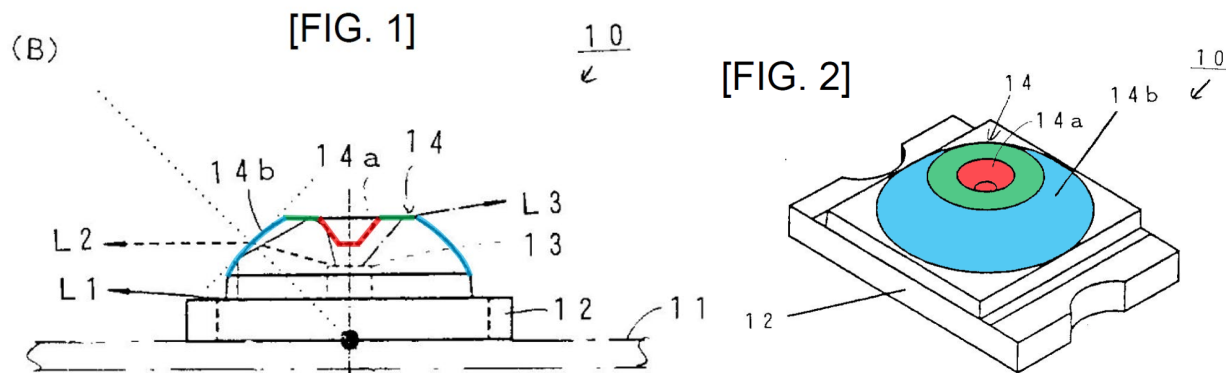
89. Odawara uses the term “totally reflected” consistently to describe the reflections occurring at both the **recessed part 14a** and the **side surface 14b**. See EX1004, [0029]. Note that Odawara does not specify that the **recessed part 14a** includes a metallization layer to enable light to be “*totally reflected*.” As a result, a POSITA would understand that Odawara teaches, or at the very least suggests, that total internal reflection is taking place at the **recessed part**.

- i. [1c] at least one of a **linear refractive surface** and a **curved refractive surface** formed to extend away from the central axis and beyond a periphery of the **total reflection surface**.
- ii. [2] The lens as claimed in claim 1, wherein the refractive surface comprises a **linear refractive surface** formed by being bent at the periphery of the **total reflection surface**; and a **curved refractive surface** formed to extend from a periphery of the **linear refractive surface**.

90. In my opinion, Odawara teaches [1c] and [2]. At a minimum, Odawara renders obvious [1c] and [2].

91. As a preliminary matter, I note that claim 2 refers to “*the* refractive surface,” although claim 1 specifies two different types of refractive surfaces: “a linear refractive surface” and “a curved refractive surface.” Additionally, claim 2 repeats the phrases “a linear refractive surface” and “a curved refractive surface” that was already recited in claim 1. For the purposes of my analysis here, I have interpreted claim 2 to recite that “the linear refractive surface is formed by being bent at the periphery of the total reflection surface; and the curved refractive surface is formed to extend from a periphery of the linear refractive surface.”

92. As is illustrated in Figures 1B and 2 below (and also Figures 1-3 in general), Odawara's lens includes both a **linear refractive surface** and a **curved refractive surface**.



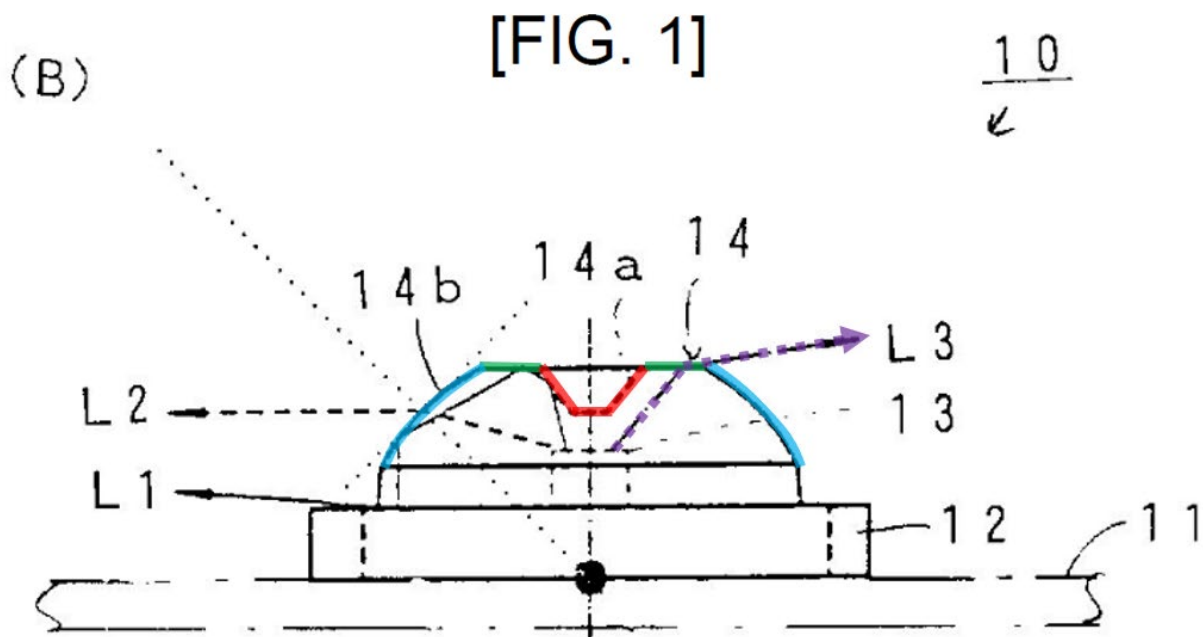
EX1004, Figures 1B and 2

93. As shown, the **linear refractive upper surface** is designed to extend away from the central axis of the lens, continuing beyond the periphery of the **recessed part**. This surface is not only positioned to stretch beyond the **recessed part's** periphery but is also bent at the periphery of the **recessed part**, creating a distinct flat **upper surface** in the overall design.

94. Particularly, as is illustrated in Figures 1-3, the lens part 14 has an **upper surface** that is linear in shape. Both Figures 1 and 3 distinctly highlight the linear nature of this **upper surface**, setting it apart from other components like the **side surface 14b**, which is explicitly depicted and described as curved. This

distinction between the **linear upper surface** and the **curved side surface** is further detailed later in this section. As I already stated in Paragraph 24, I understand that patent drawings can teach a claim limitation if it is clearly shown.

95. Odawara also clearly shows and describes the **upper surface** as refractive, as Odawara describes that “**light L3** incident on the upper surface of the lens part 14 ... is refracted at the **upper surface** of the lens part 14...” EX1004, [0031].



EX1004, Figure 1B; *see also* EX1004, Figures 1-3.

96. In my opinion, a POSITA would, at the very least, find that Odawara renders obvious the “**linear refractive surface**.” Odawara states that the “**upper surface** of the lens part 14 ... is appropriately adjusted ... based on the intended use of the surface mounted LED 10.” EX1004, [0031]. Determining that the **upper surface** should be linear would have been a straightforward matter of routine experimentation using optical engineering techniques that were well-known in the field. In my opinion, a POSITA would have been capable of designing the upper surface to be linear with a reasonable expectation of success. This process would have simply required creating a flat surface and using established methods to evaluate how light refracts through that portion of the lens part 14.

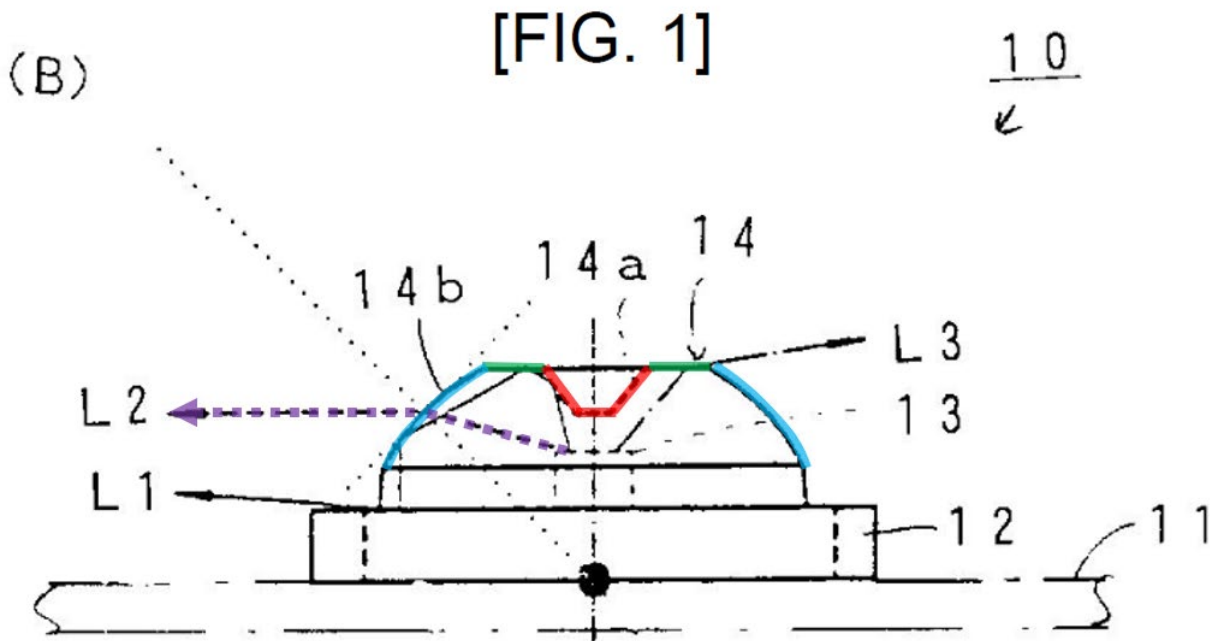
97. And, as is also shown in Odawara’s Figures 1-3, the **upper surface** stretches outward from the central optical axis, extending beyond the periphery of the **recessed part**. In addition, the **linear upper surface** is shaped by being bent at the periphery of the **recessed part**, creating a distinct transition in its form.

98. Furthermore, Odawara teaches that the **curved refractive surface** is designed to extend away from the central axis and beyond a periphery of the

recessed part. Additionally, as is illustrated in Figures 1-3, **side surface 14b** is configured to extend from the periphery of the **linear refractive surface**.

99. Odawara explains that “the surrounding **side surface 14b** is formed so as to *taper upward*.” EX1004, [0025]; *see also* EX1004, claim 3, [0011], [0018], [0020], [0025], [0033]. One example of this tapering is described as having a curved shape that forms part of a sphere. For instance, claim 4 specifies that “the **peripheral side surface** of the lens part is formed as a portion of *a sphere* having a center below an upper surface of the LED chip.” EX1004, claim 4; *see also* EX1004, [0012], [0018].

100. This **side surface 14b** also functions as a refractive surface. Odawara describes that “**light L2** incident on the **side surface 14b** of the lens part 14 is *refracted* slightly downward when passing through the **side surface 14b**, as depicted in FIG. 1(B), ...” EX1004, [0030]. his demonstrates that the side surface interacts with light by bending it as it exits, thereby highlighting its refractive properties.



EX1004, Figure 1B.

2. Reasons To Combine The Embodiments Of Odawara With A Reasonable Expectation Of Success

101. If Odawara's Figures 1-3 are directed to different embodiments, in my opinion, a POSITA would have understood that any of Odawara's embodiments would have been easily combined with the expectation that such combinations would work effectively and achieve the intended results.

102. Odawara identifies Figures 1-3 as illustrating "[a] preferred embodiment" of the invention. Specifically, it states, "[a] preferred embodiment of

the present invention will be described in detail with reference to FIG. 1 to FIG.

3.” EX1004, [0021]. Odawara also clarifies that these figures are merely “preferred specific examples” and that “various technically preferable limitations are applied.” EX1004, [0021].

103. Additionally, Odawara discusses how light rays L1-L3 reflect and/or refract within the embodiment shown in Figure 1B. Odawara further explains that “FIG. 3 is a graph depicting the light distribution characteristics of the surface mounted LED of FIG. 1.” EX1004, [0034]. This indicates that the **recessed parts** in Figures 1 and 3 are treated as comparable, with Odawara concluding that “the light has wide directivity of approximately 180 degrees, and a particularly large amount of light is emitted in the horizontal directions....” EX1004, [0032]; see also EX1004, [0029]-[0032].

104. In other words, a POSITA would have easily understood that both embodiments—whether employing the **recessed part** shown in Figure 1 or Figure 3—achieve the same goal of reflecting light primarily in the horizontal direction. This demonstrates that the embodiments are interchangeable in achieving the desired light distribution.

105. Lastly, in my opinion, a POSITA would have been capable of using either the **recessed part** depicted in Figure 1 or Figure 3 with a reasonable expectation of success. This is because the modification involves nothing more than a straightforward substitution of one **recessed part** for the other, relying on well-established optical calculations concerning the reflection of light off the **recessed part**. Such a substitution would have yielded the same predictable outcome of light emission in the horizontal direction. See EX1004, [0029]-[0032].

3. Dependent Claims 4[1] and 4[2]

- i. **[4] The lens as claimed in any one of claims 1 to [2], wherein the **curved refractive surface** takes the shape of an ellipse, and a ratio of minor and major axes of the ellipse is 1:4 or less.**

106. In my opinion, Odawara teaches 4[1] and 4[2].

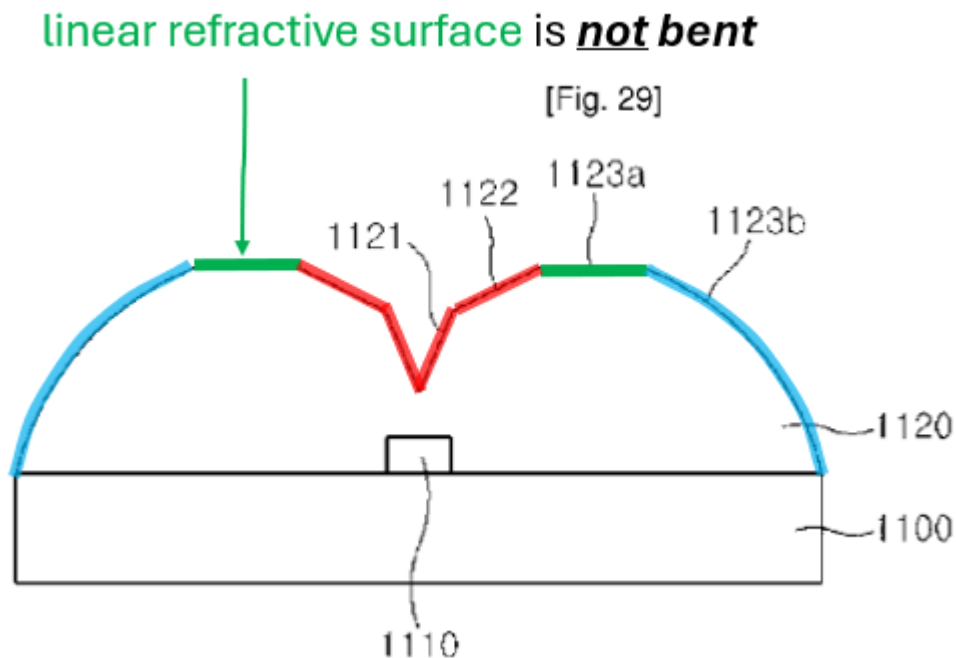
107. As a preliminary matter, the '873 Patent explains that an ellipse can encompass a circle. Specifically, it states, "[t]he second refractive surface 1123 b is made in the form of an ellipse as shown in FIG. 29, and a ratio of minor and major axes of the ellipse is in a range of 1:4 or less. *That is, it may be a circle.*" EX1001, 16:51-54. This indicates that the claimed ratio of the minor and major axes of the ellipse can include a ratio of 1:1.

108. Odawara discloses that “the peripheral **side surface** of the lens part is formed as a portion of *a sphere* having a center below an upper surface of the LED chip.” EX1004, claim 4; *see also* EX1004, [0012], [0018]. This means that the **side surface 14b** would appear as a circle when observed in a two-dimensional cross-section, with a ratio of minor and major axes of approximately 1:1.

4. Dependent Claims 5[1] and 5[2]

- i. **[5] The lens as claimed in any one of claims 1 to [2], wherein the linear refractive surface is bent more than once.**

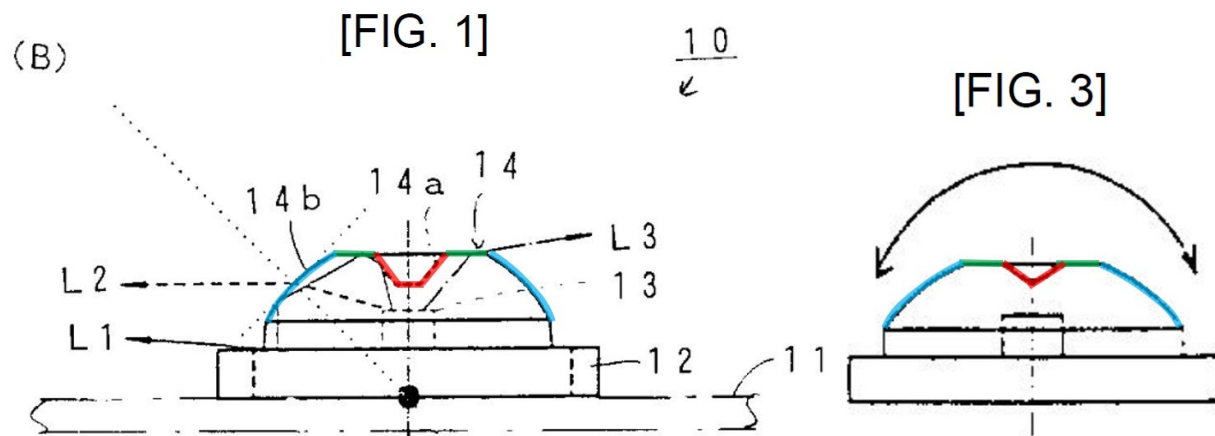
109. As I already explained in Paragraphs 65-69, the term “the **linear refractive surface** is bent more than once” excludes bends that occur at the transitions between the different surfaces, such as the **total reflection surface** and the **linear refractive surface**, or the **linear refractive surface** and the **curved refractive surface**, as shown in the illustration below.



EX1001, Figure 29.

110. I have nevertheless been asked to opine that if the Board considers that “**linear refractive surface** is bent more than once” encompasses the embodiment illustrated in Figure 29 of the '873 Patent due to the presence of a bend between the **total reflection surface** and the **linear refractive surface** and a second bend between the **linear refractive surface** and the **curved refractive surface**, whether Odawara would also teach 5[1] and 5[2]. In my opinion, it would.

111. Specifically, Odawara describes a configuration where the **linear refractive surface** is situated between the **total reflection surface** and the **curved refractive surface**. As shown in Figures 1B and 3, Odawara depicts a lens structure where the **linear refractive surface** is situated between the **total reflection surface** and the **curved refractive surface**.



EX1004, Figures 1B and 3.

5. Dependent Claim 7

- i. [7] The lens as claimed in claim 1, wherein the refractive index of the body is 1.2 to 2.0.

112. In my opinion, Odawara teaches [7].

113. Odawara specifies that the “lens part 14 is made of a transparent or translucent material, such as a thermosetting epoxy resin.” EX1004, [0024]. It is well-known and a POSITA would have been aware that epoxy resin has a

refractive index of approximately 1.5. *See*, for instance, EX1006 (Sommers) at 1:40-41, stating that the “an epoxy resin or the like, [has] a refractive index $n \sim 1.5$.”

B. Ground III: Odawara In Combination With West Renders Obvious Claims 1, 2, 4[1], 4[2], 5[1], 5[2], 6, And 7

1. Independent Claim 1 And Dependent Claim 2

i. [1pre] A lens, comprising:

114. I understand that the preamble may not limit the claims. Regardless, in my opinion, Odawara teaches [1Pre] for at least the same reasons I already discussed in Paragraphs 72-73.

ii. [1a] a body;

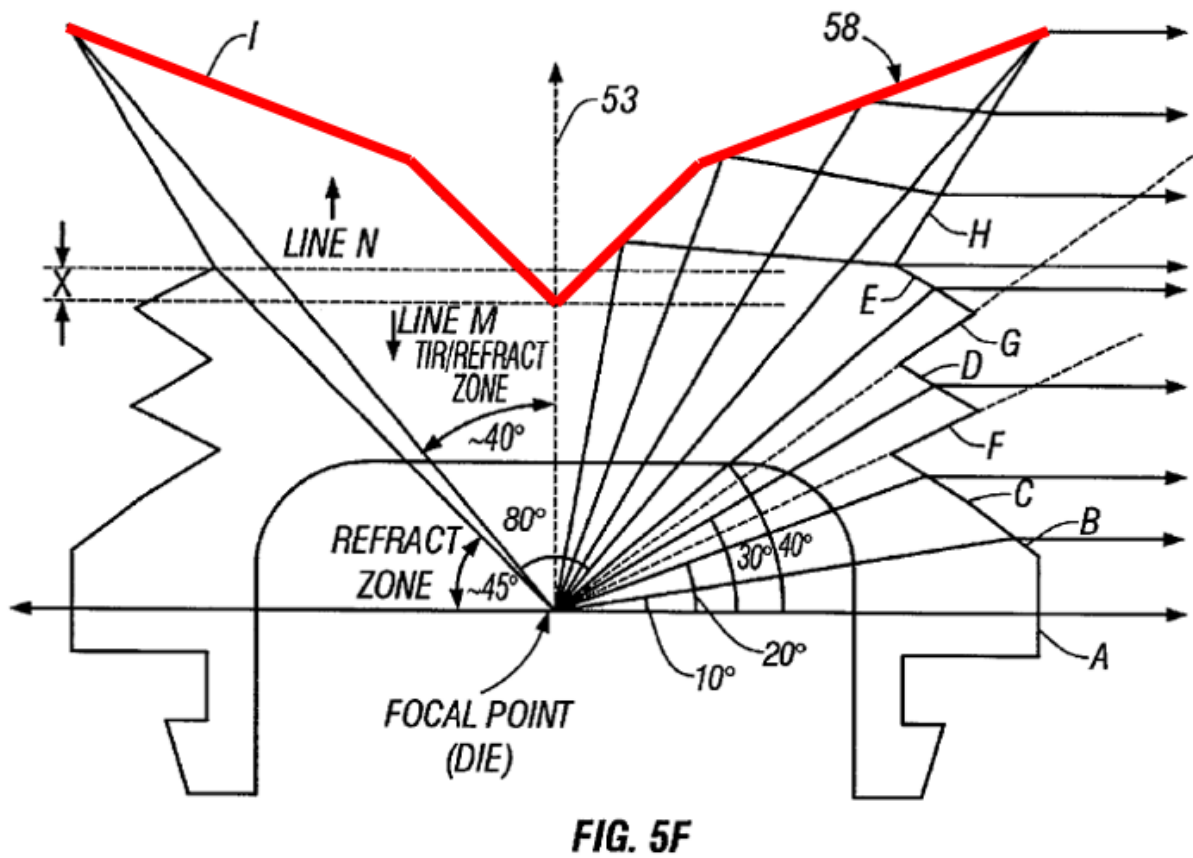
115. In my opinion, Odawara teaches [1a] for at least the same reasons I already discussed in Paragraphs 74-76.

iii. [1b] a **total reflection surface with a total reflection slope with respect to a central axis of the body; and**

116. In my opinion, as I already discussed in Paragraphs 77-89, Odawara alone teaches or suggests [1b], including even if the Board considers “total reflection surface” to achieve total reflection using total internal reflection. However, to the extent that the lack of the explicit mention of total internal reflection is required, that was well-known in the art, such as in West.

117. As a preliminary matter, the '873 Patent begins by admitting that a **“total reflection surface”** capable of achieving total internal reflection (TIR) was already well-known in the field. Specifically, the Background section of the patent discusses conventional lenses designed to use TIR, citing West as an example. It states that “[i]n the patent[], a lens comprises a **total reflection surface** which is formed on the lens and has a predetermined slope.” EX1001, 1:42-59. This indicates that a **total reflection surface** based on total internal reflection to direct light was not a novel concept at the time of the '873 Patent.

118. West provides further details on such lenses, describing a “[l]ens 44 [that] includes ... a **total internal reflection (TIR) funnel portion 58**.” According to West, this funnel portion “is designed as a TIR surface”. The reflected light is directed in such a way that it exits the lens “as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.” EX1005, 4:1-15.



EX1005, Figure 5F.

- iv. [1c] at least one of a **linear refractive surface** and a **curved refractive surface** formed to extend away from the central axis and beyond a periphery of the **total reflection surface**.
- v. [2] The lens as claimed in claim 1, wherein the refractive surface comprises a **linear refractive surface** formed by being bent at the periphery of the **total reflection surface**; and a **curved refractive surface** formed to extend from a periphery of the **linear refractive surface**.

119. In my opinion, Odawara teaches [1c] and [2] for at least the same reasons I already discussed in Paragraphs 90-100.

2. Reasons To Combine Odawara And West With A Reasonable Expectation Of Success

120. In my opinion, a POSITA would have found it obvious to combine Odawara and West, and particularly to replace Odawara's **recessed part** with West's **TIR funnel portion 58**, with a reasonable expectation of success. Both Odawara and West address similar design goals, as they are directed to side-emitting LEDs. For example, Odawara explains that "a particularly large amount of light is emitted in the horizontal directions." EX1004, [0032]. Similarly, West describes a lens that "internally redirects light within the lens so that a majority of light is emitted from the lens approximately perpendicular to a package axis of the light emitting diode package." EX1005, Abstract. Given this shared objective of

horizontal light emission, a POSITA would have been motivated to consider the teachings of both Odawara and West. Both patents describe systems in which light emitted from the LED is redirected toward the sides, with Odawara and West each employing specific designs to achieve this result. Thus, substituting Odawara's **recessed part** with West's **TIR funnel portion** would have been a logical modification to achieve the desired horizontal light emission.

121. The use of West's **TIR funnel portion** in Odawara's lens would have involved nothing more than applying a well-known technique to a known device to achieve predictable results. As I already discussed in Paragraphs 77-89, Odawara teaches that the **recessed part** is specifically designed to "totally reflect" light emitted upwards from the LED. For example, Odawara states, "[a]s described above, the present invention provides a **cone shaped recessed part** at the center of the upper surface of the lens part surrounding the LED chip, so light emitted from the LED chip upward in the optical axis direction is *totally* reflected by the inner surface of the recessed part and travels along the entire periphery in the lateral direction." EX1004, [0034]; see also EX1004, [0014], [0017], [0029].

122. Similarly, West's **funnel portion 58** serves the same purpose by reflecting light from the LED using the well-established principle of total internal

reflection. According to West, “[f]unnel portion 58 is designed as a TIR surface.

The TIR surface reflects light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.”

EX1005, 4:1-23.

123. A POSITA would have been able to readily substitute Odawara’s **recessed part** with West’s **funnel portion 58** to achieve the same objective—reflecting light horizontally toward the periphery of the lens to increase the amount of light emitted to the side. This modification would have been straightforward for a POSITA, who would have a reasonable expectation of success because the substitution simply replaces one known reflective surface with another to produce the same predictable result: increased horizontal light emission.

3. Dependent Claims 4[1] and 4[2]

- i. [4] The lens as claimed in any one of claims 1 to [2], wherein the **curved refractive surface** takes the shape of an ellipse, and a ratio of minor and major axes of the ellipse is 1:4 or less.

124. In my opinion, Odawara teaches 4[1] and 4[2] for at least the same reasons I already discussed in Paragraphs 106-108.

4. Dependent Claims 5[1] and 5[2]

- i. **[5] The lens as claimed in any one of claims 1 to [2], wherein the linear refractive surface is bent more than once.**

125. In my opinion, if the Board considers that the “**linear refractive surface** is bent more than once” encompasses Figure 29 of the '873 Patent, Odawara teaches 5[1] and 5[2] for the same reasons I already discussed in Paragraphs 109-111.

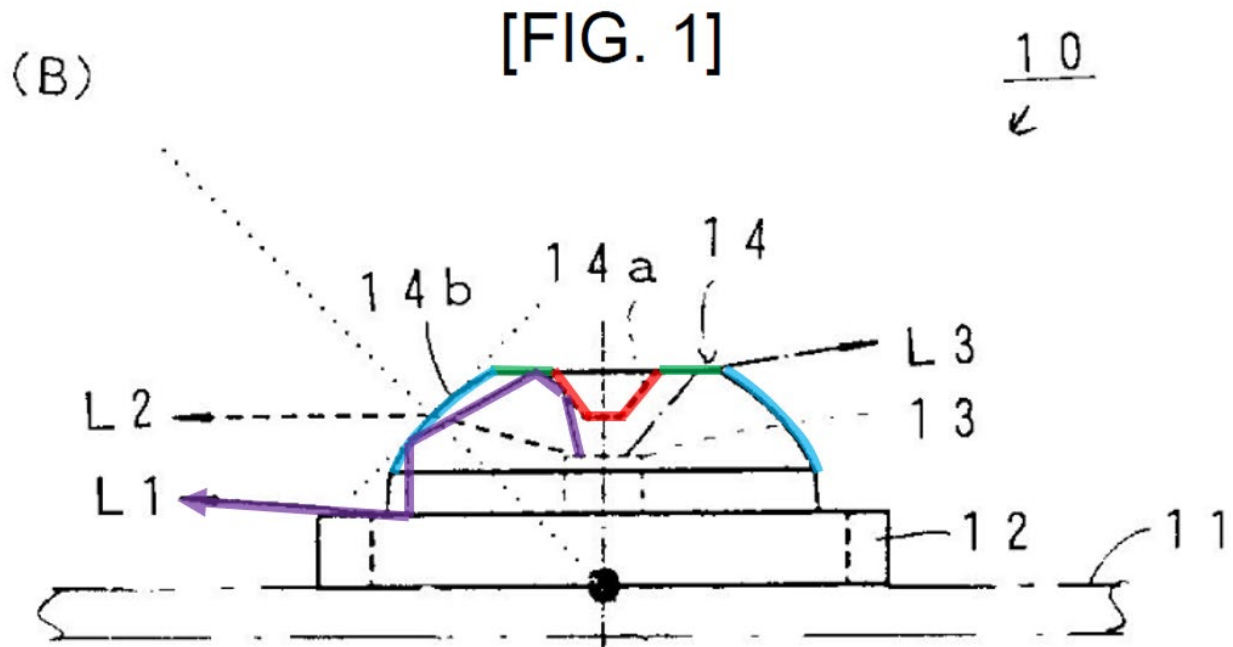
5. Dependent Claims 5[1] and 5[2]

- i. **[5] The lens as claimed in any one of claims 1 to [2], wherein the linear refractive surface is bent more than once.**

126. As I discussed in Paragraphs 65-69, the term “**linear refractive surface** is bent more than once” requires the claimed “**linear refractive surface**” to have at least two bends. Under this proper construction of the claim term, Odawara in combination with West renders obvious 5[1] and 5[2].

127. Odawara illustrates in Figure 1B that **light rays L1**, after being “totally reflected” by the **recessed part 14a**, subsequently interact with several surfaces within the lens system. These rays first reflect off the **upper surface** of the lens, then “totally reflect” again off the **side surface 14b**, and finally interact

with the chip substrate 12 before exiting the lens. Odawara explains, “the **light L1** incident on the **recessed part 14a** of the lens part 14 is totally reflected, as depicted in FIG. 1(B), and travels laterally, and is totally reflected again by the **side surface 14b** of the lens part 14, and is incident on the surface of the chip substrate 12.” EX1004, [0029]. Odawara also explains that the chip substrate 12 has a rough surface, causing the **light** to undergo diffuse reflection. Specifically, it states, “the surface of the chip substrate 12 is rough, so the **light L1** is *diffusely reflected* by the surface of the chip substrate.” EX1004, [0029]. This means that the light hitting the chip substrate will randomly scatter in all directions, some of it scattering/reflecting sideways as desired (as shown in L1) while a large portion of the light will scatter/reflect in other directions, such as upwards (not shown). This means that while the lens design enables light to exit sideways, the use of diffuse reflection from the rough substrate introduces inefficiencies. A POSITA would have understood that relying on such diffuse reflections inherently results in light scattering and losses, as this process reduces the control and efficiency of light transmission, diminishing the intended performance of the system.



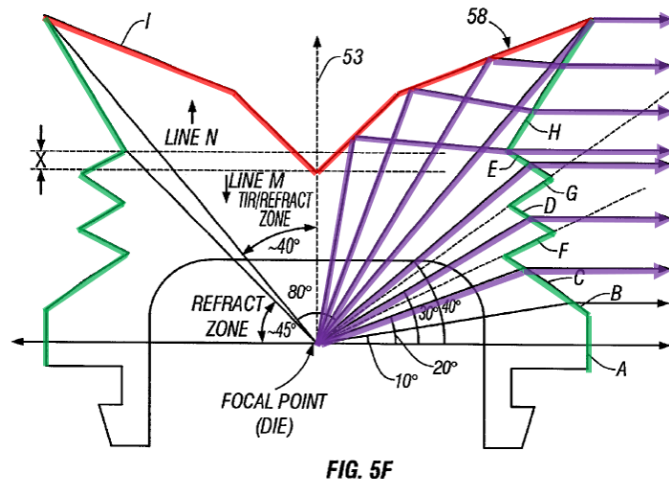
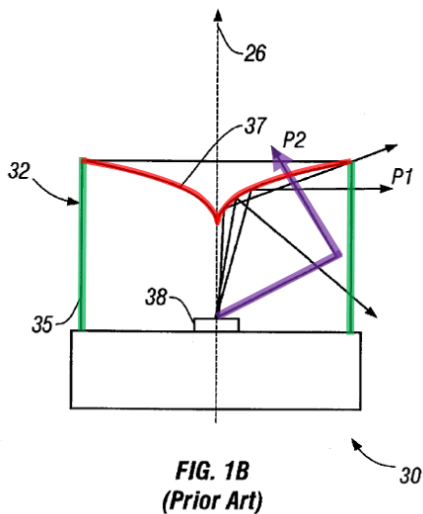
EX1004, Figure 1B.

128. In my opinion, a POSITA would have been motivated to increase side emission by reducing the downward reflection of light from the **upper surface (through total internal reflection)** toward the chip substrate 12 that ultimately causes diffuse scattering. A POSITA would have understood that a commonly used method to mitigate total internal reflection on such surfaces is to add additional bends, such as a sawtooth pattern that can remove the conditions necessary for total internal reflection.

129. For example, as shown below, West illustrates in Figure 1B a “known light emitting diode (LED) package 30 ... [that] includes an LED chip 38, a lens 32 with **straight vertical sidewall 35** and a funnel-shaped top surface 37.”

EX1005, 1:29-32. West identifies an issue with this design, noting that the “**second light path P2** is emitted from chip 38 toward **sidewall 35** at an angle causing TIR or a reflection from **sidewall 35** causing the light to exit package 30 at an angle not close to perpendicular to the longitudinal axis. This path is not desirable and limits the efficiency of side extracted light.” EX1005, 1:38-44.

130. To address this inefficiency, West introduces a solution involving a “**sawtooth portion 56** [that] is designed to refract and bend light so that the **light exits** from the lens 44 as close to 90 degrees to the longitudinal package axis 43 as possible.” EX1005, 4:2-9. West further specifies that “[t]he **sawteeth** or **refractive surfaces 59 of the sawtooth portion 56** are all light transmissive.” EX1005, 4:5-7. Additionally, West notes the flexibility of this design, teaching that “[a]ny number of **sawteeth 69** may be used within a sawtooth portion of a given length; preferably there is at least one sawtooth.” EX1005, 4:7-9. This modification effectively mitigates the undesirable effects of TIR, improving the side extraction of light and overall efficiency of the LED package.

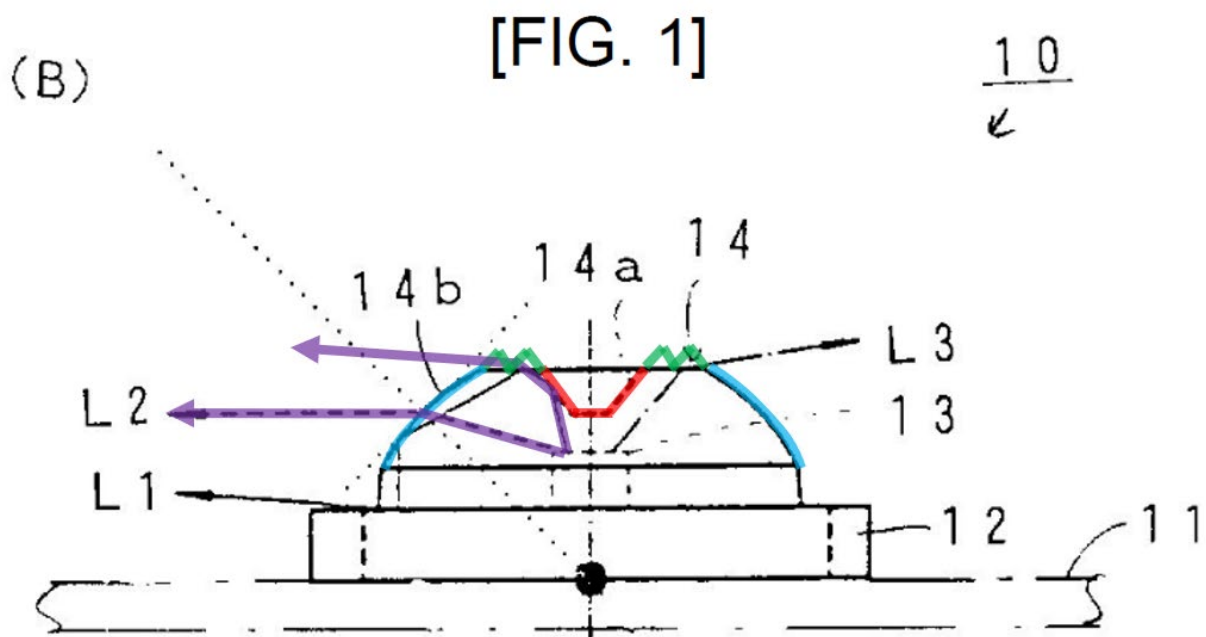


EX1005, Figures 1B and 5F.

131. In my opinion, a POSITA would have found it obvious to modify the **upper surface** of Odawara's lens by incorporating **two or more sawtooth patterns**, as taught by West, to achieve the well-recognized benefit of reducing total internal reflection and promoting light refraction out of the lens in a sideways direction. This modification would involve angling the **sawtooth patterns** to align approximately with the local slope of the **side surface 14b**, where **light rays L2** refract sideways.

132. By implementing this change, light rays L1, which currently undergo total internal reflection downward (as illustrated in Figure 1B), would no longer rely on "diffuse" reflections off the rough chip substrate 12 to exit sideways.

EX1004, [0029]. Instead, these light rays could directly refract out of the lens in the desired horizontal direction, eliminating losses associated with diffuse reflection. A POSITA would have recognized that this modification would lead to an improved design, resulting in increased side emission and greater efficiency of the lens system. This straightforward substitution would align with established optical engineering principles to improve the overall performance of the lens.



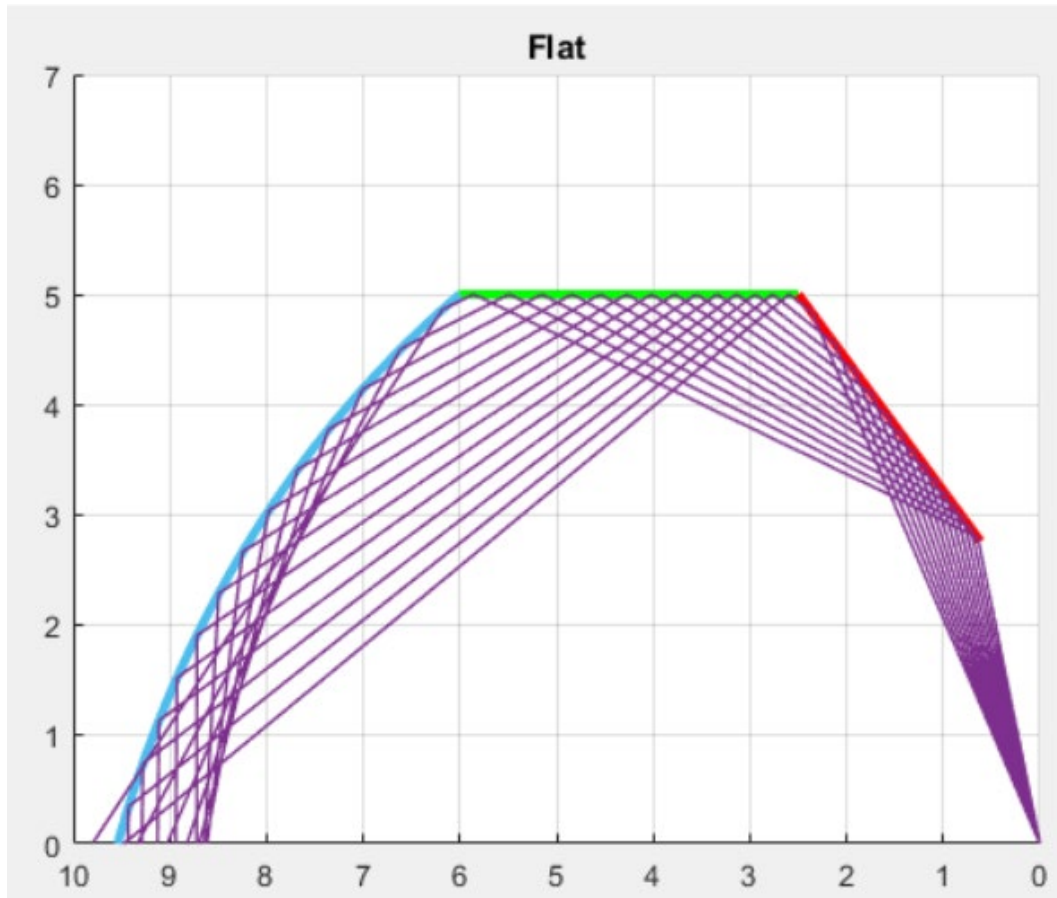
EX1004, Figure 1B (as modified with West).

133. I have carried out some simulations to demonstrate that this effect is readily observed using simple optics. I designed the program myself using the

Declaration of Dr. Tom D. Milster
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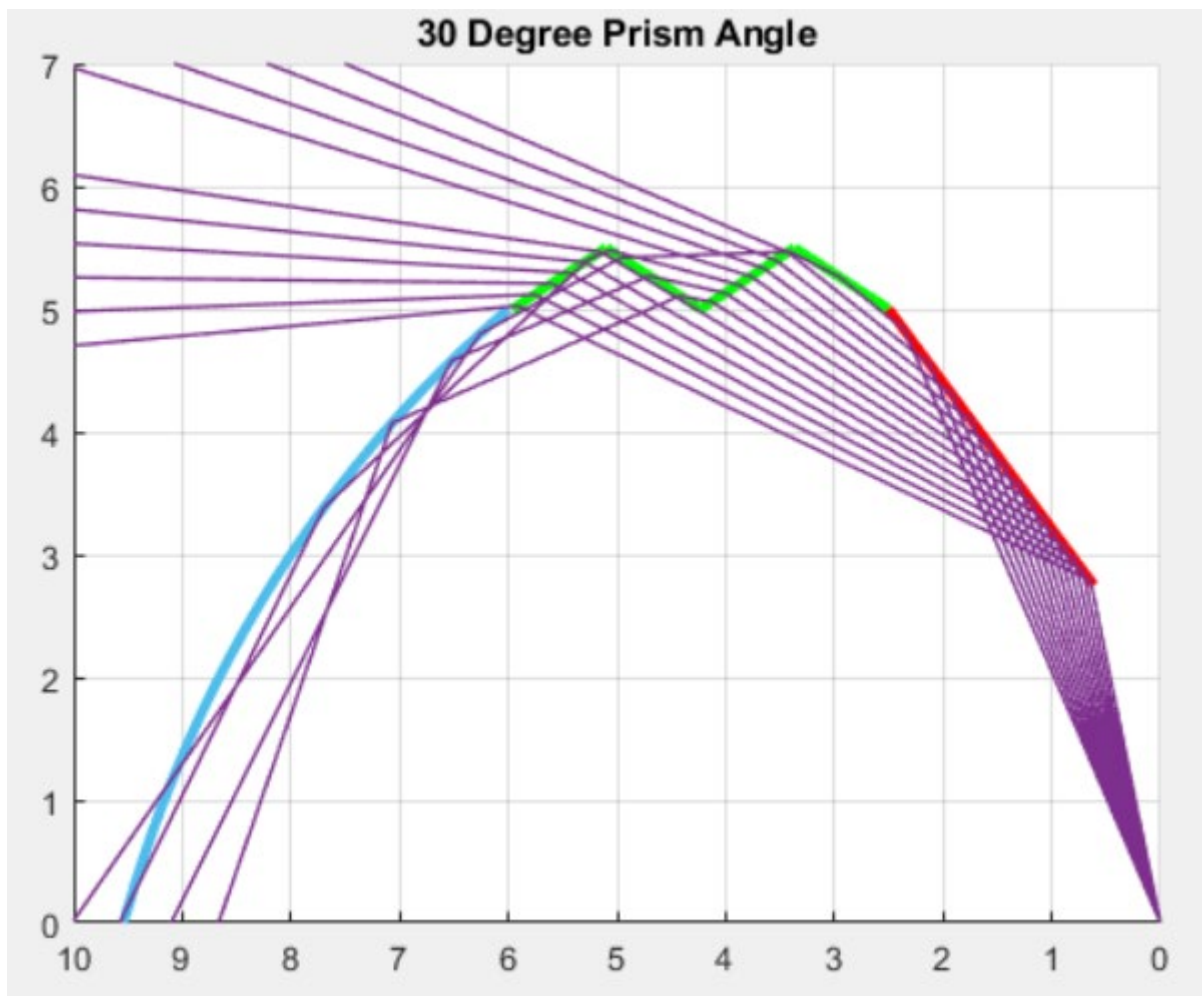
Matlab® programming language (R2023a Update (9.14.02239454) 64-bit (win64)) , which is attached as Appendix B. I personally had access to earlier versions of Matlab® since at least 1991 and confirm that these functions that I utilized in Appendix B (or equivalent functions) were widely available to the general public as of the claimed priority date of the '873 Patent.

134. First, I reproduced the lens shown in Figure 1B of Odawara assuming a refractive index of about 1.5, because, as I discussed in Paragraph 113, Odawara's lens is made of epoxy resin, which has a refractive index of approximately 1.5. I assumed that a point light source emits light and calculated rays that would totally internally reflect off the **recessed part**, **upper surface**, and the **side surface**. As a representative data set, I selected 14 light rays that would satisfy these conditions, as shown below.

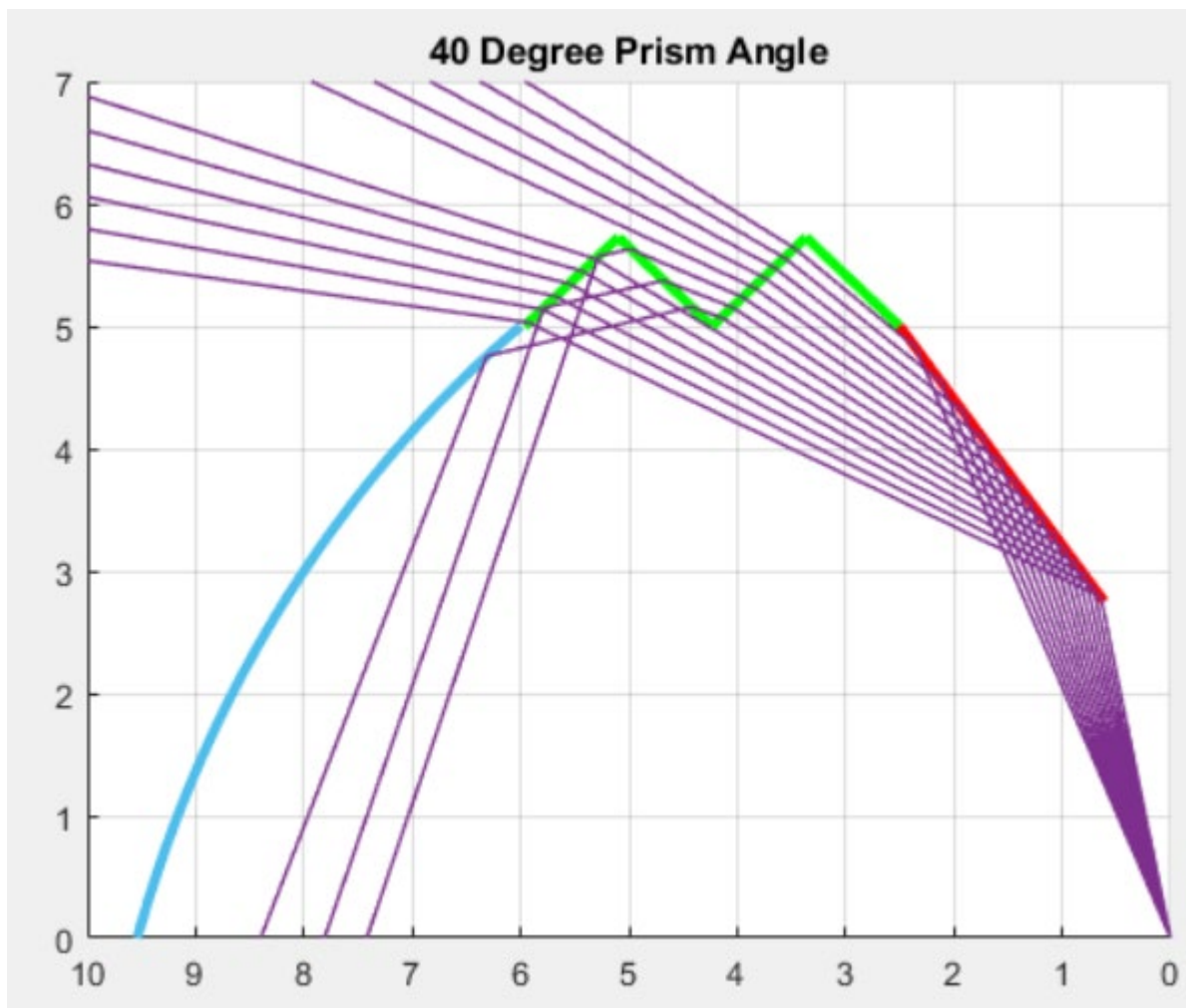


135. Then, I introduced two **sawteeth patterns** instead of the **flat upper surface** at four different angles (30, 40, 50, and 60 degrees). As shown below, each of these modifications leads to improved sideways emission of light. Specifically, whereas zero out of the 14 total light rays refract out of the lens sideways with the **flat upper surface**, 10 to 14 light rays out of the 14 total light rays refract out of the lens in the sideward direction after the **sawteeth patterns** are added.

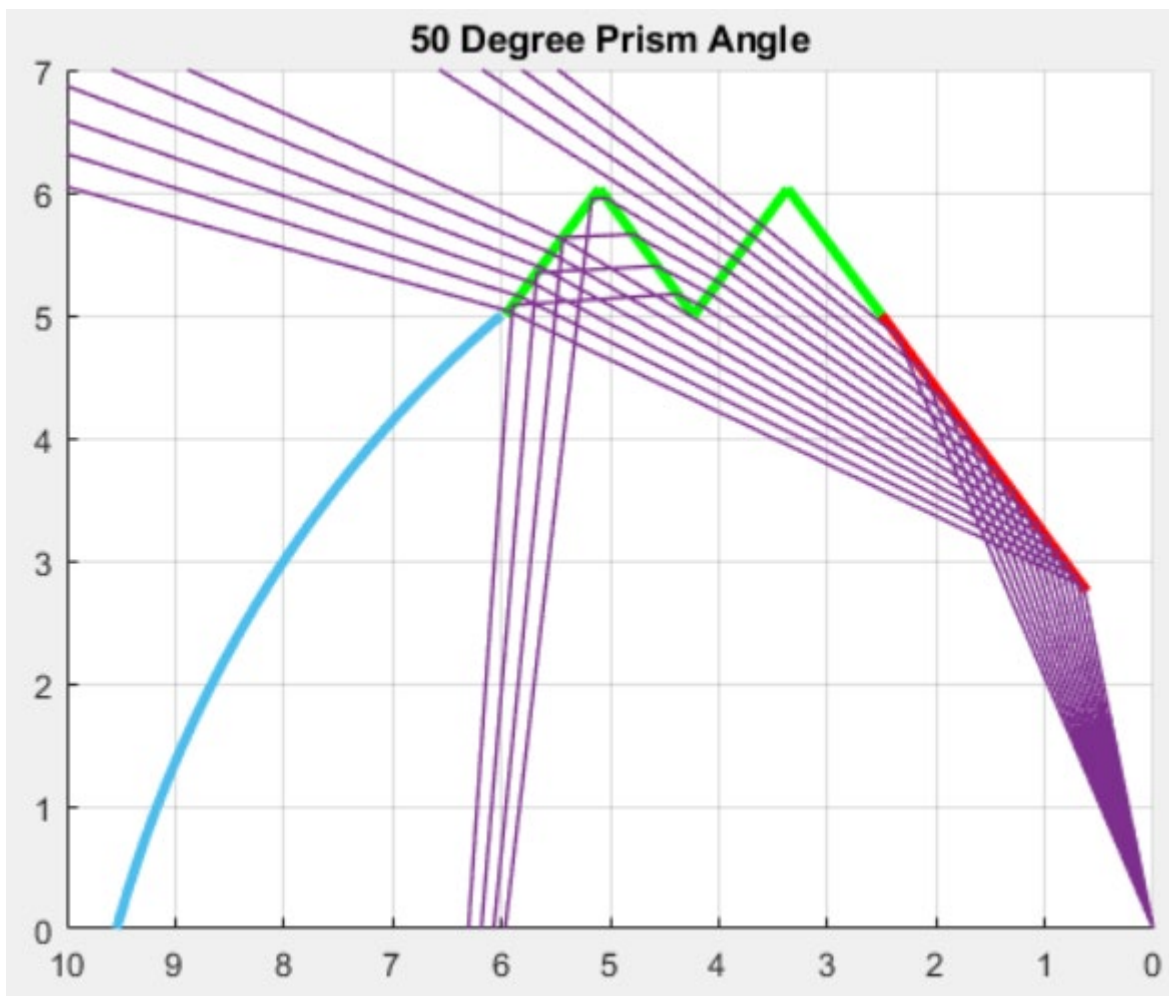
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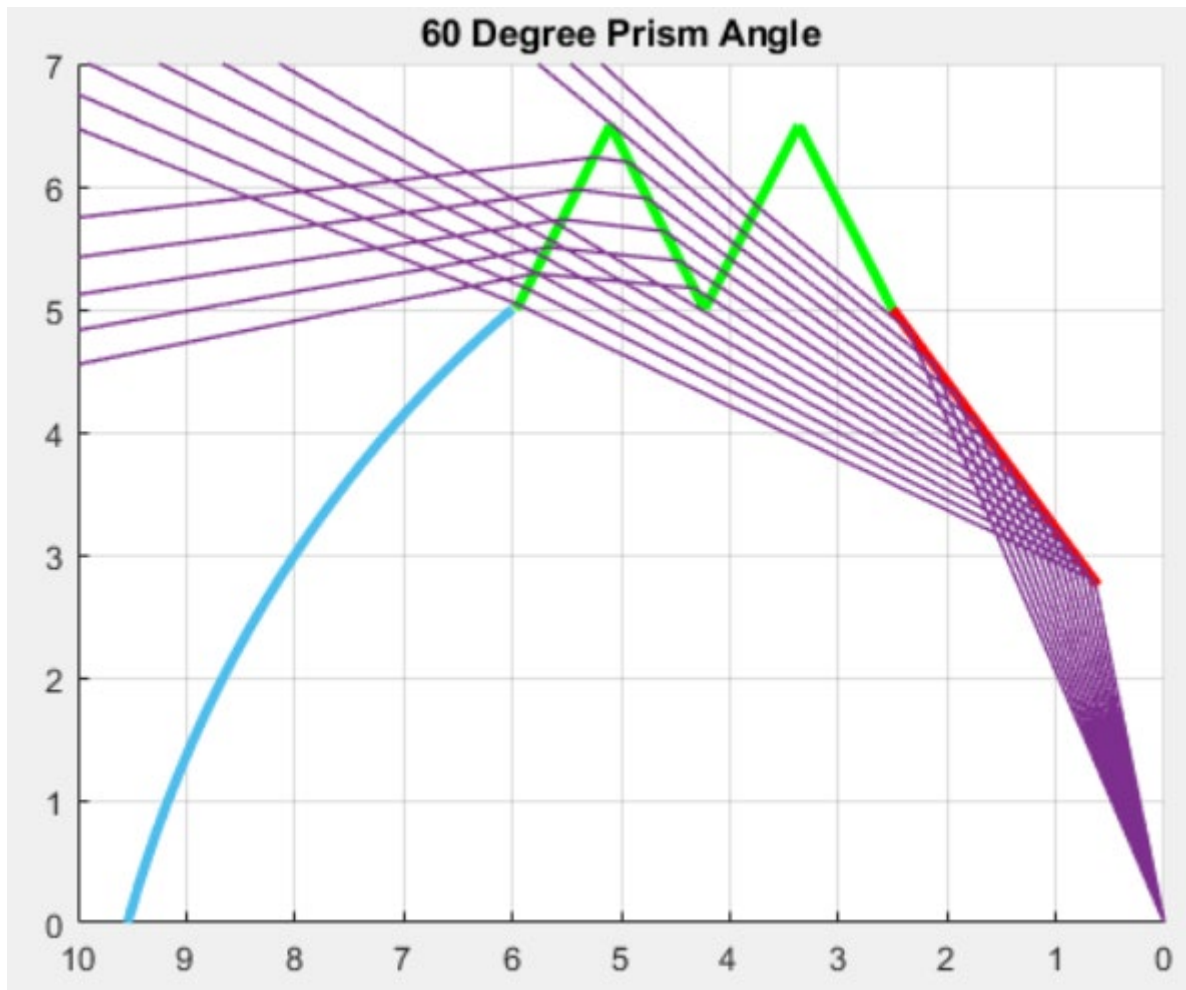
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136. The table below summarizes the results obtained from my simulations.

Angle of Sawtooth (degrees)	Number of light rays refracting out sideways (14 total light rays)
0 (flat)	0
30	10
40	11
50	10
60	14

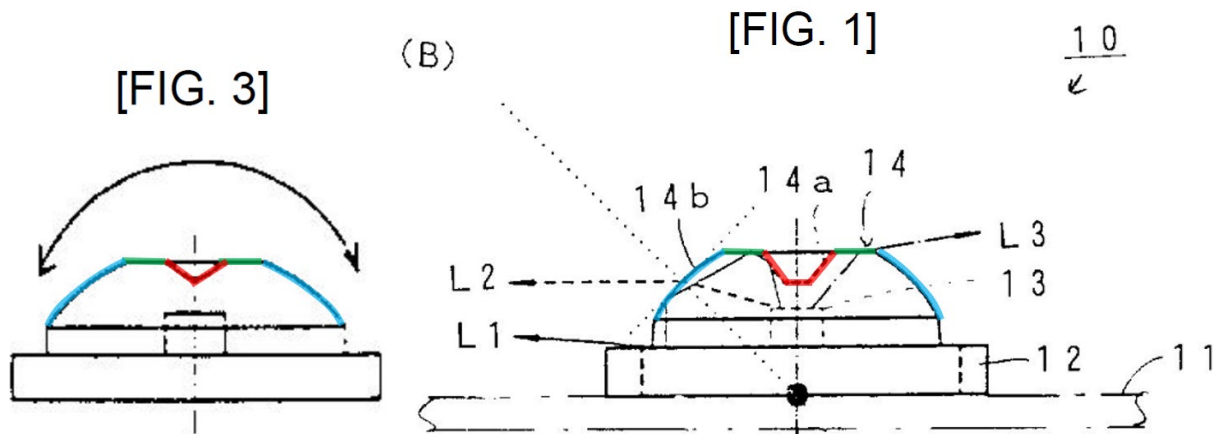
137. In my opinion, since this modification involves a straightforward substitution of one known **flat linear refractive surface**, as taught by Odawara, with another **refractive surface** having a **sawtooth pattern**, as taught by West, with the well-recognized result of increasing refractions that allow more light to emit out sideways, a POSITA would have been motivated to make this change. This modification has the predictable result of removing conditions that cause total internal reflection and enhancing sideways emission through refraction. Given the well-understood principles of optical design, a POSITA would have had a reasonable expectation of success in implementing this adjustment to achieve improved side emission efficiency.

6. Dependent Claim 6

- i. [6] The lens as claimed in claim 1, wherein the **total reflection surface** comprises: a **first total reflection surface** having a section in the form of a V-shaped recess with a predetermined slope; and a **second total reflection surface** extending upward from a periphery of the **first total reflection surface** and formed to be sloped with a gradient smaller than that of the **first total reflection surface**.

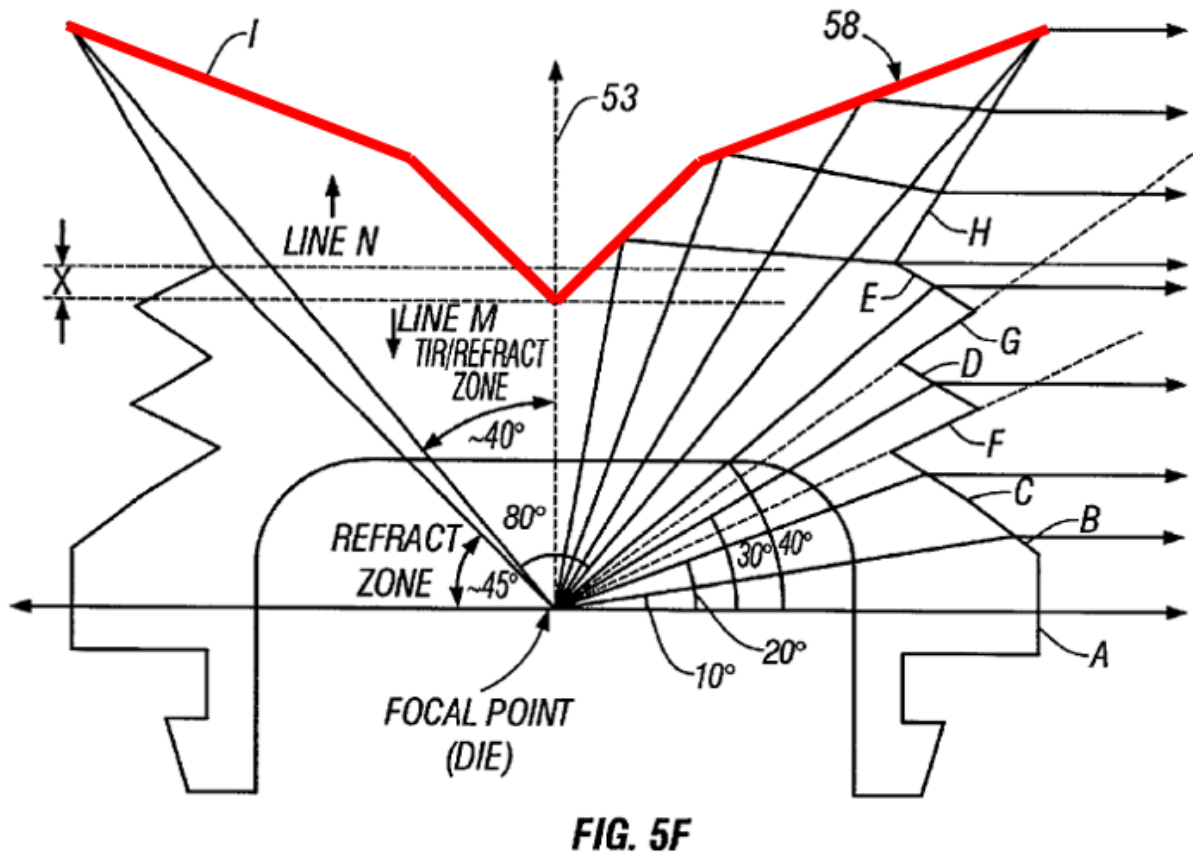
138. In my opinion, Odawara and West render obvious [6].

139. As I already discussed in Paragraphs 77-89, as in shown in Figures 1B and 3, Odawara teaches cone-shaped **recessed part**.



EX1004, Figures 3 and 1B.

140. Furthermore, side-emitting lenses featuring multiple sloped regions as part of their **total reflection surface** were well-established in the art. For instance, West, as depicted in Figure 5F below, includes a “total internal reflection (TIR) **funnel portion 58**,” which is “designed as a TIR surface.” This TIR surface “reflects light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.” EX1005, 4:1-15. This is an example of the use of sloped regions to effectively redirect light for side emission.



EX1005, Figure 5F.

141. West provides additional detail, stating that “FIG. 5F illustrates a bent-line **funnel-shaped portion 58** where Surface I is defined from a *line bent into two linear portions*, each portion at an angle greater than the critical angle for TIR but directs the light out of the package roughly at 90 degrees to the package axis.” EX1005, 4:64-5:2. This figure shows a **central V-shaped recess** with a defined slope, designed to redirect light. Beyond this central area is a **second**

region with a more gradual slope, illustrating a layered approach where the slopes progressively adjust to guide the light outward near 90 degrees to the package axis. As I noted above in Paragraph 24, I understand that patent drawings can teach a claim limitation if it is clearly shown.

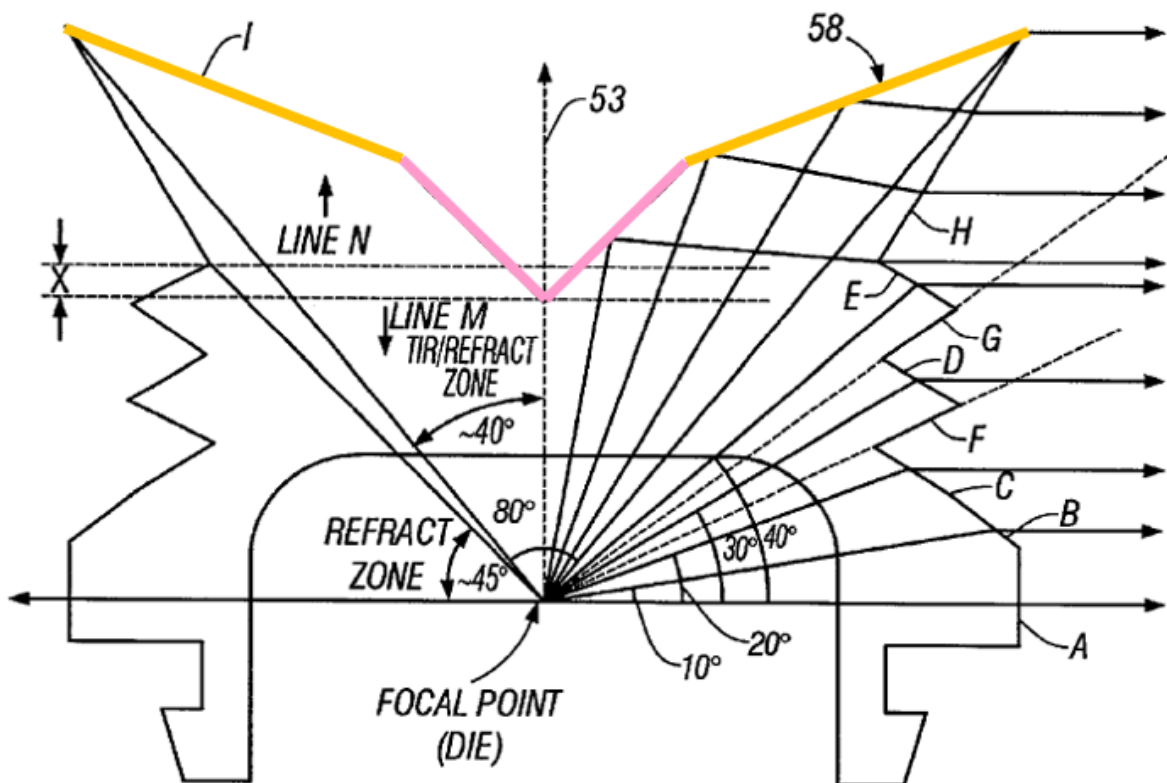


FIG. 5F

EX1005, Figure 5F.

142. In my opinion, a POSITA would have found it possible to replace Odawara's **recessed part** with West's bent-line **funnel-shaped portion 58**. This

substitution would produce the well-recognized benefit of utilizing two different slopes to improve total internal reflection conditions. A POSITA would have understood that this modification could improve the efficiency of light redirection and lead to the desirable outcome of increasing the performance of side-emitted light output.

143. Additionally, because this change involves the straightforward substitution of one known cone-shaped **recessed part** that achieves total reflection of light, as taught by Odawara, with another design—a bent-line **funnel-shaped portion 58**, as taught by West—a POSITA would have been motivated to make the modification. This adjustment would predictably maintain the redirection of light to the sides for side emission while offering potential improvements. Given the simplicity of the substitution and the predictable result, a POSITA would have had a reasonable expectation of success in implementing such a change.

7. Dependent Claim 7

- i. [7] The lens as claimed in claim 1, wherein the refractive index of the body is 1.2 to 2.0.**

144. In my opinion, Odawara teaches [7] for at least the same reasons I already discussed in Paragraphs 112-113.

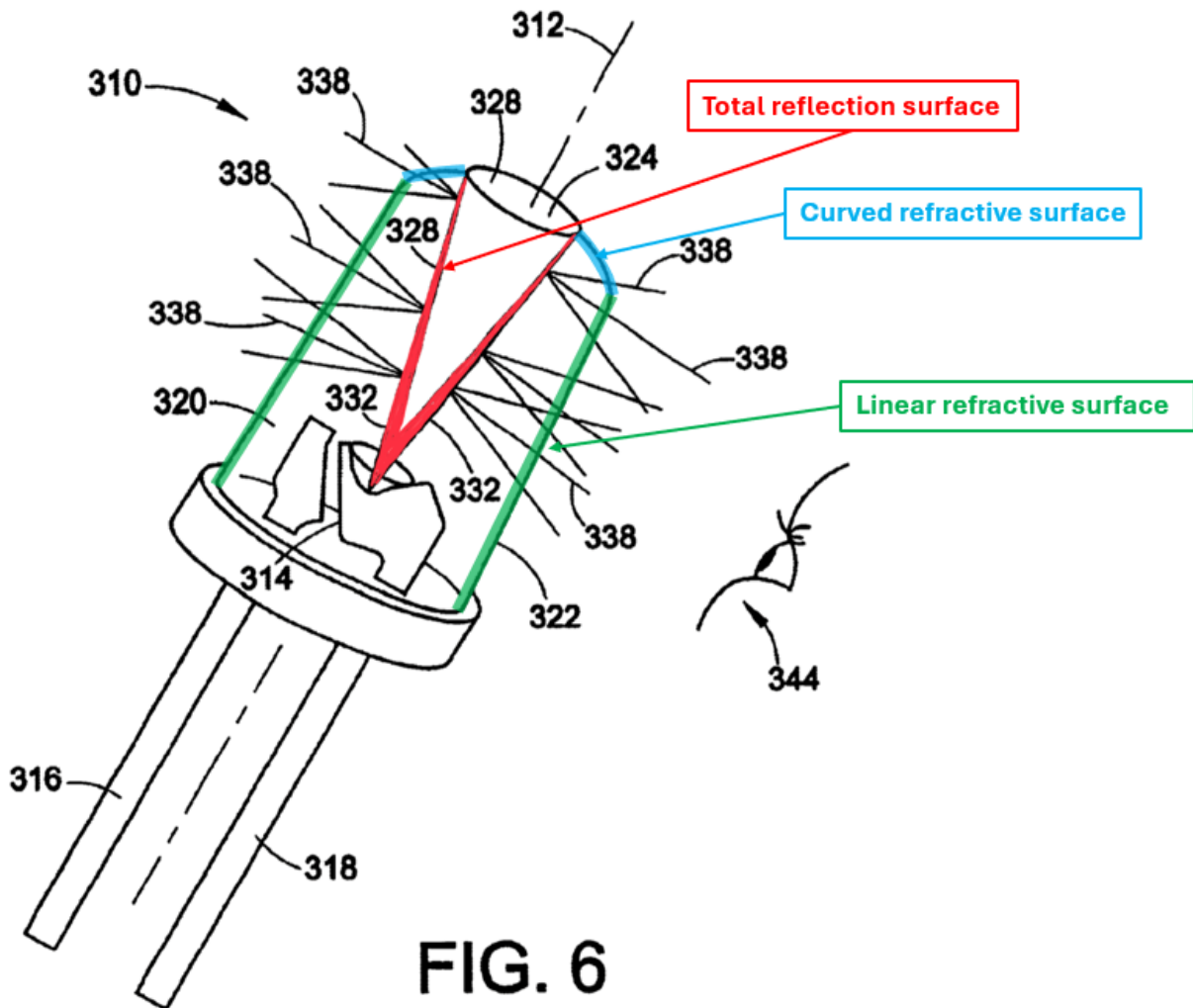
**C. Grounds IV And V: Sommers Anticipates Or Renders Obvious
Claims 1, 3, 4[1], 4[3], And 7**

1. Independent Claim 1 And Dependent Claim 3

i. [1pre] A lens, comprising:

145. I understand that the preamble may not limit the claims. Regardless, in my opinion, Sommers teaches [1Pre].

146. As illustrated in Figure 6 below, Sommers provides an “encapsulant 320.” EX1006, 5:51-55. This encapsulant 320 functions as a lens because it redirects light rays 332 emitted from the LED, scattering them off surface 328 to produce light rays 338 that exit to the side. Sommers explains that “[l]ight 332 emanating from the LED die ... scatters off surface 328.” The scattering process results in “a diffuse reflection rather than a specular reflection,” which is illustrated in FIG. 6. Sommers notes that this scattering effect produces “a plurality of rays 338 emanating from each point where an incident ray 332 scatter[s] off inner surface 328.” EX1006, 5:60-6:3.



EX1006, Figure 6.

i. [1a] a body;

147. In my opinion, Sommers teaches [1a].

148. Sommers describes that encapsulant 320 is radially symmetric about a central axis 312, and is positioned approximately over the LED die and aligned

roughly parallel to the LED die's surface normal. EX1006, 5:51-55 (“In this alternate embodiment encapsulant 320 exhibits radial symmetry about a central axis 312 centered approximately on the LED die and approximately parallel to the LED die surface normal (not shown).”).

ii. [1b] a **total reflection surface** with a total reflection slope with respect to a central axis of the body; and

149. In my opinion, Sommers teaches [1b].

150. As I discussed in Paragraphs 79-82, the plain and ordinary meaning of the term “**total reflection surface**” includes surfaces that reflect light through total internal reflection, those coated with reflective materials, and surfaces that combine total internal reflection with metallization.

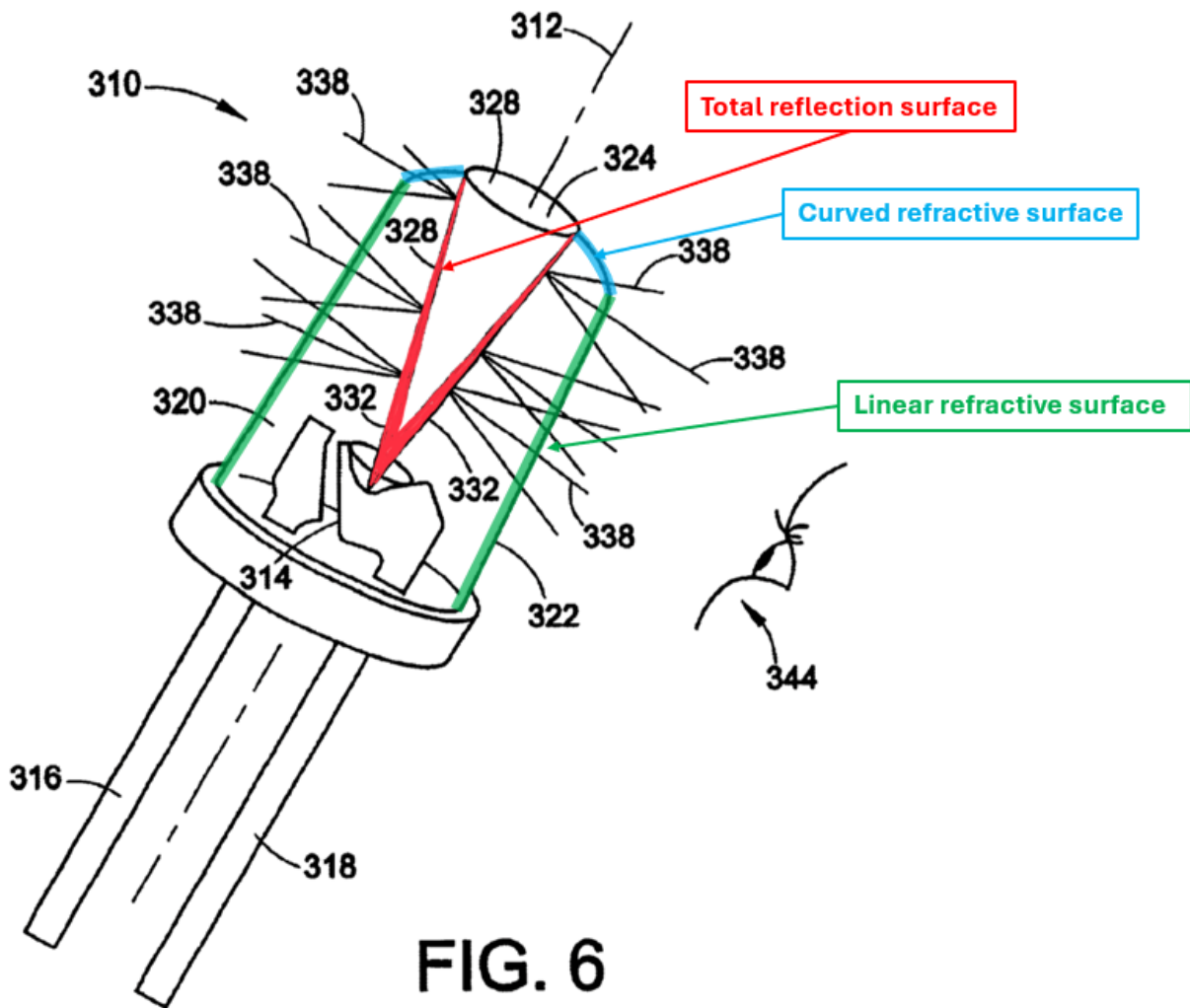
151. Under the plain and ordinary meaning of the term “**total reflection surface**,” Sommers teaches or at minimum renders [1b] obvious. Sommers describes that encapsulant 320 has a “**depression 324**” that may be filled with a metal or another reflective material. This material is “pressed against outer surface 328” to reflect light toward the side portions 322, which can also be referred to as “**reflective surface 328**.” EX1006, 6:6-10. Sommers explains that the scattering strength of light can be enhanced “either by coating the outer surface 328 with a

reflective coating, or by filling depression 324 with a metal or other reflective filling material which is pressed against outer surface 328 and conforms to the roughness of that surface.”

152. Furthermore, Sommers notes that light scattering is diffuse rather than specular. It states, “because the light is scattered diffusely, any refraction occurring at side surface 322 will not significantly change the intensity distribution, and so the detailed curvature of the side surfaces is also not critical.” EX1006, 6:26-29. A POSITA would have understood that applying a reflective metal coating, as described by Sommers, would result in total reflection of all incident light. This concept aligns with well-known optical principles, since mirrors are typically created by coating surfaces like glass with reflective metals, such as aluminum. EX1009.

153. The **reflective surface 328** also has a “total reflection slope with respect to a central axis” of encapsulant 320. As described by Sommers, “the encapsulant 320 exhibits radial symmetry about a central axis 312 centered approximately on the LED die.” EX1006, 5:51-55. Additionally, “[d]epression 324 defined by **curved surfaces 328** is centered approximately on symmetry axis 312 and is essentially conical in shape.” EX1006, 5:55-57. And as illustrated in Figure

6 below, the **reflective surface 328** is sloped relative to the central axis 312, forming a conical design that contributes to the reflection and direction of light.



EX1006, Figure 6.

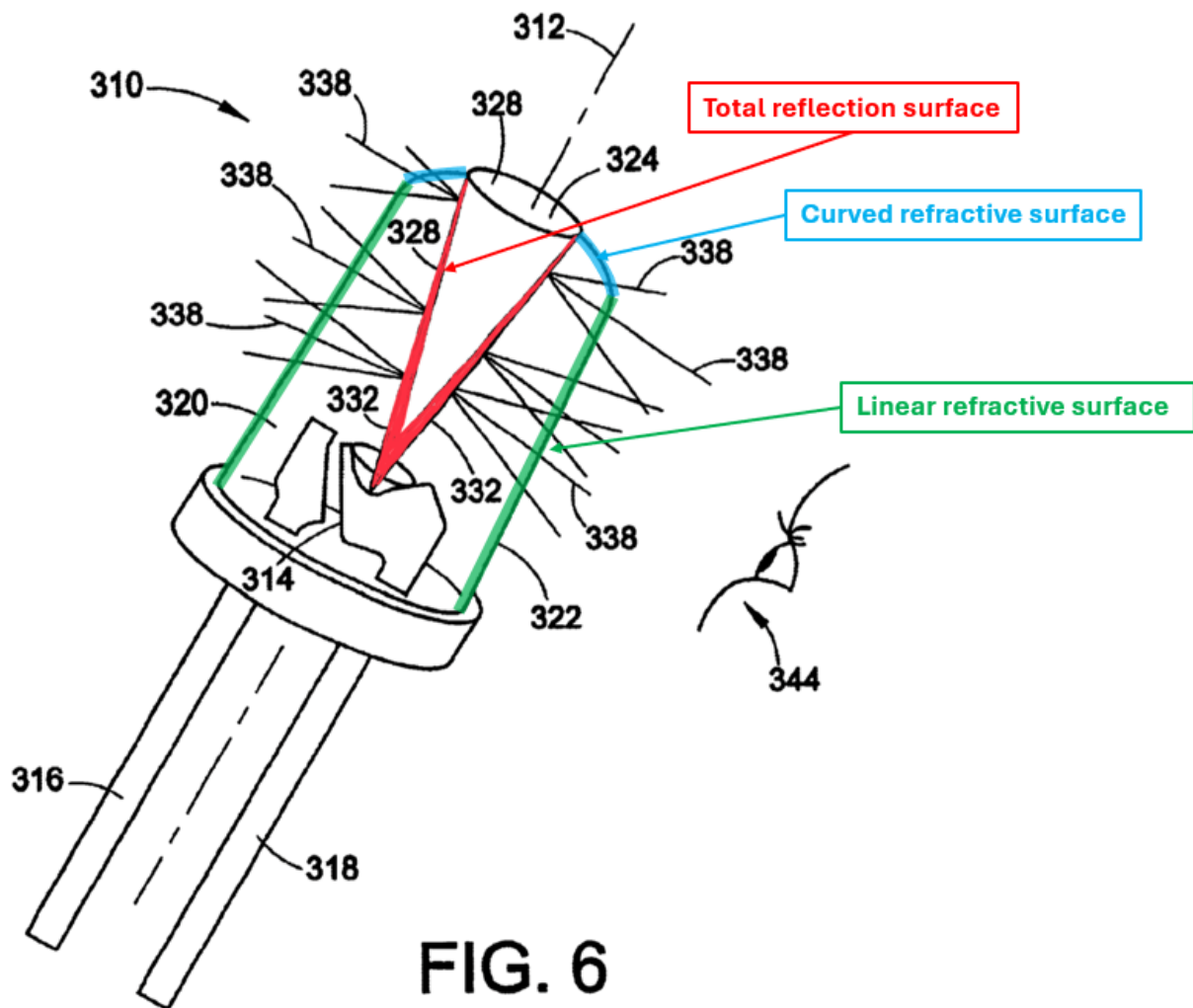
- i. [1c] at least one of a **linear refractive surface** and a **curved refractive surface** formed to extend away from the central axis and beyond a periphery of the **total reflection surface**.
- ii. [3] The lens as claimed in claim 1, wherein the refractive surface comprises: a **curved refractive surface** formed to extend from the periphery of the **total reflection surface**; and a **linear refractive surface** formed by being bent at a periphery of the **curved refractive surface**.

154. In my opinion, Sommers teaches or renders obvious [1c] and [3].

155. As a preliminary matter, I note that claim 3 refers to “*the* refractive surface,” while claim 1 specifies “a linear refractive surface” and “a curved refractive surface.” Additionally, claim 3 repeats the phrases “a linear refractive surface” and “a curved refractive surface.” For the purposes of my analysis here, I have interpreted claim 3 to recite that “the curved refractive surface is formed to extend from *the* periphery of the total reflection surface; and the linear refractive surface is formed by being bent at a periphery of the curved refractive surface.”

156. Sommers describes a side surface 322 that refracts light. Sommers explains that “because the light is scattered diffusely, any refraction occurring at side surface 322 will not significantly change the intensity distribution, and so the detailed curvature of the side surfaces is also not critical.” EX1006, 6:26-29. As

illustrated in Figure 6 below, side surface 322 includes a curved portion (referred to hereafter as “the **curved portion of side surface 322**”). This curved portion starts at the periphery of the **total reflection surface** and extends outward, away from the central axis of the encapsulant. The curvature makes the surface extend beyond the outer edge of the total reflection surface, facilitating the redirection of light emitted from the reflective region.



EX1006, Figure 6.

157. Furthermore, as illustrated in Figure 6 above, side surface 322 includes a linear portion (referred to hereafter as “**linear portion of side surface 322**”) that originates at the periphery of the curved portion of side surface 322. This linear portion is distinct in its geometry, as it is formed by a bend at the

transition point where the curved portion ends. And as I already discussed in paragraph 24, I understand that patent drawings can teach a claim limitation if it is clearly shown.

2. Dependent Claims 4[1] And 4[3]

- i. [4] The lens as claimed in any one of claims 1 [or] 3, wherein the curved refractive surface takes the shape of an ellipse, and a ratio of minor and major axes of the ellipse is 1:4 or less.**

158. In my opinion, Somers teaches or renders obvious 4[1] and 4[3]. As a preliminary matter, as I already explained in Paragraph 107, the '873 Patent explains that an ellipse can encompass a circle. Specifically, it states, “[t]he second refractive surface 1123 b is made in the form of an ellipse as shown in FIG. 29, and a ratio of minor and major axes of the ellipse is in a range of 1:4 or less. *That is, it may be a circle.*” EX1001, 16:51-54. This indicates that the claimed ratio of the minor and major axes of the ellipse can include a ratio of 1:1.

159. Sommers teaches that the encapsulant “has a preselected shape which is *preferably essentially hemispherical.*” EX1006, 3:54-56; *see also* EX1006, claims 1 and 9. This indicates that the curved portion of side surface 322 can have a shape that is “essentially” circular when observed in a two-dimensional cross-

section. Such a shape would exhibit a ratio of minor to major axes that is approximately or 1:1. At a minimum, in my opinion, a POSITA would have recognized that it would be obvious for the curved portion of encapsulant 320 to take on this circular shape.

3. Dependent Claim 7

i. [7] The lens as claimed in claim 1, wherein the refractive index of the body is 1.2 to 2.0.

160. In my opinion, Sommers teaches or renders obvious [7].

161. Sommers describes encapsulant 320 in EX1006, 51-55. While Sommers does not specifically identify the material used for encapsulant 320 in the embodiment shown in Figure 6, it teaches that epoxy resin is a suitable material for encapsulants in other embodiments. For example, the Abstract states, “An encapsulant (20), preferably an epoxy resin,” and claim 5 explicitly recites, “wherein the encapsulant is an epoxy.” Additionally, Sommers explains that epoxy resins typically have a refractive index of approximately 1.5. EX1006, 1:40-41 (“The encapsulant material is usually an epoxy resin or the like, with a refractive index $n \sim 1.5$.”).

162. In view of this disclosure, it is my opinion that a POSITA would have at least found it obvious to use epoxy resin as the material for encapsulant 320 in the embodiment associated with Figure 6. Since Sommers explicitly teaches epoxy as a suitable material for encapsulants in the same context, applying this material to encapsulant 320 would be a straightforward substitution. Such a modification would merely involve employing a well-known and widely used material, as taught by Sommers, for the same purpose of serving as an encapsulant in an LED assembly.

D. Ground VI: Sommers In Combination With West Renders Obvious Claims 1, 3, 4[1], 4[3], 5[1], 5[3], 6, And 7

1. Independent Claim 1 And Dependent Claim 3

i. [1pre] A lens, comprising:

163. In my opinion, Sommers teaches [1pre] for at least the same reasons already discussed in Paragraphs 145-146.

ii. [1a] a body;

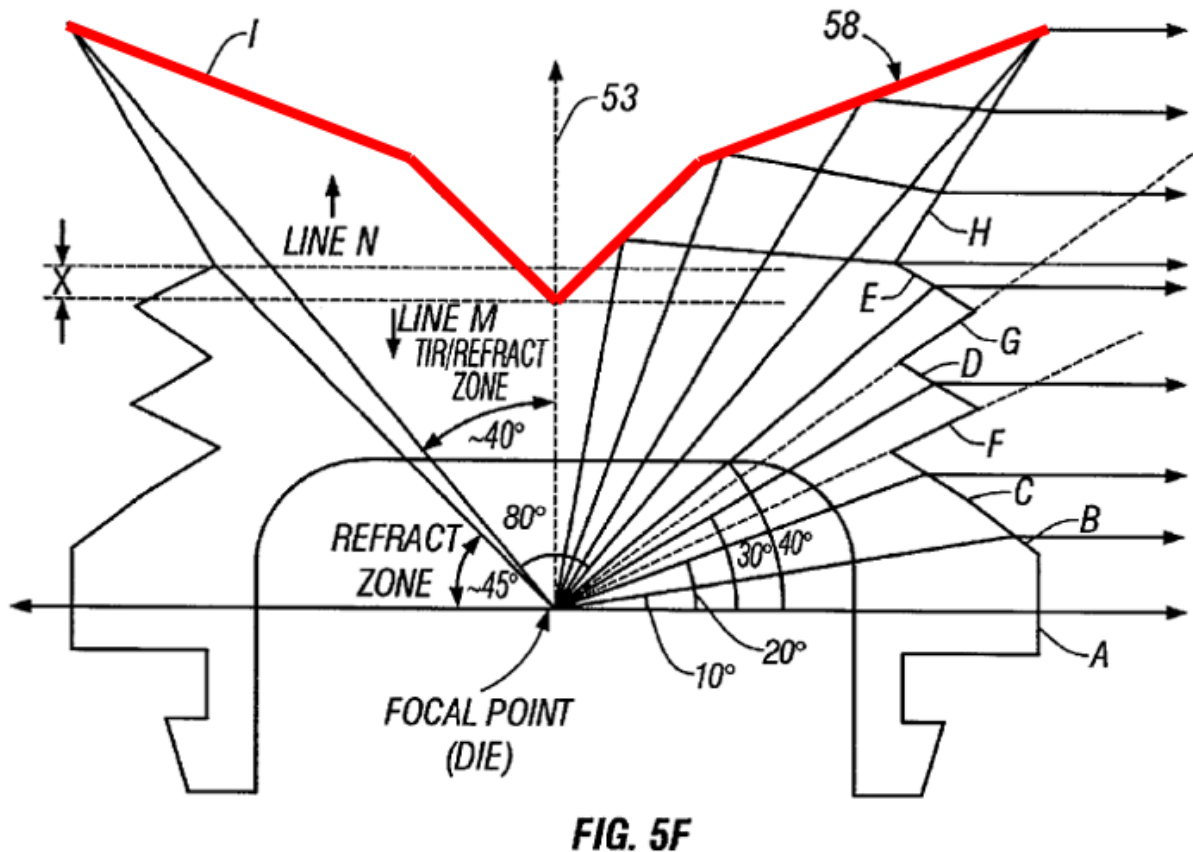
164. In my opinion, Sommers teaches [1a] for at least the same reasons already discussed in Paragraphs 147-148.

iii. [1b] a **total reflection surface** with a total reflection slope with respect to a central axis of the body; and

165. To the extent that [1b] requires total internal reflection, that was well-known in the art, such as in West.

166. As a preliminary matter, the '873 Patent begins by admitting that a "**total reflection surface**" capable of achieving total internal reflection (TIR) was already well-known in the field. Specifically, the Background section of the patent discusses conventional lenses designed to use TIR, citing West as an example. It states that "[i]n the patent[], a lens comprises a **total reflection surface** which is formed on the lens and has a predetermined slope." EX1001, 1:42-59. This indicates that a **total reflection surface** based on total internal reflection to direct light was not a novel concept at the time of the '873 Patent.

167. West describes a lens that incorporates a funnel-shaped portion, identified as "**[f]unnel portion 58**," specifically designed to function as a total internal reflection (TIR) surface. This TIR surface is structured to "reflect light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible." EX1005, 4:12-15.



EX1005, Figure 5F.

168. Sommers also discusses the adjustability of the slope of its **reflecting surface 328**, highlighting that it can be tailored to meet specific requirements by applying standard optical engineering methods. Sommers states that “[t]he precise preselection of the curvatures of the reflecting and refracting surfaces so as to achieve an optimal apparent approximate point light source 42 involves conventional optical engineering methods which are well known to those skilled in

the art and which need not be described here for an enabling disclosure of the invention.” EX1006, 4:43-48. This demonstrates that the curvature and slope of the reflecting and refracting surfaces can be optimized using established techniques familiar to those skilled in the field.

169. Given this teaching, it is my opinion that a POSITA would have found it obvious to modify the slope of Sommers’s **reflecting surface 328** to enable total internal reflection, as taught by West. Such a modification would leverage well-known optical engineering practices to adjust the surface geometry to achieve the same functionality demonstrated by West’s TIR **funnel portion 58**, thereby enhancing the efficiency of light redirection and side emission.

- iv. [1c] at least one of a **linear refractive surface** and a **curved refractive surface** formed to extend away from the central axis and beyond a periphery of the **total reflection surface**.
- v. [3] The lens as claimed in claim 1, wherein the refractive surface comprises: a **curved refractive surface** formed to extend from the periphery of the **total reflection surface**; and a **linear refractive surface** formed by being bent at a periphery of the **curved refractive surface**.

170. In my opinion Sommers teaches [1c] and [3a] for at least the same reasons I already discussed in Paragraphs 154-157.

vi. Reasons To Combine Sommers With West With A Reasonable Expectation Of Success

171. In my opinion a POSITA would have been able to replace Sommers' **reflective surface 328** with West's **TIR funnel portion 58** and would have had a reasonable expectation of success doing so.

172. As a preliminary matter, both Sommers and West focus on side-emitting LED designs. Sommers shows a "plurality of rays 338 emanating" to the side of the LED package 310, illustrating the intent to achieve horizontal light emission. EX1006, 5:60-6:3. Similarly, West describes a lens designed to "internally redirect[] light within the lens so that a majority of light is emitted from the lens approximately perpendicular to a package axis of the light emitting diode package." EX1005, Abstract. These shared objectives would have motivated a POSITA to consider the teachings of both references to achieve improved horizontal light output by reflecting light emitted by the LED towards the sides.

173. Furthermore, the proposed modification involves nothing more than applying a known technique to a known device to obtain predictable results. As I already discussed in Paragraphs 149-153, Sommers teaches that **reflective surface 328** is designed to redirect light sideways, with its performance adjustable as

needed. For example, Sommers explains that “the scattering strength may be increased either by coating the outer surface 328 with a reflective coating, or by filling depression 324 with a metal or other reflective filling material.” EX1006, 6:4-10. Similarly, West’s **funnel portion 58** performs the same function of reflecting light, relying on the well-established principle of total internal reflection (TIR). West explains, “[f]unnel portion 58 is designed as a TIR surface. The TIR surface reflects light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.” EX1005, 4:1-23.

174. In my opinion, a POSITA would have been readily able to substitute Sommers’s **reflective surface 328** with West’s **funnel portion 58** to achieve the same goal of reflecting light horizontally toward the periphery of the lens, thereby increasing side emission. This modification would have been straightforward, involving the replacement of one known reflective surface with another, both of which are designed to accomplish similar results. And a POSITA would have had a reasonable expectation of success, as the modification would predictably increase horizontal light emission.

2. Dependent Claims 4[1] And 4[3]

- i. [4] The lens as claimed in ... claim[] ... 3, wherein the **curved refractive surface** takes the shape of an ellipse, and a ratio of minor and major axes of the ellipse is 1:4 or less.

175. In my opinion, Sommers teaches [4] for at least the same reasons I already discussed in Paragraphs 158-159.

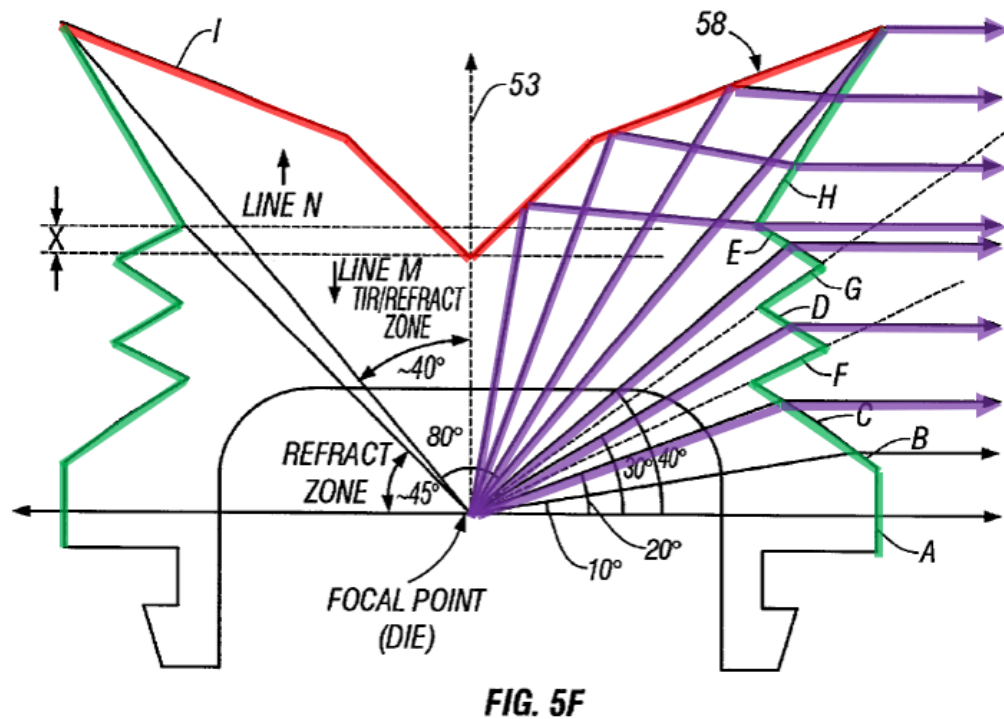
3. Dependent Claims 5[1] And 5[3]

- i. [5] The lens as claimed in ... claim[] ... 3, wherein the **linear refractive surface** is bent more than once.

176. As I discussed in Paragraphs 65-69, the term “**linear refractive surface** is bent more than once” requires the claimed “**linear refractive surface**” to have at least two bends. Under this proper construction of the claim term, Sommers in combination with West teaches 5[1] and 5[3].

177. West discloses a “**sawtooth portion 56** [that] is designed to refract and bend light so that the **light exits** from the lens 44 as close to 90 degrees to the longitudinal package axis 43 as possible.” EX1005, 4:2-9. West further explains that “the **sawteeth** or **refractive surfaces 59 of the sawtooth portion 56** are all light transmissive.” EX1005, 4:5-7. Additionally, West notes that “[a]ny number of **sawteeth 69** may be used within a sawtooth portion of a given length; preferably

there is at least one sawtooth.” EX1005, 4:7-9. This flexibility allows the design to be tailored to specific optical requirements while maintaining its core function of bending light for optimal side emission.

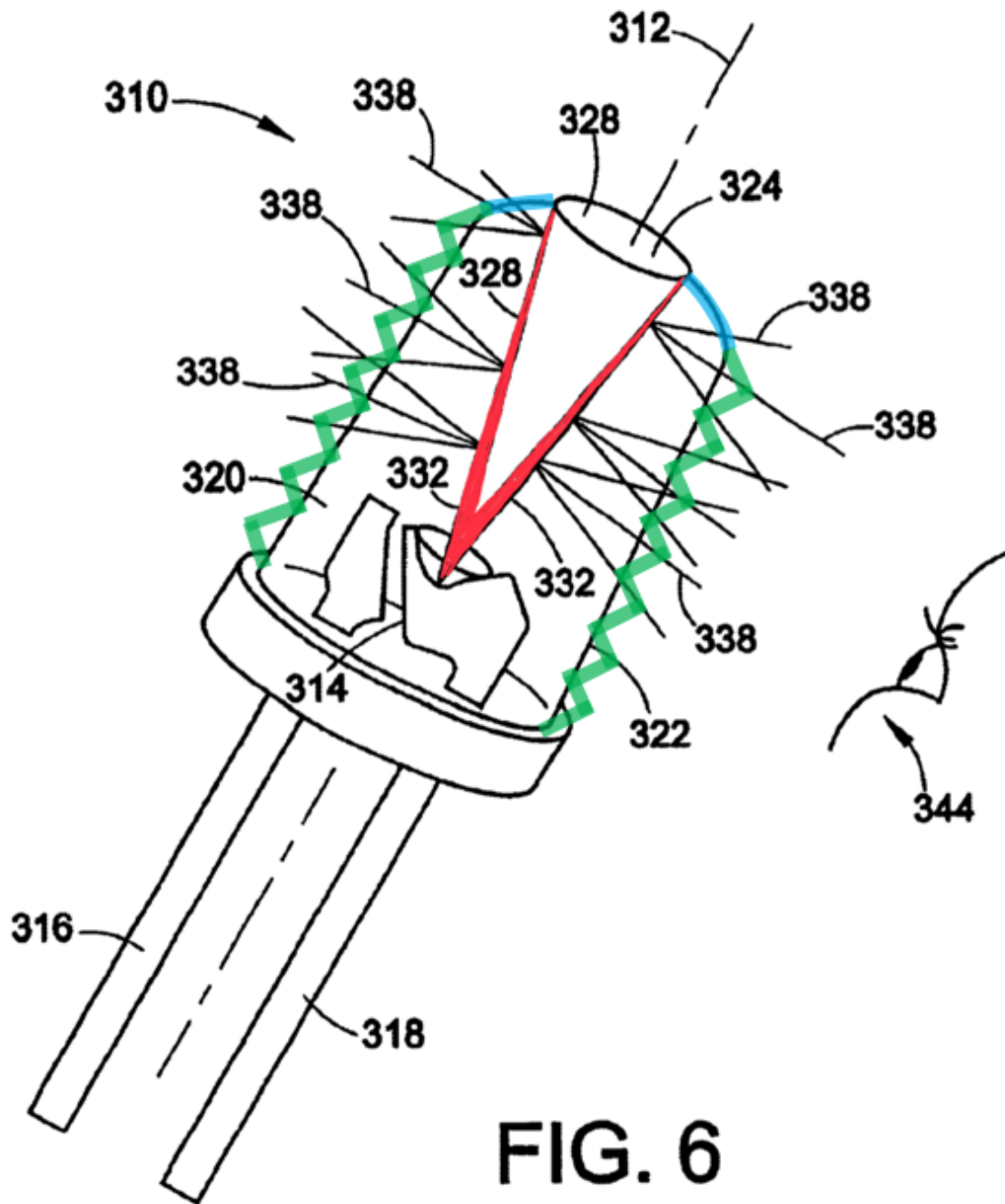


EX1005, Figure 5F.

178. In my opinion, incorporating West’s **sawtooth patterns** into Sommers’s **linear portion of side surface 322** would have simply involved the application of a well-known optical design technique (introducing a sawtooth pattern) to an existing structure (Sommers’s **linear portion of side surface 322**).

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U.S. Patent No. 7,748,873

This straightforward modification would predictably result in light refracting outward from the side of the LED package 310, enhancing the system's functionality by enabling light to exit the lens at angles close to 90 degrees relative to the optical axis. The modification would not require significant changes to the overall design but rather a simple adaptation of Sommers's existing surface to include the sawtooth structure described by West. This adjustment would directly contribute to improved light redirection and side-emission performance, as shown below, achieving the desired outcome of a more efficient system for emitting light horizontally.



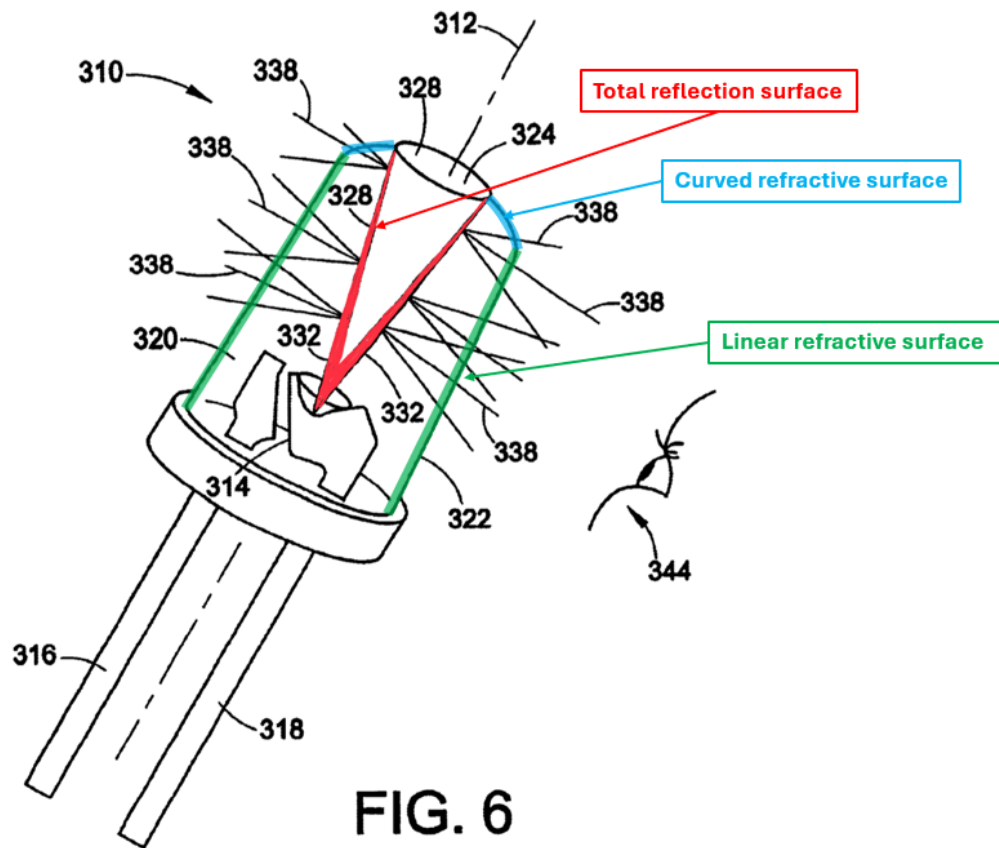
EX1006, Figure 6 (as modified with West).

4. Dependent Claim 6

- i. [6] The lens as claimed in claim 1, wherein the **total reflection surface** comprises: a **first total reflection surface** having a section in the form of a V-shaped recess with a predetermined slope; and a **second total reflection surface** extending upward from a periphery of the **first total reflection surface** and formed to be sloped with a gradient smaller than that of the **first total reflection surface**.

179. In my opinion, the combined disclosures of Sommers and West render obvious [6].

180. As I already discussed in Paragraph 149-153, Sommers discloses a conically-shaped **reflective surface 328** that reflects the light towards the side portions 322.



EX1006, Figure 6.

181. Side-emitting lenses with **total reflection surfaces** comprising multiple sloped regions were already well-established in the field. For instance, Sommers itself shows in a different embodiment a lens that has a “[d]epression 124 defined by curved surfaces 128 [that] is an *essentially linear depression* preferably centered on the plane of symmetry, and reflective coating 126 is disposed on at least a portion of surface 128.” EX1005, 5:5-9; see also EX1005, 5:26-30, claim 7,

3:53-64, 4:18-26. This is shown in Figure 4, in which depression 124 has multiple segments, each having a different slope.

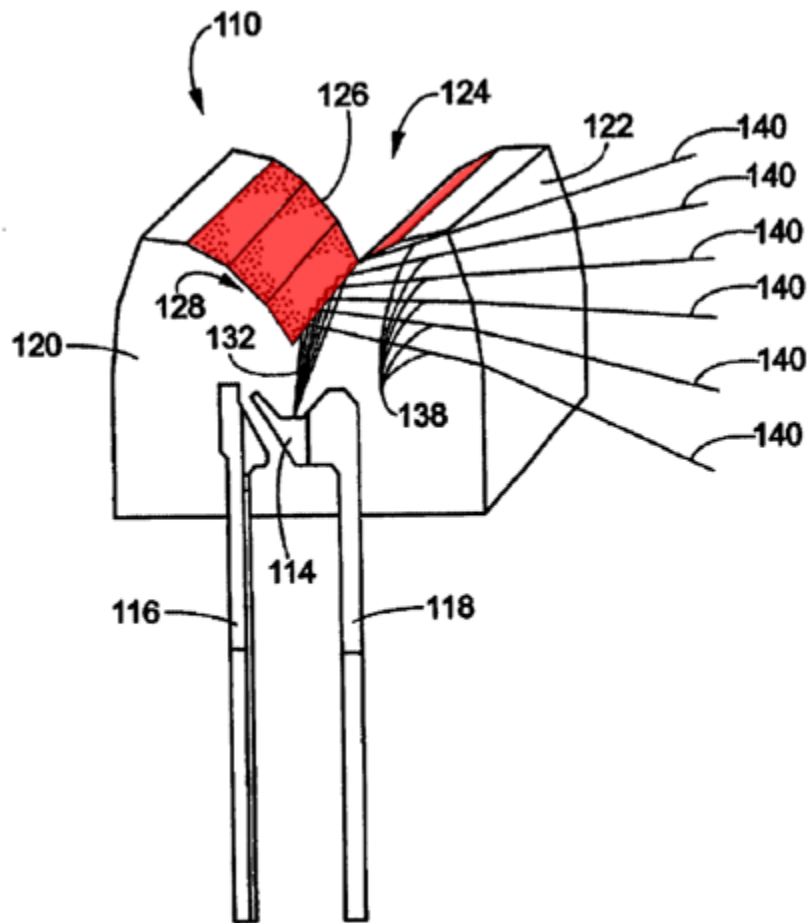


FIG. 4

EX1006, Figure 4.

182. As shown, the **central region** of the **linear depression** has a V-shaped recess with a predetermined slope, and a **second region** that has a slope that is smaller than that of the **V-shaped central region**.

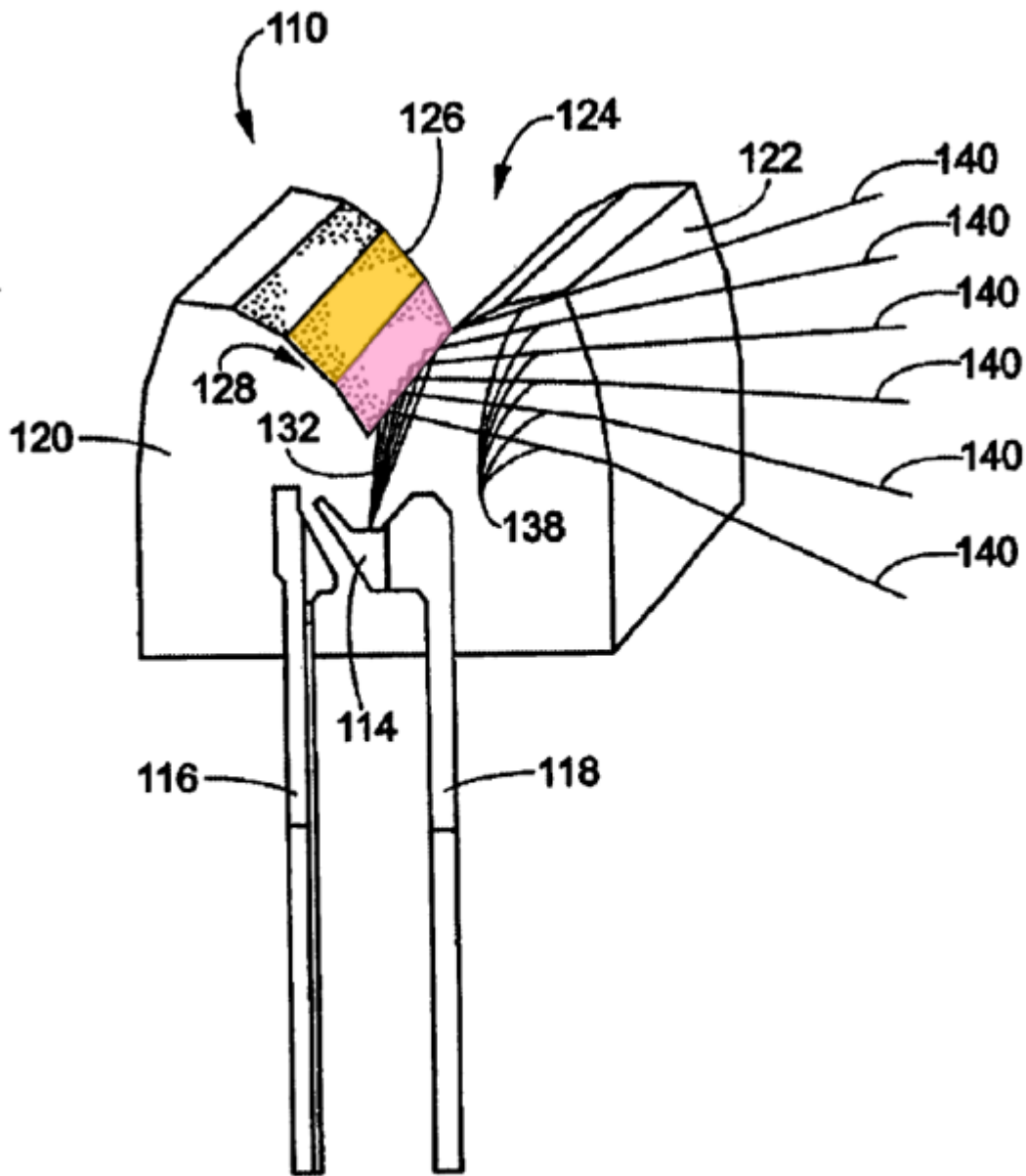


FIG. 4

EX1006, Figure 4.

183. West also discloses a side-emitting lenses with **total reflection surfaces** comprising multiple sloped regions. For instance, in Figure 5F, West depicts a “total internal reflection (TIR) **funnel portion 58.**” According to West, this TIR funnel is “designed as a TIR surface” and “reflects light such that light exits from lens 44 as close to 90 degrees to a longitudinal package axis 43 of LED package 40 as possible.” EX1005, 4:1-15.

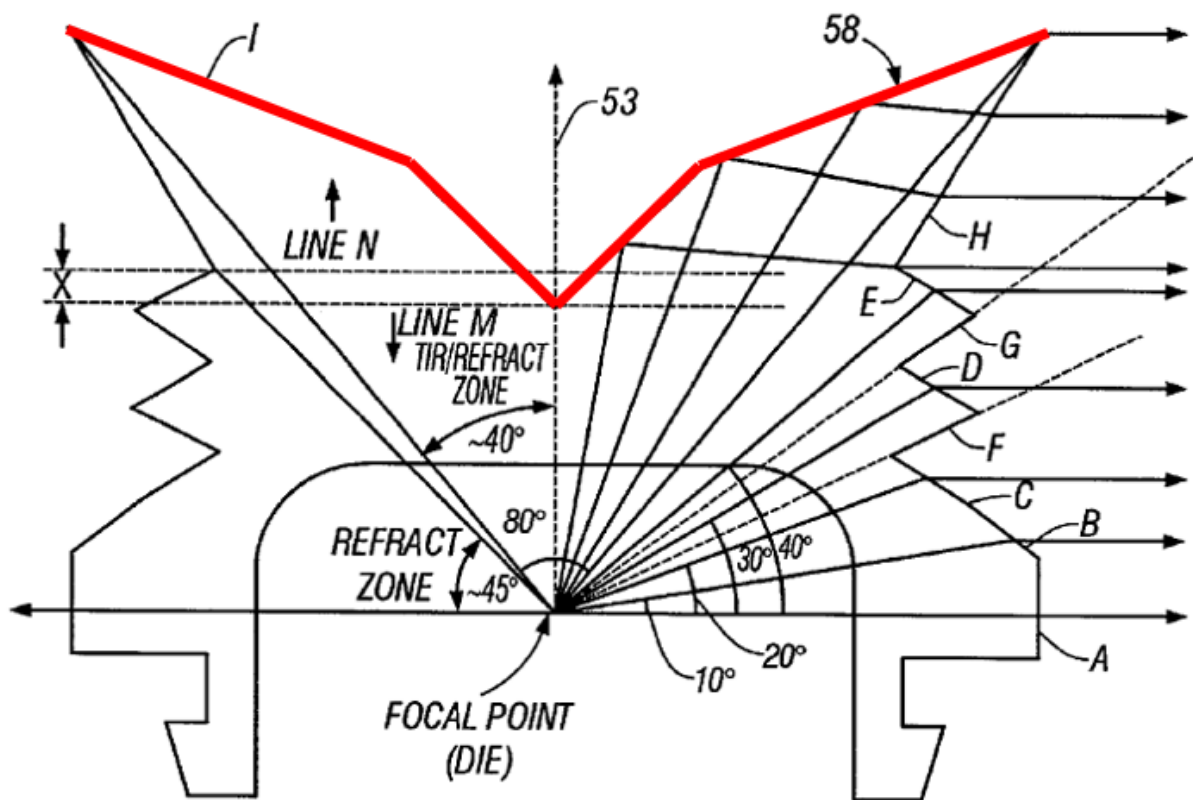
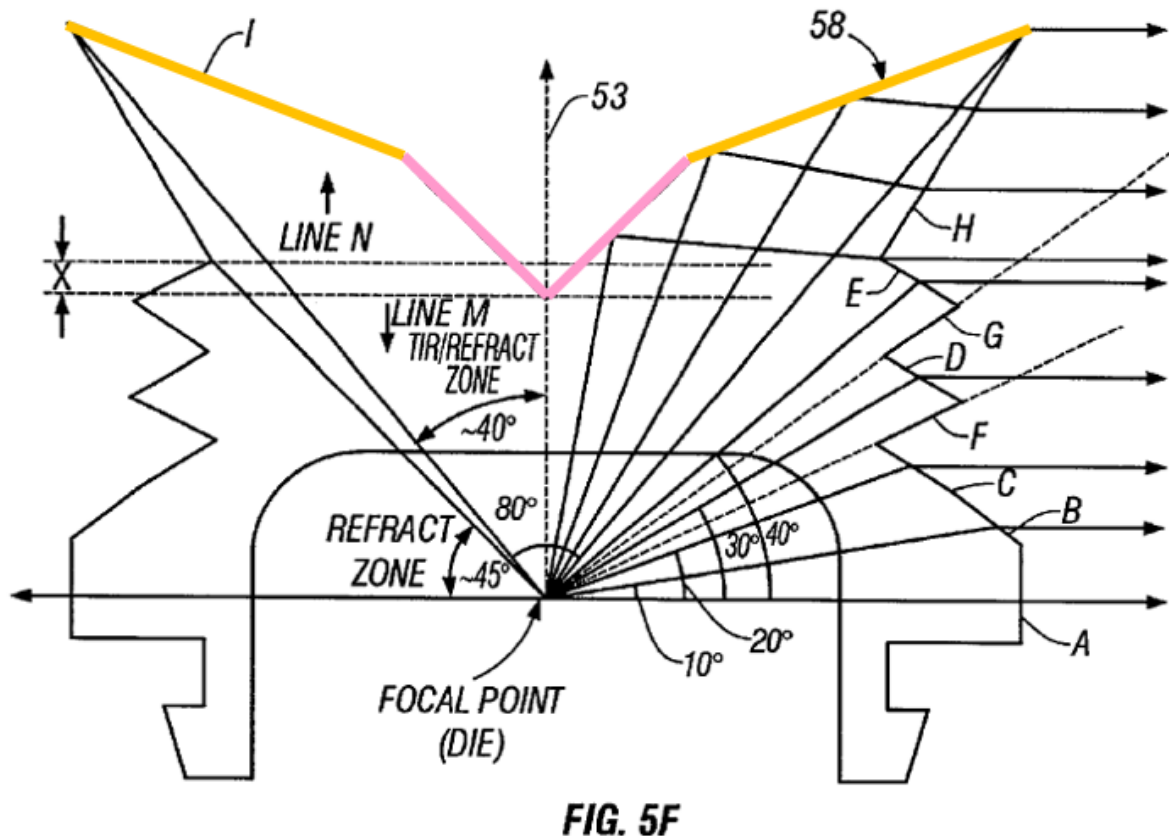


FIG. 5F

EX1005, Figure 5F.

184. West provides additional detail, explaining that “FIG. 5F illustrates a bent-line **funnel-shaped portion 58** where Surface I is defined from a *line bent into two linear portions*, each portion at an angle greater than the critical angle for TIR but directs the light out of the package roughly at 90 degrees to the package axis.” EX1005, 4:64-5:2. As depicted in Figure 5F, the **central part** of the funnel has a V-shaped recess with a specific slope designed to reflect light efficiently. Beyond this central V-shaped region lies a **second region** with a more gradual slope, which is configured to complement the light redirection initiated by the central section, enhancing the overall functionality of the lens. As I already stated in Paragraph 24, I understand that patent drawings can teach a claim limitation if it is clearly shown.



EX1005, Figure 5F.

185. In my opinion a POSITA would have been motivated to replace Sommers's **reflective surface 328** with either Sommers multiple **linear depressions** or West's bent-line **funnel-shaped portion 58**. This substitution would yield the well-recognized benefit of utilizing two distinct slopes to improve total internal reflection conditions, thereby optimizing the redirection of light. A POSITA would have readily appreciated that such a modification would lead to the

desirable outcome of increasing side emission light output performance.

Furthermore, the proposed modification involves a straightforward substitution of one known reflective surface—Sommers’s **reflective surface 328**, which redirects light sideways—with another known design, West’s bent-line **funnel-shaped portion 58**. This change would predictably maintain the functionality of reflecting light to the side for side emission while introducing potential improvements through the enhanced reflective properties of the bent-line funnel. Given the simplicity of the modification and the established principles underlying both designs, a POSITA would have been motivated to make this adjustment with a reasonable expectation of success.

5. Dependent Claim 7

- i. [7] The lens as claimed in claim 1, wherein the refractive index of the body is 1.2 to 2.0.**

186. In my opinion, Sommers teaches or renders obvious [7] for at least the same reasons I already discussed in Paragraphs 160-162.

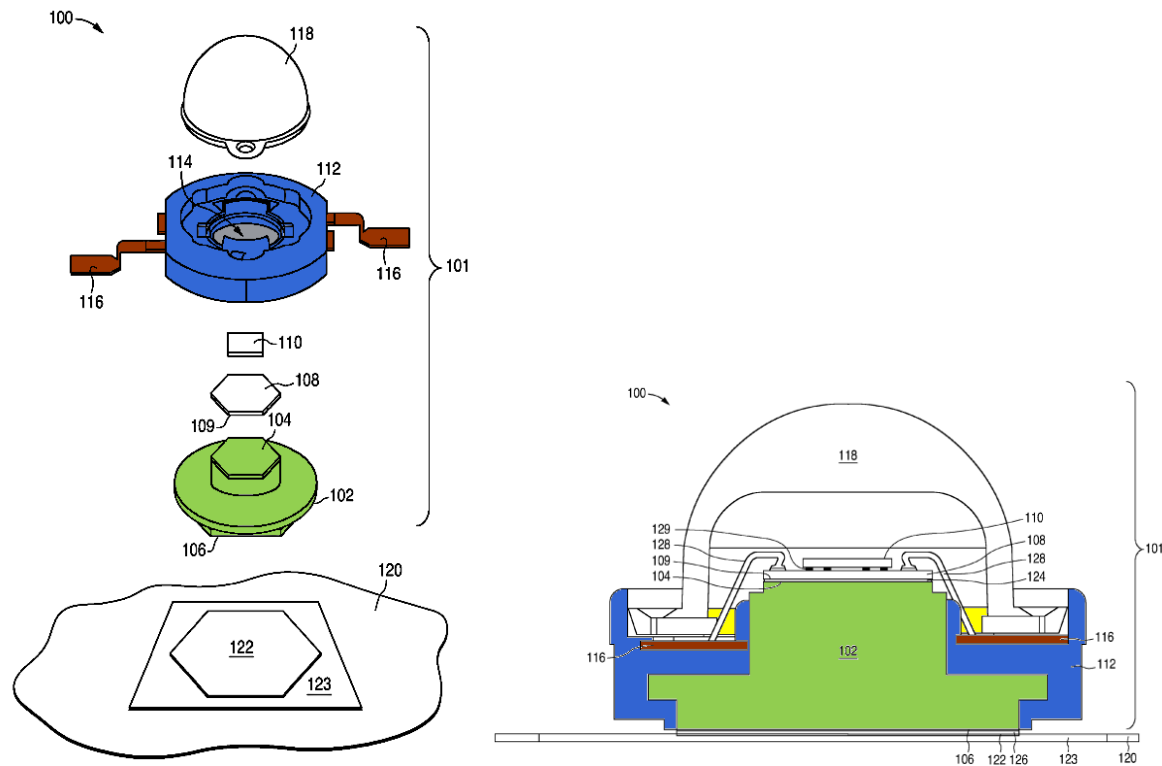
E. Grounds VII Through X: (Ground VII) Elpedes And Odawara; (Ground VIII) Elpedes, Odawara, And West; (Ground IX) Elpedes And Sommers; Or (Ground X) Elpedes, Sommers, And West Render Obvious Claims 8 And 10-13

1. Independent Claim 8

i. [8pre] A luminescent device, comprising:

187. I understand that the preamble may not limit the claims. Regardless, in my opinion, Elpedes teaches [8pre].

188. Specifically, Elpedes teaches an “LED [light emitting diode] assembly 100” or “LED [light emitting diode] package 100.” EX1007, [0008], [0013]. A POSITA would know that an “LED assembly” of an “LED package” is a luminescent device. EX1007, [0001].



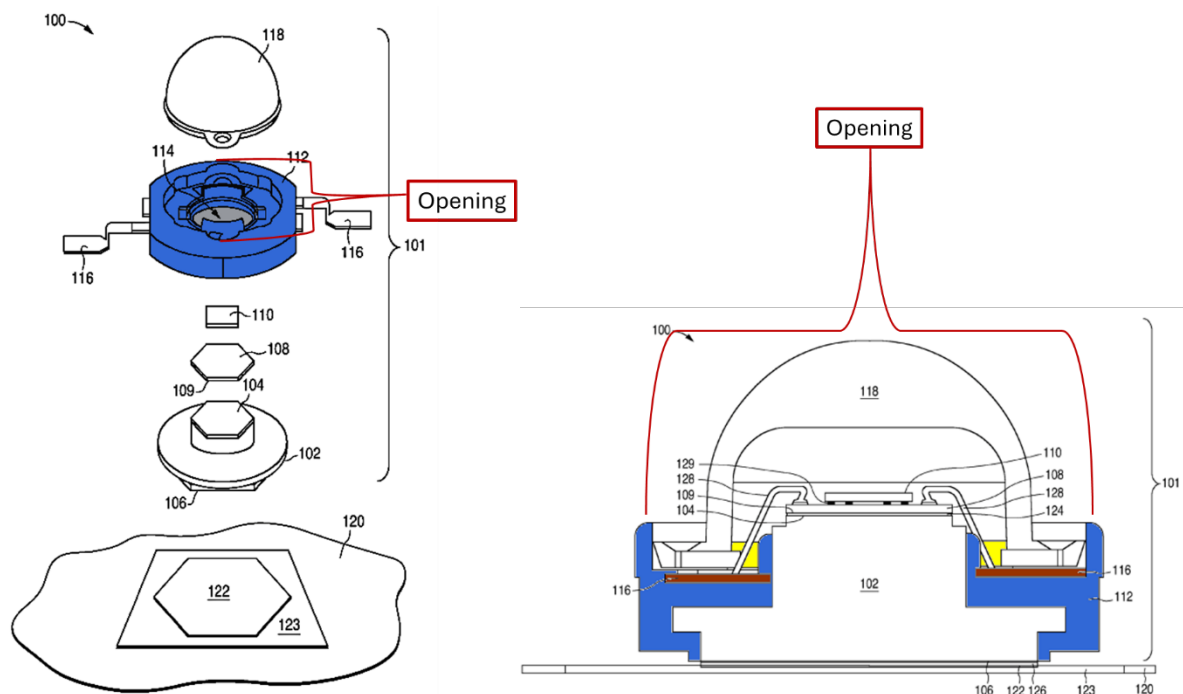
ii. [8a] a **package housing** with an opening and a through-hole exposed by the opening;

189. In my opinion, Elpedes teaches [8a].

190. Elpedes teaches an LED package 100 that includes a **body 112**.

EX1007, [0013] (“LED package 100 further includes a **body 112** ... (FIGS. 1A and 1B).”). As illustrated in Figure 1A below, this **body 112** corresponds to the “**package housing**.” The body 112 contains a recessed area in its central region—shown as the rounded portion surrounding the **cavity 114**—that aligns with the claimed “opening,” as highlighted in the Figures 1A and 2 below. EX1001, 8:18-

26 further supports this, explaining that “the recessed portion and the **through-hole 380** form an opening portion of the package housing.” Additionally, the **cavity 114**, which matches the characteristics of the claimed “**through-hole**,” is visible through this “opening.”

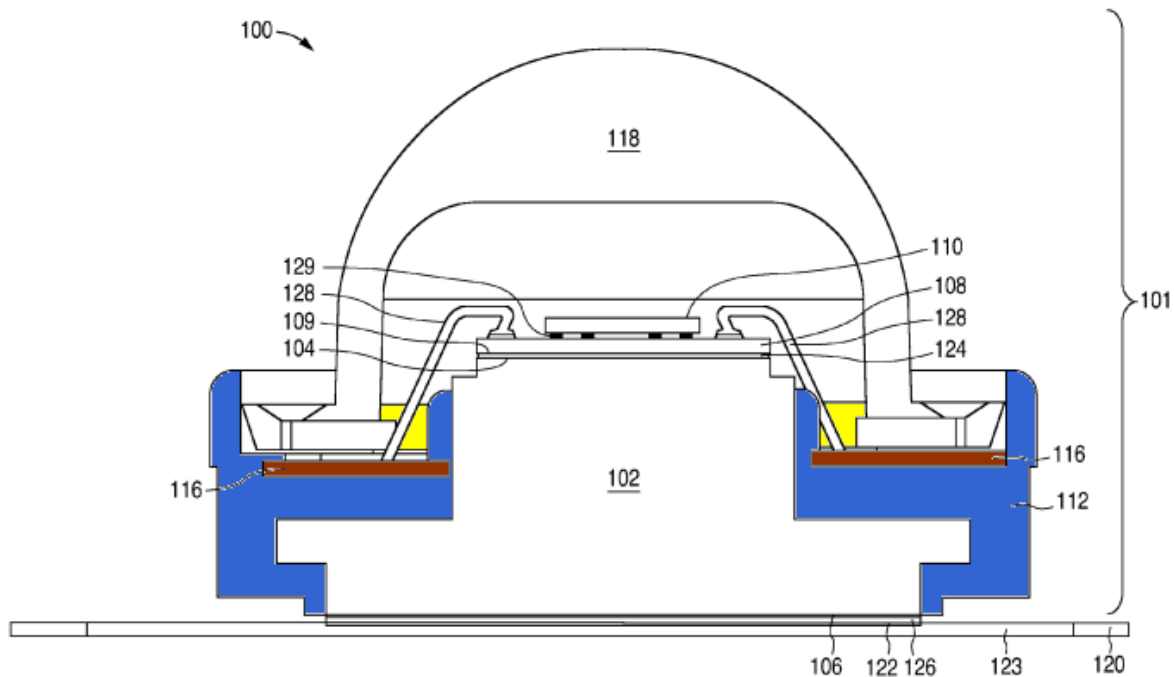


EX1007, Figures 1A and 2.

- iii. [8b] a **lead terminal** having an inner portion exposed within the opening of the **package housing** and an outer portion extending from the inner portion and protruding to the outside of the **package housing**;

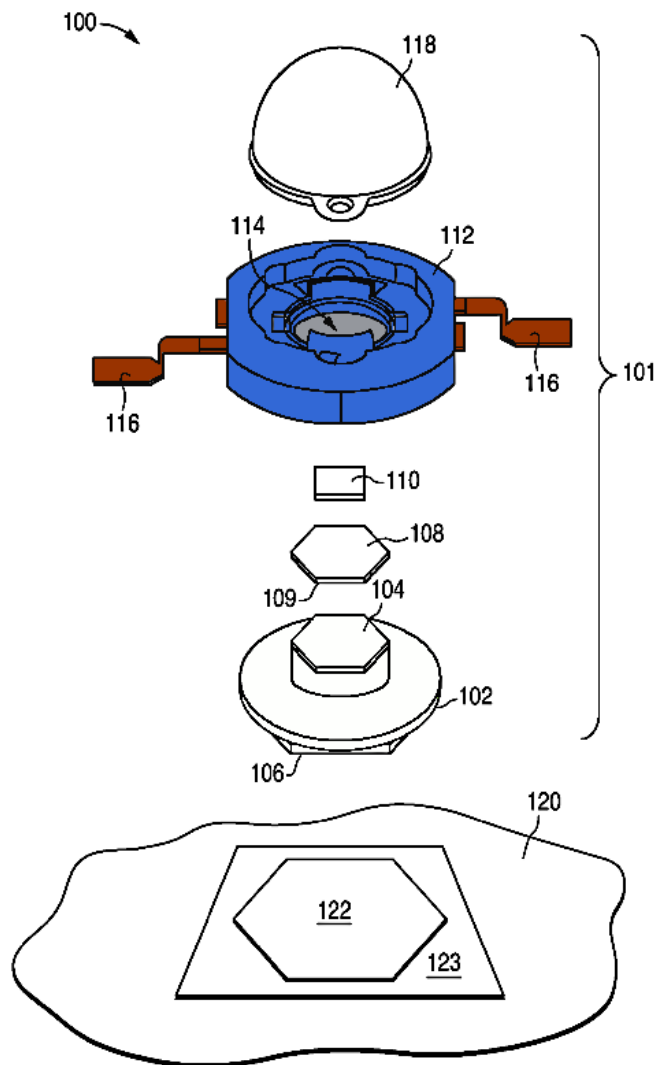
191. In my opinion, Elpedes teaches [8b].

192. First, as shown in the Figure below in brown, Elpedes teaches **leads 116** that correspond to the claimed “**lead terminal**.” See EX1005 [0013] (“**Body 112** includes **leads 116** that pass electrical signals between LED package 100 and other components.”). As an initial matter, as shown below in Figure 2, **leads 116** have inner portions that are exposed within the opening of **body 112**. These exposed sections are visible below the yellow-colored area in Figure 2. Elpedes further explains that [b]ond wires 128 (FIG. 2) couple submount 108 to **leads 116**.” EX1007, [0013]. This indicates that the yellow-highlighted regions expose the inner portions of the underlying **leads 116**. This exposure allows bond wires to connect the submount 108 to the **leads 116**, thereby allowing for proper electrical contact and functionality.



EX1005, Figure 2.

193. Furthermore, as illustrated in Figure 1A below, the **leads 116** include an outer portion that extends from the inner portion and protrudes outward from the **body 112**. This design allows the leads to “pass electrical signals between LED package 100 and other components.” EX1007, [0013]. The outer portion enables external electrical connections, facilitating the integration of the LED package with other devices or systems.

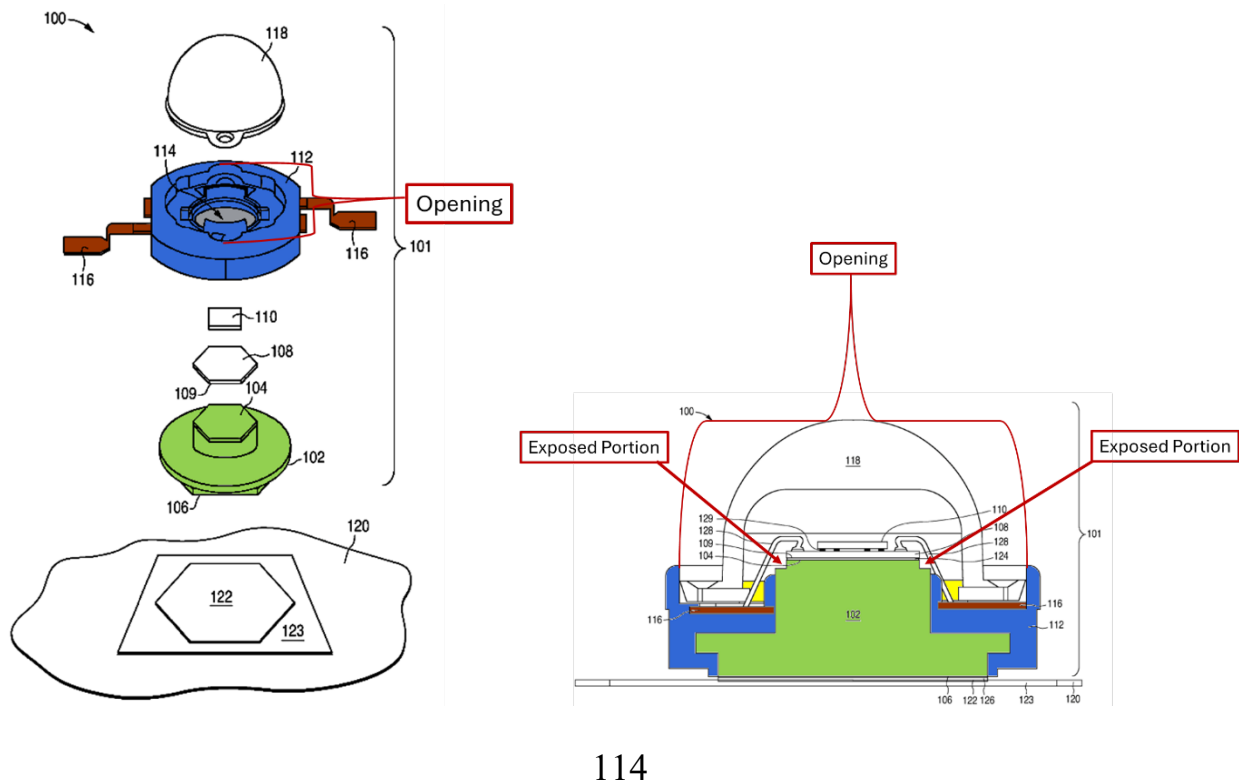


EX1007, Figure 1A.

- iv. [8c] a **heat sink** coupled to a lower portion of the **package housing** and having a portion exposed through the opening; and

194. In my opinion, Elpedes teaches [8c].

195. Elpedes' **heat sink 102** has two portions - a **top mating surface 104** and a **bottom mating surface 106**. Elpedes explains that “[s]ubmount 108 is mounted on a **heat sink 102** (also called a ‘slug’) ... **Slug 102** has a **top mating surface 104** (shown in FIGS. 1A and 2) and a **bottom mating surface 106** that are solder wettable.” EX1007, [0010]. As illustrated, a portion of the **heat sink 102** by the **top mating surface 104** is visible through **cavity 114** within the opening of the **body 112**. Additionally, the portion of the **heat sink 102** near the **bottom mating surface 106** is attached to the lower portion of the **body 112**, creating a structural connection between the heat sink and the LED package.

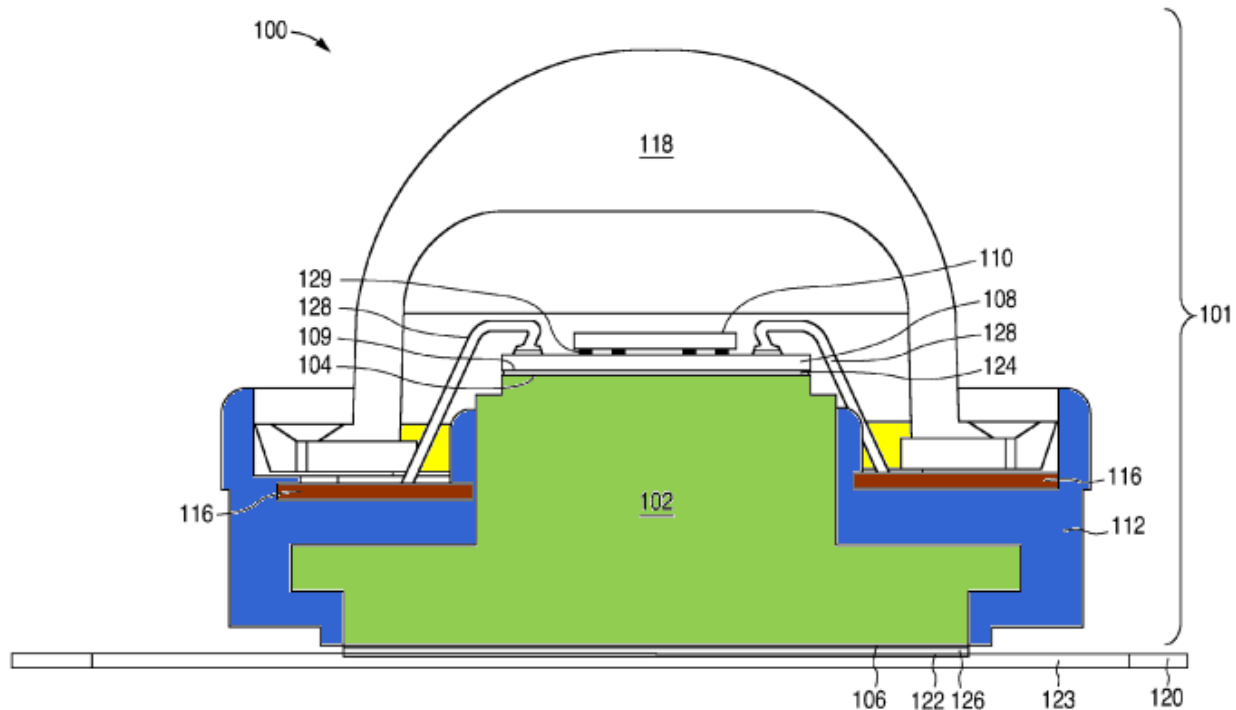


EX1007, Figures 1A and 2 (annotated).

- v. [8d] a lens including a **total reflection surface** encapsulating the **package housing** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery of the **total reflection surface**.

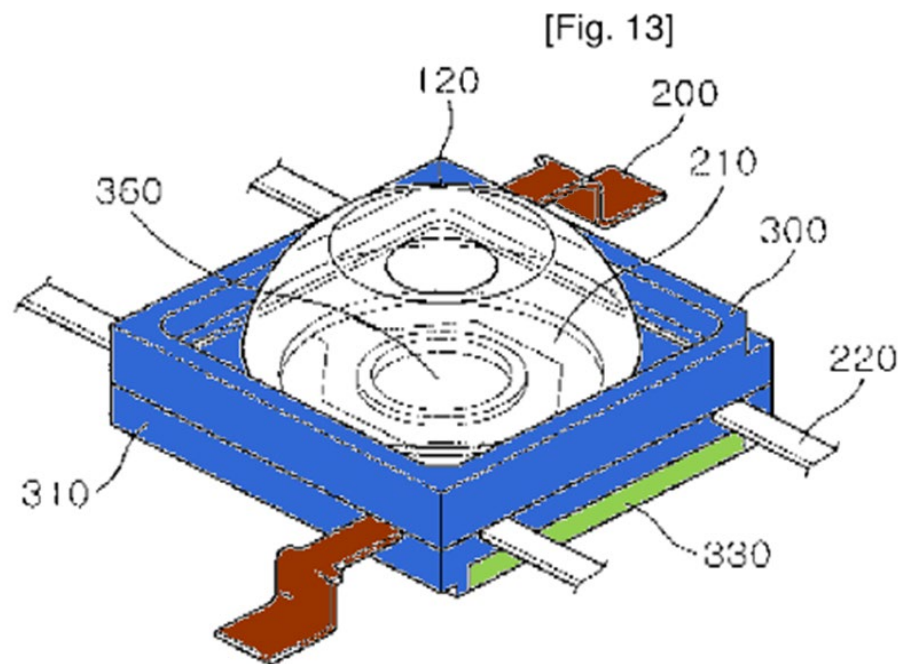
196. In my opinion, Elpedes in combination with any one of Odawara or Sommers, and optionally further combined with West disclose [8d].

197. Elpedes discloses that “[b]ody 112 further includes a lens 118 fitted on body 112.” EX1007, [0013].



EX1007, Figure 2.

198. Elpedes describes lens 118 as “encapsulating” the **body 112**, functioning in the same way as the '873 Patent's lens 120, which “encapsulates” the **package housing 300**. This is illustrated in Figure 13(a) below, where both lenses are shown serving a similar purpose of enclosing and protecting their respective internal components while aiding in the redirection and emission of light.



EX1001, Figure 13(a).

199. Although Elpedes does not provide a detailed description of its lens and does not disclose each limitation of the lens in [8d], I have already explained in Paragraphs above that such lens was well-known.

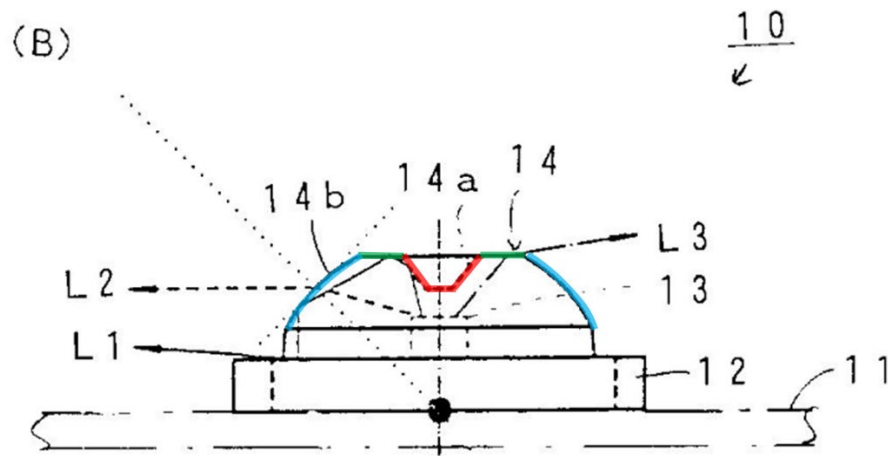
200. Specifically, as I already explained in Paragraphs, 72-100, Odawara teaches a lens including a **total reflection surface** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery of the **total reflection surface**. And, as I will further discuss below, it is my opinion that it would have been obvious to a POSITA to utilize Odawara's lens in Elpedes' device.

201. Furthermore, as I already explained in Paragraphs 114-119, Odawara together with West teaches a lens including a **total reflection surface** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery of the **total reflection surface**. And, as I will further discuss below, it is my opinion that it would have been obvious to a POSITA to utilize such a lens in Elpedes' device.

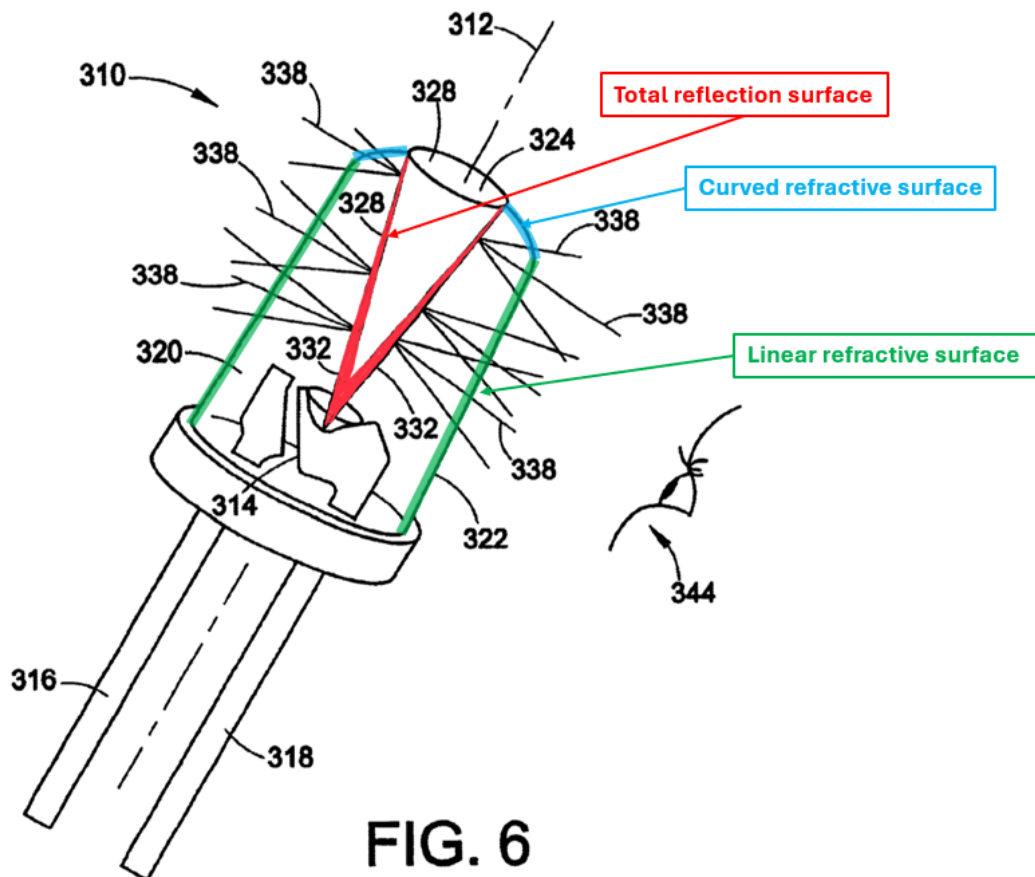
202. Additionally, as I already explained in Paragraphs 145-157, Sommers teaches a lens including a **total reflection surface** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery of the **total reflection surface**. And, as I will further discuss below, it is my opinion that it would have been obvious to a POSITA to utilize Sommers' lens in Elpedes' device.

203. Moreover, as I already described in Paragraphs 163-174, Sommers together with West teaches a lens including a **total reflection surface** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery of the **total reflection surface**. And, as I will further discuss below, it is my opinion that it would have been obvious to a POSITA to utilize such a lens in Elpedes' device.

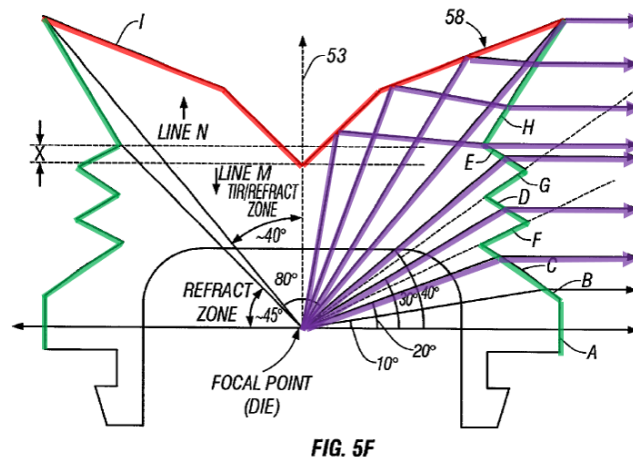
204. In particular, Elpedes teaches a similar configuration of the lens relative to the LED and the **package housing** as taught in each of Odawara, West, and Sommers.



EX1004, Figure 1.



EX1006, Figure 6.



EX1005, Figure 5F.

2. Reasons To Combine Elpedes with Odawara, West, And/Or Sommers With A Reasonable Expectation Of Success

205. In my opinion, a POSITA would have recognized that combining Elpedes with Odawara, West, or Sommers represents a straightforward substitution of one known lens design (Elpedes's lens) with another (Odawara's lens or Sommers's lens, optionally incorporating features taught by West) to achieve a predictable result: an LED package that directs light in a desired direction.

206. As an initial matter, Elpedes, Odawara, West, and Sommers all describe LED packages that include a lens. For instance, Elpedes teaches an LED package with a lens, stating, "LED package 100 further includes a body 112 ...

Body 112 further includes a lens 118 fitted on body 112.” EX1007, [0013].

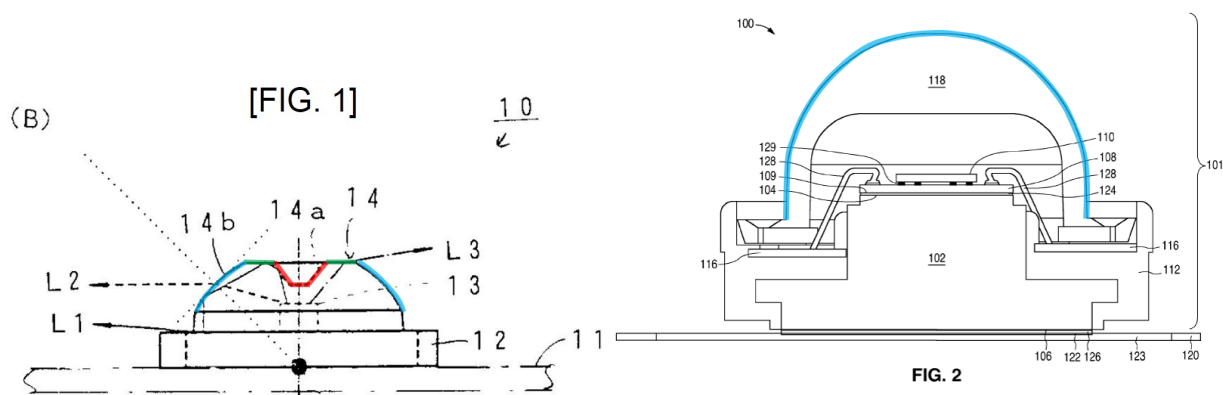
Similarly, Odawara discloses an LED package with a lens, explaining that “a surface mounted LED 10 is configured as a chip LED and includes a chip substrate 12 placed on a mounting substrate 11 (depicted by a dotted line in FIG. 1(B)), an LED chip 13 mounted on the chip substrate 12, and a lens part 14 formed so as to cover the entire surfaces of LED chip 13 and chip substrate 12.” EX1004, [0022]-[0023].

207. West also describes an LED package with a lens, detailing a light-emitting device that includes a “light emitting diode package” with “a lens extending from the front surface of the package for receiving light from the diode.” EX1005, 2:1-27. Likewise, Sommers discloses an LED package in which a lens is present, describing a design where “a transparent encapsulant surrounds the LED die.” EX1006, 2:6-10.

208. Given this shared purpose of including a lens in LED packages, a POSITA would readily understand that substituting Elpedes’s lens with another lens design—such as those taught by Odawara or Sommers and optionally incorporating West’s features—would achieve predictable results. This substitution would align with established practices in optical engineering to optimize light

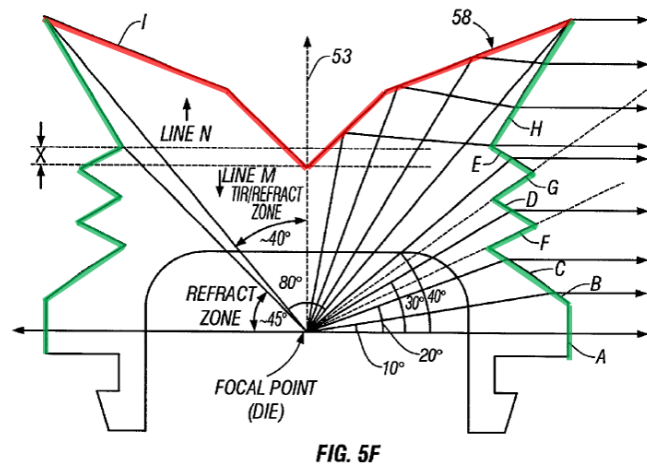
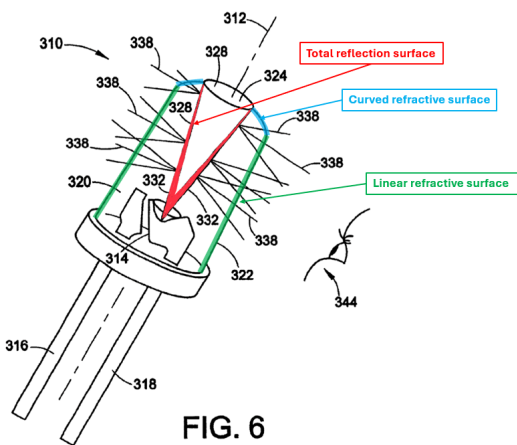
emission, direction, and performance, thereby enhancing the overall functionality of the LED package.

209. Furthermore, as I explained in Paragraphs 196-204, a POSITA would have observed clear similarities in the arrangement of the lenses in Elpedes, Odawara, West, and Sommers relative to the LED die. For example, as illustrated in Figure 1B of Odawara and Figure 2 of Elpedes, both designs depict lenses that surround their respective LED components. In Odawara, lens 14 is described as being “formed of a transparent or translucent resin on the chip substrate so as to surround the LED chip.” EX1004, Abstract. Similarly, Elpedes describes lens 118 as being “fitted on body 112,” which houses the LED die 110. EX1007, [0013].



EX1004, Figure 1B; EX1007, Figure 2.

210. Similar configurations are found in the LED packages of Sommers and West. In Sommers, the lens is represented by a transparent encapsulant that encloses the LED die, as shown in Figure 6. EX1006, 2:6-10. In West, the lens is positioned around the diode and extends outward from the package, as depicted in Figure 5F. EX1005, 2:1-27.



EX1006, Figure 6; EX1005, Figure 5F.

211. Given these consistent arrangements of the lenses surrounding the LED die across all references, a POSITA would have readily understood that replacing Elpedes's lens with Odawara's or Sommers's lens, optionally incorporating features taught by West, would be a simple design change. This

modification would not require significant alterations to the existing design and would yield predictable results.

212. Additionally, a POSITA would have easily recognized the interchangeability of the lenses described in Elpedes, Odawara, Sommers, and West due to the similarity of materials used across these references. For example, Odawara teaches that, “[t]he lens part 4 is made of a transparent or translucent material, such as a thermoplastic resin.” EX1004, [0004]. West similarly describes a “[l]ens 44 [that] is made of a transparent material.” EX1005, 3:45-55. Sommers notes that “[t]he encapsulant material is usually an epoxy resin or the like, with a refractive index $n \sim 1.5$,” and further elaborates that “[a] transparent encapsulant encapsulates the LED die and at least a portion of the lead frame.” EX1006, 1:39-40, 2:39-41. Likewise, Elpedes states, “[a]n encapsulant may fill lens 118 to protect LED die 110.” EX1007, [0013].

213. Given the material similarities, a POSITA would have understood that substituting Odawara’s or Sommers’s lens, optionally modified with features taught by West, into Elpedes’s LED package would involve no more than replacing one known lens with another. This substitution would achieve the same predictable outcome of an LED package equipped with a lens to emit light.

214. For at least the reasons outlined above, it is my opinion that a POSITA would have reasonably expected success in making this substitution. The modification would involve replacing a well-known lens design (as described in Elpedes) with another established lens design (as taught by Odawara or Sommers, optionally incorporating features from West) to achieve the predictable result of enabling sideways light emission from an LED package.

3. Dependent Claim 10

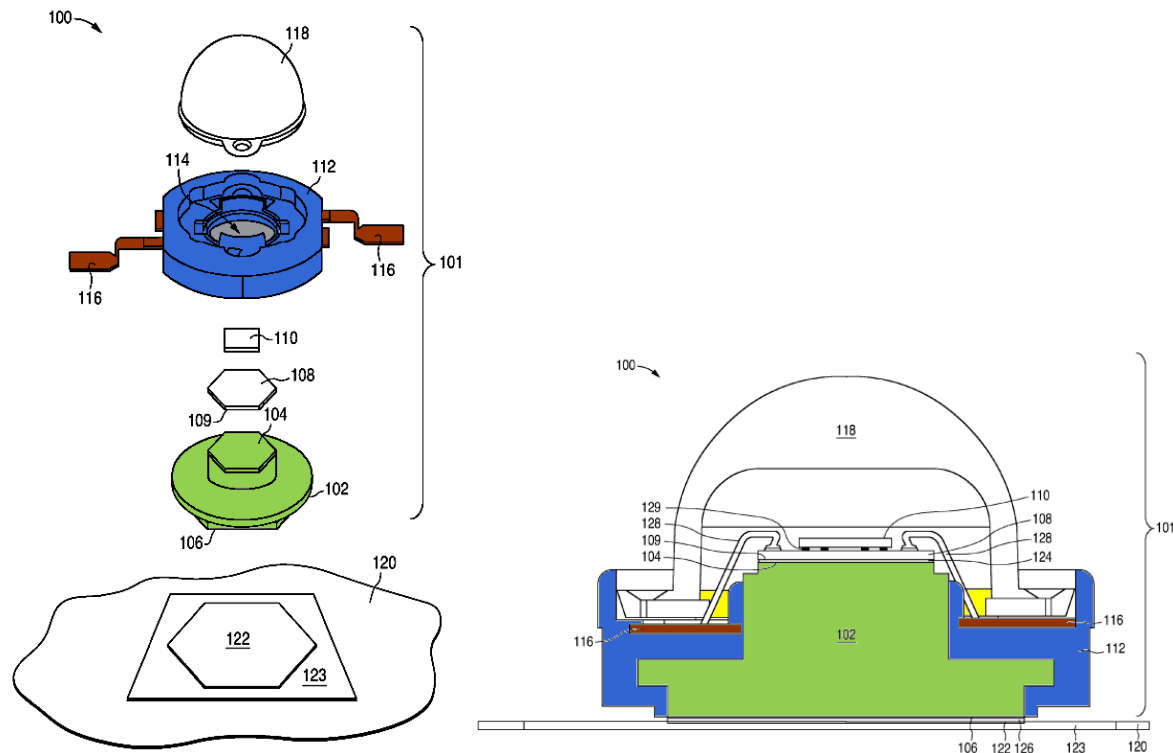
- i. [10pre] The luminescent device as claimed in claim 8, wherein the **heat sink** comprises:

215. In my opinion, Elpedes teaches [10pre] for at least the same reasons I already discussed in Paragraphs 187-204.

- ii. [10a] a **heat sink** body corresponding to a bottom surface of the **package housing**; and

216. In my opinion, Elpedes teaches [10a].

217. In particular, Elpedes teaches a **heat sink 102**. This **heat sink 102** has a body that corresponds to **body 112** near the **bottom portion 106** of **heat sink 102**. EX1007, [0010].

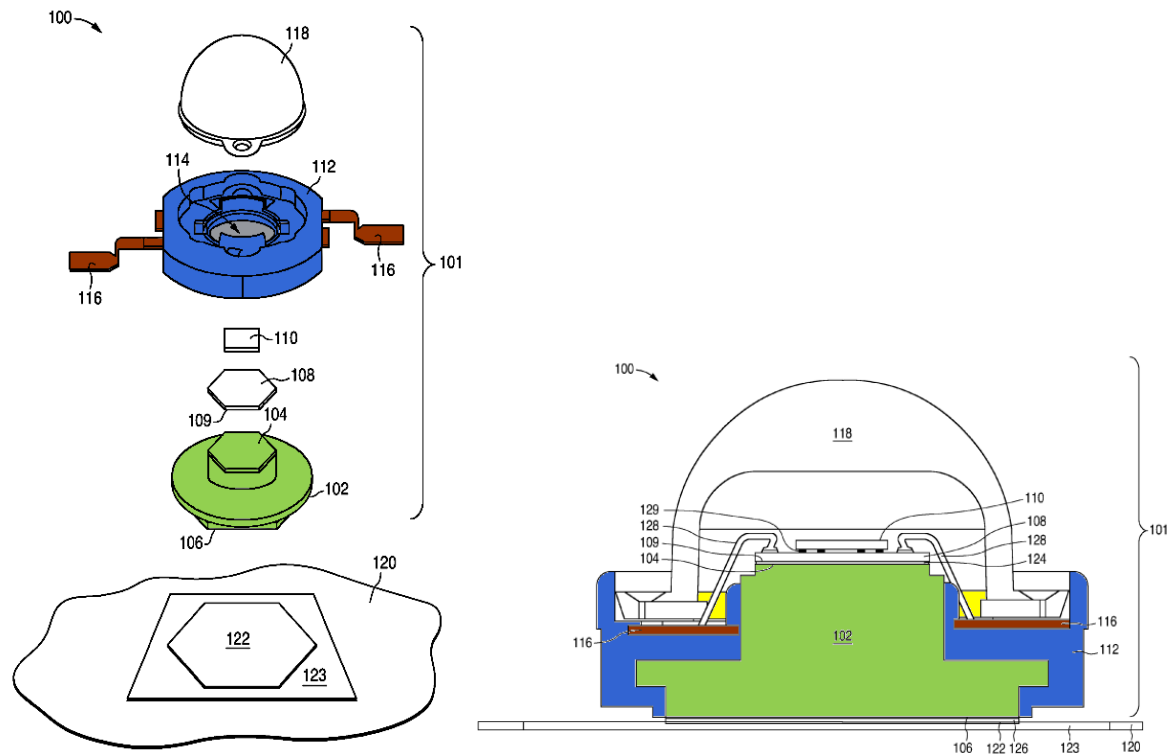


EX1007, Figures 1A and 2.

- i. [10b] an **insertion projection** protruding upward from a central portion of the **heat sink** body and inserted into the **through-hole** of the **package housing**.

218. In my opinion, Elpedes teaches [10b].

219. As shown in Figures 1A and 2, **heat sink 102** includes a “**mating surface[] 104** [that is] raised....” in relation to the central portion of heat **heat sink 102**. EX1007, [0010]. This raised section, located near **mating surface 104**, is positioned within **cavity 114** of **body 112**, as depicted below.



EX1007, Figures 1A and 2.

4. Dependent Claim 11

- i. [11] The luminescent device as claimed in claim 10, wherein the **heat sink** has a **coupling projection** on at least one of the **heat sink** body and the **insertion projection**.

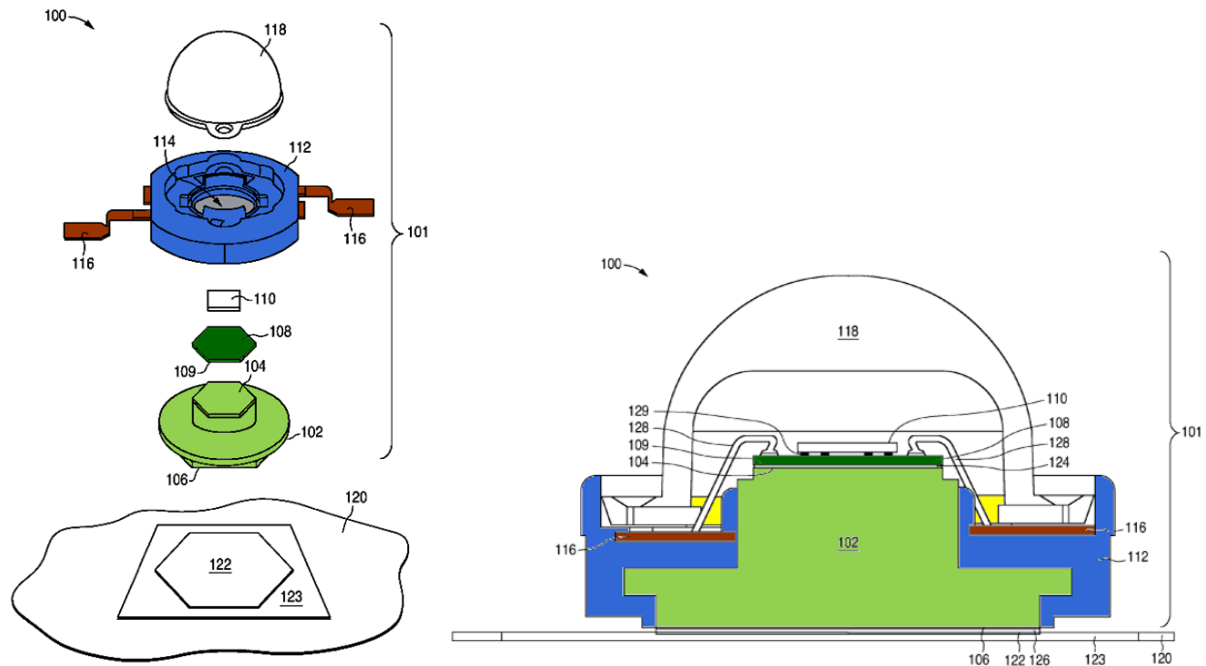
220. In my opinion, Elpedes teaches and/or renders obvious [11].

221. The '873 Patent identifies a "chip-seating portion 360" as an example of the claimed "coupling projection." Specifically, the '873 Patent describes a "chip-seating portion 360," stating, "an inner space of the insertion projection 340

becomes a luminescent chip-seating portion 360 in which a luminescent chip 400 to be described later will be fixedly seated.” EX1001, 8:38-41.

222. Elpedes teaches a **submount 108**, and explains that the “LED die 110 ... is mounted on a **submount 108**.” EX1007, [0009]. Elpedes further notes that “[s]**ubmount 108** is mounted on a heat sink 102 (also called a ‘slug’).” EX1007, [0009].

223. To the extent it is argued that claim 11 requires the **coupling projection** to be a part of the **heat sink**, it is my opinion that a POSITA would have found it obvious to integrate **submount 108** into **heat sink 102**. Both the **submount 108** and **heat sink 102** can be fabricated from the same materials, such as “silicon, copper, silver, ... or other thermally conductive materials.” EX1007, [0009]; *see also* EX1007, [0010] (“**Slug 102** may be made of silicon, copper, silver, ... or other thermally conductive materials...”). This commonality in materials highlights the feasibility of combining the **submount 108** with the **heat sink**.



EX1007, Figures 1A and 2.

5. Independent Claim 12

i. [12pre] A luminescent device, comprising:

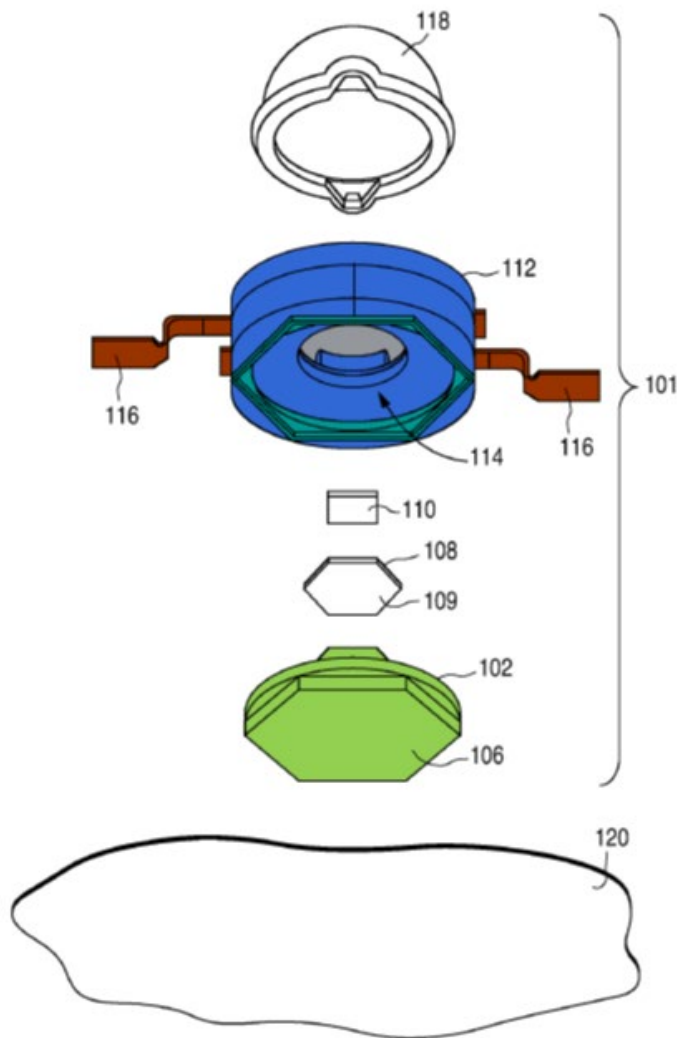
224. I understand that the preamble may not limit the claims. Regardless, in my opinion, Elpedes teaches [12pre] for at least the reasons I already described in Paragraphs 187-188.

ii. [12a] a heat sink support ring;

[12b] a heat sink inserted into the support ring;

225. In my opinion, Elpedes teaches [12a] and [12b].

226. As shown in Figure 1B, the underside of **body 112** incorporates a **hexagonal ring** structure surrounding **cavity 114**. This **hexagonal ring** serves as a support ring for the **heat sink 102**, ensuring proper alignment and stability when the **heat sink** is inserted into the **ring**. The design facilitates secure placement of the heat sink within the LED package, allowing for efficient thermal management and mechanical stability.



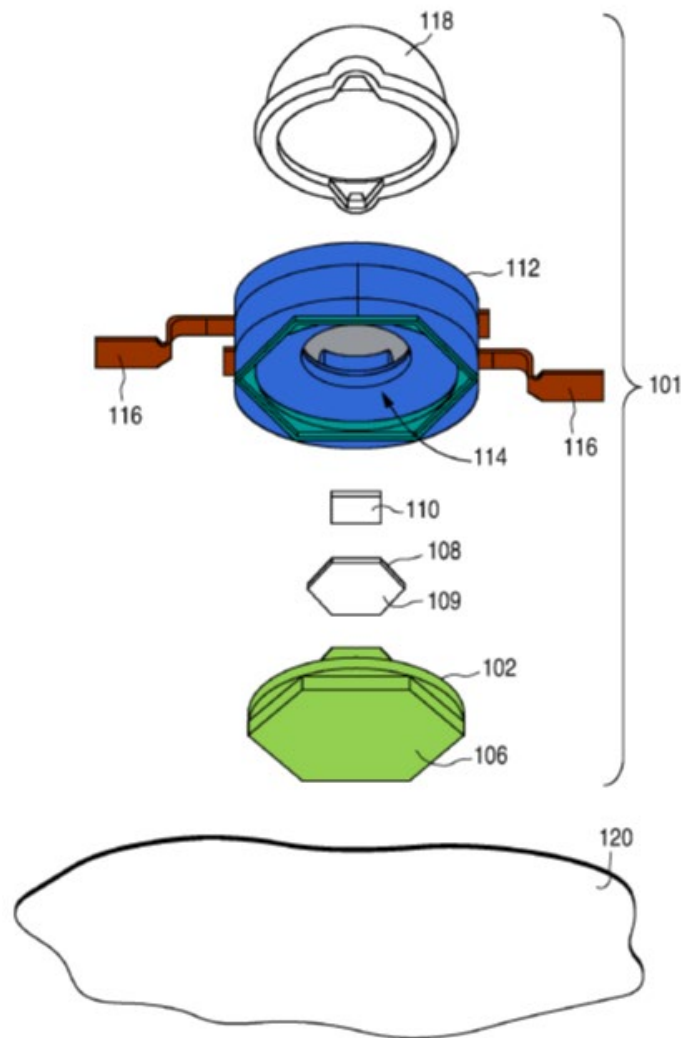
EX1007, Figure 1B.

- iii. [12c] at least two **lead terminals** arranged at both sides of the **support ring** while being spaced apart from the **support ring** and the **heat sink**;

227. In my opinion, Elpedes teaches [12c].

228. In Figure 1B of Elpedes, **leads 116** are shown positioned to the left and right of the **hexagonal ring** within **body 112**. Therefore, the **leads** are located on opposite sides of the support ring and maintain a clear separation from both the **hexagonal ring** and the **heat sink 102**.

229. Elpedes further states that “[s]lug 102 is mounted to **body 112** inside cavity 114. **Body 112** includes **leads 116** that pass electrical signals between LED package 100 and other components.” EX1007, [0013]. See also, EX1007, [0010]. (“Submount 108 is mounted on a **heat sink 102** (also called a “**slug**”)”).



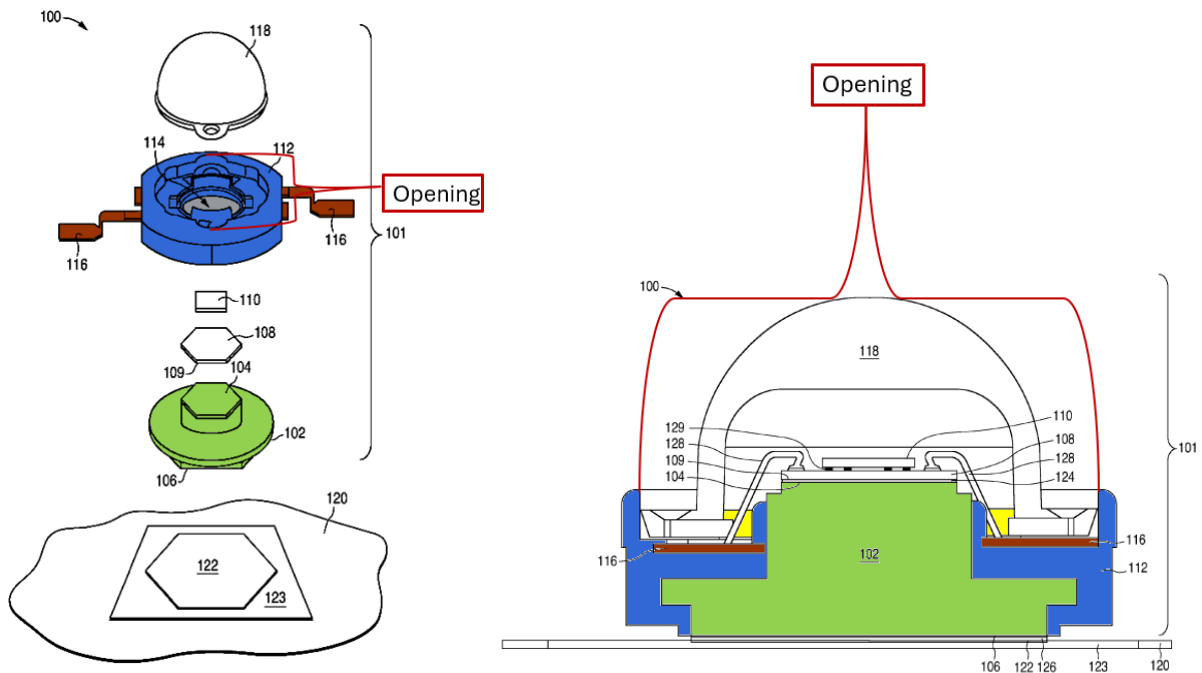
EX1007, Figure 1B.

- iv. [12d] a **package body** for molding the **heat sink** and the **lead terminals** to support them, the **package body** having an opening through which an upper portion of the **heat sink** and portions of the **lead terminals** are exposed; and

230. In my opinion, Elpedes teaches [12d].

231. Elpedes' LED package 100, as illustrated in Figure 1A, includes a **body 112** that corresponds the claimed "package housing," as I already discussed in Paragraph 190. EX1007, [0013] ("LED package 100 further includes a **body 112** ... (FIGS. 1A and 1B)."). The **body 112** includes a recessed portion in the central region, represented by the round area surrounding the **cavity 114**, which corresponds to the claimed "opening," as labeled below. This description aligns with the description of the '873 Patent, which explains that the "recessed portion and the through-hole 380 form an opening portion of the package housing." EX1001, 8:18-26.

232. Additionally, as depicted in Figure 2, **heat sink 102**, includes a **top mating surface 104** and a **bottom mating surface 106**. EX1007, [0010] ("Submount 108 is mounted on a **heat sink 102** (also called a "slug") ... **Slug 102** has a **top mating surface 104** (shown in FIGS. 1A and 2) and a **bottom mating surface 106** that are solder wettable."). The **top mating surface 104** is exposed through **cavity 114** within the opening, allowing the heat sink to interface with the surrounding components effectively.



233. Furthermore, as I already discussed in Paragraphs 192-193, **leads 116** have inner portions that are exposed within the opening of the **body 112**, as shown in the portions below the yellow-highlighted area in Figure 2. Elpedes explains that “[b]ond wires 128 (FIG. 2) couple submount 108 to **leads 116**.” EX1007, [0013]. This configuration indicates that the yellow-highlighted regions represent an opening exposing the underlying leads 116, allowing bond wires to connect the leads to the submount.

234. Lastly, as depicted in Figure 1B and Figure 2, **body 112** molds both the **heat sink 102** and **leads 116** to provide structural support for these components within the LED package.

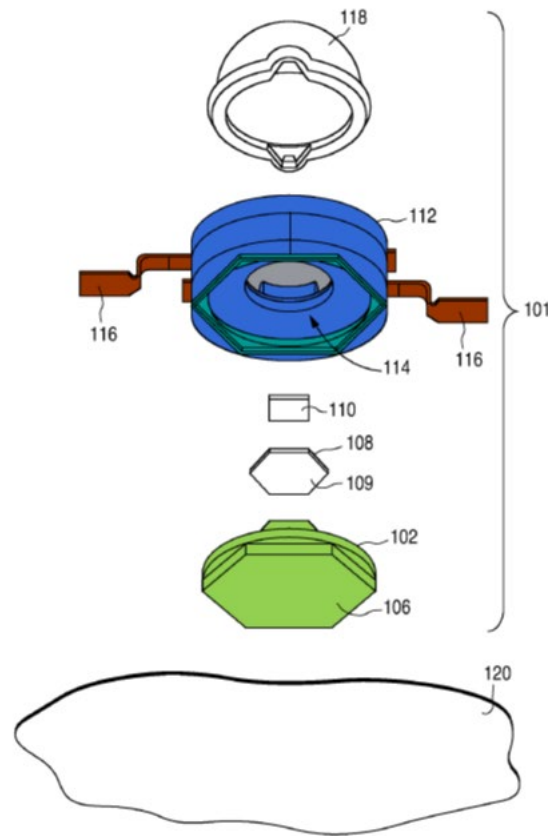


FIG. 1B

EX1007, Figure 1B.

- v. [12e] a lens including a **total reflection surface** encapsulating the **package housing** and having a total reflection slope with respect to a central axis of a body of the lens, and a refractive surface formed to extend away from the central axis and beyond a periphery edge of the **total reflection surface**.

235. In my opinion, Elpedes in view of any one of Odawara or Sommers, and optionally further combined with West disclose [12e]. See, generally, the discussion in Paragraphs 196-204.

6. Dependent Claim 13

- i. [13] The luminescent device as claimed in claim 12, wherein the **heat sink** has a base and a projection protruding upward from the base at the center thereof, and the projection is inserted into the **support ring**.

236. In my opinion, Elpedes teaches [13]. See, generally, the discussion in Paragraphs 216-219, and 226.

X. Availability for Cross-Examination

237. In signing this declaration, I recognize that the declaration will be filed as evidence in a case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place within the United States. If cross examination is required of me, I will appear for cross

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examination within the United States during the time allotted for cross
examination.

XI. Right to Supplement

238. I reserve the right to supplement my opinions in the future to respond to any arguments that the Patent Owner may raise and to take into account new information as it becomes available to me.

XII. Jurat

239. I declare 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.

01/15/2025
Date



Dr. Tom D. Milster

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Appendix A

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CURRICULUM VITAE

TOM D. MILSTER

1/7/2025

Wyant College of Optical Sciences and Department of Electrical and Computer Engineering
University of Arizona
Tucson, Arizona 85721
(520) 621-8280
milster@optics.arizona.edu

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

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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

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)
1. 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:

2. T. Milster, “The Gerchberg-Saxton Phase Retrieval Algorithm and Related Variations.” In Optical Holography-Materials, Theory and Applications (Elsevier, 2020) pp. 61-72.
3. T. Milster, “Superresolution Microscopy,” in Springer Handbook of Nanotechnology (Springer, Berlin, Heidelberg 2017) pp. 845-865.
4. T. Milster and T. Tkaczyk, “Miniature and Micro Optics,” Chapter 22, Handbook of Optics, 3rd Ed. Optical Society of America 2010.
5. T. Milster; J. J. Butz, T. Nakano, J. Tominaga, W. L. Bletscher, “Signal power in the angular spectrum of AgOx SuperRENS media,” in Optical Nanotechnologies: Manipulation of Surface

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 7. 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).
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 11. T. D. Milster and S. B. Hamilton, "Testing," in MO Data Recording -- Materials, Subsystems, Techniques, T. McDaniel and R. Victora, eds. (Noyes Publications, Park Ridge, NJ., 1997).
 12. 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:

1. Shao, Yixuan, Robert Lupoiu, Jiaqi Jiang, You Zhou, Tom D. Milster, and Jonathan A. Fan. "Multifunctional Spaceplates for Optical Aberration Correction." *ACS Photonics* (2024).
2. Wang, Zichan, Youngsik Kim, and Tom D. Milster. "High-harmonic diffractive lens color compensation." *Applied Optics* 60, no. 19 (2021): D73-D82.
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.
4. Zhang, Yingying, Rongguang Liang, Oliver Joshua Spires, Shaohui Yin, Allen Yi, and Tom D. Milster. "Precision glass molding of diffractive optical elements with high surface quality." *Optics Letters* 45, no. 23 (2020): 6438-6441.
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7. Finan, Emily, and Tom Milster. "Phase retrieval and adaptive optics correction for systems with diffractive surfaces." *Applied Optics* 59, no. 22 (2020): G92-G98.

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1. Eguchi, Akira, and Tom D. Milster. "Single-shot phase retrieval with complex diversity." *Optics Letters* 44, no. 21 (2019): 5108-5111.

2. Apai, Dániel, Tom D. Milster, Dae Wook Kim, Alex Bixel, Glenn Schneider, Ronguang 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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2. Kang, Dongyel, and Tom D. Milster. "Effect of optical aberration on Gaussian speckle in a partially coherent imaging system." *JOSA A* 26, no. 12 (2009): 2577-2585.
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 11. Chen, Tao, and Tom D. Milster. "Properties of induced polarization evanescent reflection with a solid immersion lens (SIL)." Optics Express 15, no. 3 (2007): 1191-1204.
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30. Milster, Tom D. "Physical optics simulation in Matlab for high-performance systems." *Optical review* 10 (2003): 246-250.
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2. Paxman, Richard G., Harrison H. Barrett, Warren E. Smith, and Thomas D. Milster. "Image reconstruction from coded data: II. Code design." JOSA A 2, no. 4 (1985): 501-509.

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

1. Milster, Thomas D., Lee C. Johnson, and Daniel Apai. "Multi-order diffractive Fresnel lens (MOD-DFL) and systems that incorporate the MOD-DFL." U.S. Patent 12,189,141, issued January 7, 2025.
2. 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.
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"Systems and methods for increasing data rate and storage density in multilayer optical discs."
U.S. Patent 11,456,010, issued September 27, 2022.

4. E. Finan, E. Bendek and T. Milster, "Active coating apparatus, methods and applications," USP 10,866,406 (2020).
5. 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).
6. B. Gelernt, T. D. Milster and T. Jota, "Interferometric systems and methods," USP 9,081,193 (2015).
7. T. D. Milster, K. R. Denninghoff, P. K. Khulbe, and J. Zhang, "In-vivo optical sensor," USP 9,072,473 (2015).
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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 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

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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

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3. Brar, Nick, Youngsik Kim, Zichan Wang, Allen Yi, Yuxin Cai, and Tom D. Milster, “Fabrication, Testing, and Correction of Molded MODE Lens Telescope,” in Optical Design and Testing, paper ThP-10, Optical Society of Japan, 2024.
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6. Milster, Tom D., Yuxin Shao, Zichan Wang, Youngsik Kim, Robert Lupiou and Jonathan Fan, "Modeling Non-Local Aberration Correction of Spaceplates," in Optical Design and Testing, paper ThP-41, Optical Society of Japan, 2024.
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Appendix B

```
%application_of_west_123124.m
% TDM

%parameters
fignum    = 25;
prism_angle = 60;           %angle in degrees;
prism_height = 0.5*tand(prism_angle)/tand(30); %height in mm
N_prisms   = 2;
refl_angle = 50;           %refl surf angle in degrees
refl_height = 2.25; %refl surf height in mm
% inc_angle = 41;          %incident ray elevation in degrees
inc_angle_vec = 77:-1:64;%35:40;
N_rays      = length(inc_angle_vec);
inc_xy      = [0 0];       %starting point of incident ray
nglass      = 1.5;         %index of refraction
nair        = 1;
axes_vec    = [0 10 0 7];  %limit of figure window in mm
pat_offset  = [2.5 5];     %xy offset to the start of the analysis region in mm
xlimit      = 6;          %cut off for pattern width in x
circ_center = [0 -3];
circ_rad    = sqrt((xlimit-circ_center(1))^2+(pat_offset(2)-circ_center(2))^2);
Nptscirc    = 100;        %number of points for drawing the spherical surface

%define symbolic variables
syms x y

%turn off warning about inconsistent solution
warning('off','symbolic:mldivide:InconsistentSystem');

%display prisms
figure(fignum)
clf
xbase    = prism_height/sind(prism_angle)*cosd(prism_angle);
ybase    = prism_height/sind(prism_angle)*sind(prism_angle);
offset_mata = [2*xbase*((1:N_prisms)-1).' zeros(N_prisms,1)]; %upward slope
offset_matb = [xbase*(2*(1:N_prisms)-1).' zeros(N_prisms,1)]; %downward slope
x_mata     = pat_offset(1) + offset_mata(:,1) + ones(N_prisms,1)*[0 xbase];
y_mata     = pat_offset(2) + offset_mata(:,2) + ones(N_prisms,1)*[0 ybase];
indx       = find(x_mata(:,1)> xlimit);
```

```
x_mata(indx,1) = xlimit*ones(1,length(indx));
y_mata(indx,1) = pat_offset(2)*ones(1,length(indx));
indx = find(x_mata(:,2)> xlimit);
x_mata(indx,2) = (xlimit+0.01)*ones(1,length(indx));
y_mata(indx,2) = pat_offset(2)*ones(1,length(indx));
x_matb = pat_offset(1) + offset_matb(:,1) + ones(N_prisms,1)*[0 xbase];
y_matb = pat_offset(2) + ones(N_prisms,1)*[ybase 0];
indx = find(x_matb(:,1)> xlimit);
x_matb(indx,1)= xlimit*ones(1,length(indx));
y_matb(indx,1) = pat_offset(2)*ones(1,length(indx));
indx = find(x_matb(:,2)> xlimit);
x_matb(indx,2) = (xlimit+0.01)*ones(1,length(indx));
y_matb(indx,2) = pat_offset(2)*ones(1,length(indx));
line(x_mata.', y_mata.','Color','g','LineWidth',3);
line(x_matb.', y_matb.','Color','g','LineWidth',3);
```

%plot reflective surface

```
xrefl = pat_offset(1) + [-refl_height/sind(refl_angle)*cosd(refl_angle) 0];
yrefl = pat_offset(2) + [-refl_height/sind(refl_angle)*sind(refl_angle) 0];
line(xrefl,yrefl,'Color','r','LineWidth',3);
axis(axes_vec)
grid on
```

%plot spherical surface

```
eqncirc = (x-circ_center(1)).^2 + (y-circ_center(2)).^2 == circ_rad^2;
S = solve(eqncirc,x);
y = 0;
x0_circ = double(subs(S));
x0_circ = x0_circ(2);
theta_min = atan(-circ_center(2)/x0_circ)*180/pi;
theta_max = atan((pat_offset(2)-circ_center(2))/xlimit)*180/pi;
theta_vec = linspace(theta_min,theta_max,Nptscirc);
xcirc = circ_rad*cosd(theta_vec) + circ_center(1);
ycirc = circ_rad*sind(theta_vec) + circ_center(2);
hold on
plot(xcirc,ycirc,'Color',[0.3010 0.7450 0.9330],'LineWidth',3);
hold off
syms x y
```

%make combined x and y endpoint matrices of reflective surface and prisms

```
x_mat = zeros(2*N_prisms+1,2);
y_mat = x_mat;
x_mat(1,:) = xrefl;
y_mat(1,:) = yrefl;
indxa = find([0 repmat([1 0],[1 N_prisms])]==1);
indxb = find([0 repmat([0 1],[1 N_prisms])]==1);
x_mat(indxb,:) = x_matb;
x_mat(indxa,:) = x_mata;
y_mat(indxb,:) = y_matb;
y_mat(indxa,:) = y_mata;
```

%generate surface equation cell matrix

```
surf_eqn_mat = cell(2*N_prisms+2,1);
for ii = 1:(2*N_prisms+1)
    eval(['surfeqn' num2str(ii) ' = y - diff(y_mat(' num2str(ii) ',:))/diff(x_mat('
num2str(ii) ',:))*(x-x_mat(' num2str(ii) ',1)) == y_mat(' num2str(ii) ',1);' ]);
    eval(['surf_eqn_mat(' num2str(ii) ') = {surfeqn' num2str(ii) '};']);
end
surf_eqn_mat(2*N_prisms+2) = {eqncirc}; %for sphere
```

%generate surface type vector

```
% 1 = reflective
% 2 = refractive
% 3 = sphere
surf_type_vec = [1 2*ones(1,2*N_prisms) 3];
```

%Generate normal surface k vector matrix

```
surf_knorm_mat = zeros(2*N_prisms+2,2);
for ii = 1:(2*N_prisms+1)
    surf_knorm_mat(ii,:) = [sin(atan(diff(y_mat(ii,))/diff(x_mat(ii,)))) -
cos(atan(diff(y_mat(ii,))/diff(x_mat(ii,))))];
end
surf_knorm_mat(2*N_prisms+2,:) = circ_center; %for sphere. temporary value is
circ center, which is used to find intercept of ray and circle. This vector is
calculated later
```

%Generate ray equation cell matrix

```
ray_eqn_mat = cell(N_rays,1);
```

```

for ii = 1:N_rays
    eval(['rayeqn' num2str(ii) ' = y - tand(inc_angle_vec(' num2str(ii) '))*x == 0;']);
    eval(['ray_eqn_mat(' num2str(ii) ' ) = {rayeqn' num2str(ii) '};']);
end

%Generate ray k vector matrix
ray_k_mat = zeros(N_rays,2);
for ii = 1:N_rays
    ray_k_mat(ii,:) = [cosd(inc_angle_vec(ii)) sind(inc_angle_vec(ii))];
end

%Generate ray medium vector (ray is propagating in this refractive index)
ray_medium_vec = nglass*ones(1,N_rays);

%find ray paths
for jj = 1:N_rays
    disp(['Working on ray ' num2str(jj) ' out of ' num2str(N_rays)])
    ray_path_mat =
find_ray_path(jj,nglass,nair,surf_eqn_mat,surf_type_vec,surf_knorm_mat,ray_eqn
_mat,ray_k_mat,ray_medium_vec,x_mat,y_mat,axes_vec,xlimit);
end

% reverse plot
set(gca,'xdir','reverse')
axis(axes_vec)
% axis equal
%*****

function ray_path_mat =
find_ray_path(jj,nglass,nair,surf_eqn_mat,surf_type_vec,surf_knorm_mat,ray_eqn
_mat,ray_k_mat,ray_medium_vec,x_mat,y_mat,axes_vec,xlimit)
syms x y
N_rays      = length(ray_eqn_mat);
N_surfs     = length(surf_eqn_mat);
ray_path_mat = [0; 0];
Xstart      = [0 0];
count       = 1; %surface count
while (count <= N_surfs) %work through surfaces to find intersection
    %check intersction of surface at 'count' and ray(jj)

```

```
[intersection_flag, X] =  
find_intersection(jj,ray_eqn_mat{jj},surf_eqn_mat,surf_type_vec,surf_knorm_mat  
,x_mat,y_mat,count,xlimit);  
    if intersection_flag  
        if size(ray_path_mat,2) == 1  
            Xstart = [0,0];  
        end  
        line([Xstart(1) X(1)],[Xstart(2) X(2)],'Color',[0.4940 0.1840  
0.5560],'LineWidth',1)  
        Xstart = X;  
        [ray_eqn_mat, ray_k_mat,ray_medium_vec] =  
get_new_ray(jj,nglass,nair,surf_eqn_mat,surf_knorm_mat,ray_eqn_mat,ray_k_mat  
,ray_medium_vec,surf_type_vec,count,X);  
        ray_path_mat = [ray_path_mat X(:)];  
    end  
    count = count + 1;  
end  
%plot final ray  
S = solve(ray_eqn_mat{jj},y);  
if ray_k_mat(jj,1) < 0 && ray_k_mat(jj,2) < 0  
    x = 0;  
else  
    x = axes_vec(2);  
end  
Xend = [axes_vec(2) double(subs(S))];  
% disp(['jj = ' num2str(jj) ' count = ' num2str(count)])  
line(real([Xstart(1) Xend(1)]),real([Xstart(2) Xend(2)]),'Color',[0.4940 0.1840  
0.5560],'LineWidth',1)  
  
end  
  
%*****  
  
function [ray_eqn_mat, ray_k_mat, ray_medium_vec] =  
get_new_ray(jj,nglass,nair,surf_eqn_mat,surf_knorm_mat,ray_eqn_mat,ray_k_mat  
,ray_medium_vec,surf_type_vec,count,X)  
    %replaces ray info with new ray  
    plot_normal_flag = 0;  
    normal_length = 0.25;
```

```
syms x y
%calculate angle of incidence
if surf_type_vec(count) == 3 %spherical surf
    %calculate normal to spherical surface at intercept
    %describe vector from intercept to circle center and normalize
    surf_knorm_mat(count,:) = [(surf_knorm_mat(count,1)-X(1))
(surf_knorm_mat(count,2)-X(2))];
    surf_knorm_mat(count,:) =
surf_knorm_mat(count,:)/norm(surf_knorm_mat(count,:));
end
angle_of_inc = real(180-
acos(dot(surf_knorm_mat(count,:),ray_k_mat(jj,:)))*180/pi);
if angle_of_inc > 90
    surf_knorm_mat(count,:) = [-1 0; 0 -1]*surf_knorm_mat(count,:).';
    angle_of_inc = real(180-
acos(dot(surf_knorm_mat(count,:),ray_k_mat(jj,:)))*180/pi);
end
if plot_normal_flag
    line([X(1) (X(1)+normal_length*surf_knorm_mat(count,1))],[X(2)
(X(2)+normal_length*surf_knorm_mat(count,2))],'Color','k')
end
if surf_type_vec(count) == 1
    angle_new = angle_of_inc;
    ray_medium_vec(jj) = ray_medium_vec(jj);
    k_temp = surf_knorm_mat(count,:);
    %calculate rotation matrix based on surface normal
    R_mat = [cosd(angle_new) -sind(angle_new);sind(angle_new)
cosd(angle_new)];
    %calculate new ray k vector based on rotation
    k_new = R_mat*k_temp.';
else
    if ray_medium_vec(jj) == nglass
        n1 = nglass;
        n2 = nair;
    else
        n1 = nair;
        n2 = nglass;
    end
    angle_new = asin(n1/n2*sind(angle_of_inc))*180/pi;
```

```

    if ~isreal(angle_new)
        angle_new = angle_of_inc; %TIR condition
        ray_medium_vec(jj) = ray_medium_vec(jj);
        k_temp = surf_knorm_mat(count,:);
        %calculate rotation matrix based on surface normal
        R_mat = [cosd(angle_new) -sind(angle_new);sind(angle_new)
cosd(angle_new)];
        %calculate new ray k vector based on rotation
        k_new = R_mat*k_temp.';
    else
        % angle_new = angle_new; %for transmitted ray
        if ray_medium_vec(jj) == nglass
            ray_medium_vec(jj) = nair;
        else
            ray_medium_vec(jj) = nglass;
        end
        dotnk = dot(surf_knorm_mat(count,:),ray_k_mat(jj,:));
        k_new = n1/n2*ray_k_mat(jj,:) - n1/n2*(sqrt((n2/n1)^2 - 1 + dotnk^2)
+ dotnk)*surf_knorm_mat(count,:);
        % disp(['count = ' num2str(count) ' new k = ' num2str(k_new)])
    end
end

ray_k_mat(jj,:) = k_new;
ray_slope = k_new(2)/k_new(1);
ray_eqn = y - ray_slope*(x - X(1)) == X(2);
ray_eqn_mat(jj,1) = {ray_eqn};
end

%*****

function [intersection_flag, X] =
find_intersection(jj,ray_eqn,surf_eqn_mat,surf_type_vec,surf_knorm_mat,x_mat,y
_mat,count,xlimit)
syms x y
if (surf_type_vec(count) == 1) || (surf_type_vec(count) == 2)
    [Awork,Bwork] = equationsToMatrix([ray_eqn,surf_eqn_mat{count}],[x
y]);
    Xwork = real(double(linsolve(Awork,Bwork)));

```

```
if Xwork(1) >= min(x_mat(count,:)) && Xwork(1) <=
max(x_mat(count,:)) && Xwork(2) >= min(y_mat(count,:)) && Xwork(2) <=
max(y_mat(count,:)) && Xwork(1) < xlimit
    X = Xwork;
    intersection_flag = 1;
else
    X = [];
    intersection_flag = 0;
end
else
    % disp(['Intersection with circle at jj = ' num2str(jj)])
    circ_center = surf_knorm_mat(count,:);
    S = solve(surf_eqn_mat{count},y);
    x = 0;
    circ_y_intercept = double(subs(S));
    circ_y_intercept = circ_y_intercept(1);
    syms x y
    S = solve(surf_eqn_mat{count},x);
    y = 0;
    circ_x_intercept = double(subs(S));
    circ_x_intercept = circ_x_intercept(2);
    syms x y
    circ_rad = circ_y_intercept - circ_center(2);
    S = solve(ray_eqn,y);
    x = 0;
    line_y_intercept = double(subs(S));
    syms x y
    S = solve(ray_eqn,x);
    y = 0;
    line_x_intercept = double(subs(S));
    if line_y_intercept == 0 && line_x_intercept == 0
        syms x y
        S = solve(ray_eqn,y);
        x = 1;
        line_slope = double(subs(S));
    else
        line_slope = -line_y_intercept/line_x_intercept;
    end
    [xout, yout] =
```

```
linecirc(line_slope,line_y_intercept,circ_center(1),circ_center(2),circ_rad);
    if xout(1) >= xlimit && xout(1) <= circ_x_intercept && yout(1) >= 0 &&
yout(1) <= y_mat(1,2)
        X          = [xout(1) yout(1)];
        intersection_flag = 1;
    elseif xout(2) >= xlimit && xout(2) <= circ_x_intercept && yout(2) >= 0
&& yout(2) <= y_mat(1,2)
        X          = [xout(2) yout(2)];
        intersection_flag = 1;
    else
        X = [];
        intersection_flag = 0;
    end
end
end
```