

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

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 IPR2025-00331
U.S. Patent No. 7,618,162

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

CLAIMS 1, 4-6, 8, 9, 31, 39, and 43

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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, “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, “Practical measurement of cell-phone camera lens focal length,” Optical System Alignment, Tolerancing, and Verification XIII, vol. 11488, pp. 39-48. SPIE, 2020.

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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.

6. I am a named inventor in 17 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.

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9. I have been asked to provide my opinion whether the claims of the U.S. Patent No. 7,618,162 (the “’162 patent”) are valid.

10. I understand that the ’162 Patent was filed on November 9, 2005 as U.S. Patent Application No. 11/271,420, claiming priority to U.S. Provisional Patent application No. 60/627,287.

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. 7,618,162 (’162 Patent)
1003	File History of U.S. Patent No. 7,618,162
1004	U.S. Patent No. 6,356,395 (“Tawa”)
1005	U.S. Patent No. 5,384,659 (“Shikama”)
1006	U.S. Patent No. 6,105,869 (“Scharf”)
1007	Robert D. Guenther, “Modern Optics,” John Wiley & Sons, Inc. (1990)
1008	The Royal Swedish Academy of Sciences. “The Nobel Prize in Physics 2014: Press Release.” October 7, 2014. https://www.nobelprize.org
1009	Parkyn, William A. and David G. Pelka. “Uniformly illuminating dual-lens system for LED collimation.” SPIE Optics + Photonics (2001)
1010	U.S. Patent No. 3,470,561
1011	U.S. Patent No. 3,754,814
1012	U.S. Patent No. 4,655,539
1013	U.S. Patent No. 5,339,177

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Exhibit No.	DESCRIPTION
1014	U.S. Patent No. 5,600,487 (“Kiyomoto”)
1015	U.S. Patent No. 5,607,492
1016	U.S. Patent No. 5,924,788 (“Parkyn”)
1017	U.S. Patent No. 6,433,936
1018	U.S. Patent Publication No. 2004/0228131 (“Minano”)
1019	U.S. Patent Publication No. 2007/0109615
1023	U.S. Patent No. 4,864,216
1024	Love, Clyde, <i>Differential and Integral Calculus</i> (sixth ed.). New York, MacMillan. (1916)
1025	Kingslake, R., & Johnson, R. B, “Lens Design Fundamentals,” Academic Press, (2009)
1026	LinkedIn page of William (“Bill”) A. Parkyn
1027	“InteLED Corp promotes Caterina Hall to CEO” at https://www.ledsmagazine.com/company-newsfeed/article/16682414/inteled-corp-promotes-caterina-hall-to-ceo
1028	RocketReach page of David Pelka

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 '162 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 '162 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 '162 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.

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 alleged invention and whether the inventor limited the alleged 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 claims 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.

III. Summary of Opinions

29. For the reasons explained below, I conclude that claims 1, 4-6, 8, 9, 31, 39, and 43 of the '162 Patent are anticipated and/or rendered obvious by the prior art.

Grounds	Claims	Statutory Ground	Prior Art Reference(s)
I	1, 4-6, 8, 31, 39, and 43	35 U.S.C. §103	Tawa in view of Shikama
II	1, 4-6, 8, 31, 39, and 43	35 U.S.C. §102	Tawa
III	1, 4-6, 8, 31, 39, and 43	35 U.S.C. §103	Tawa
IV	9	35 U.S.C. §103	Tawa in view of Shikama and Scharf

Grounds	Claims	Statutory Ground	Prior Art Reference(s)
V	9	35 U.S.C. §103	Tawa in view of Scharf

IV. Technology Background

A. General Overview of Technology

30. The development of blue light-emitting diodes (LEDs) in the early 1990s led to the development of the modern-day LED lighting industry. This breakthrough was so impactful that the inventors were later awarded a Nobel Prize in Physics. EX1008. These blue LEDs typically emit a beam of light that has a Gaussian distribution in which the intensity is concentrated mostly near the center of the beam but falls off away from the center. *See* EX1023, 2:55-58 (“The light output from the LEDs on a large number of LED dice tends to have a more or less Gaussian distribution around a desired light output.”)

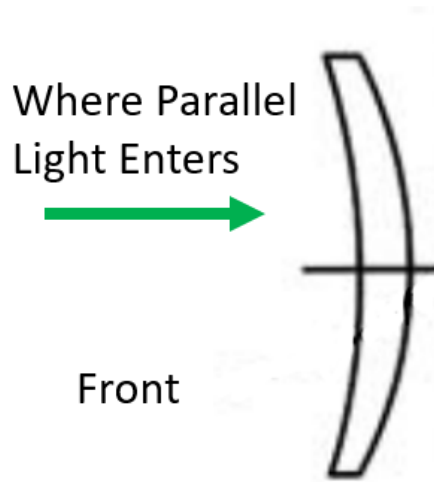
31. Often, the intensity of light is determined using a variable called “flux density.” Unfortunately, different branches of optics utilize different terms to describe the same flux density. For example, some optical engineers utilize the term “irradiance,” which refers to the power of electromagnetic radiation per unit area, and is measured in units of watts per square meter (W/m^2). In other branches of optics, the term “illuminance” is used, which describes the perceived brightness

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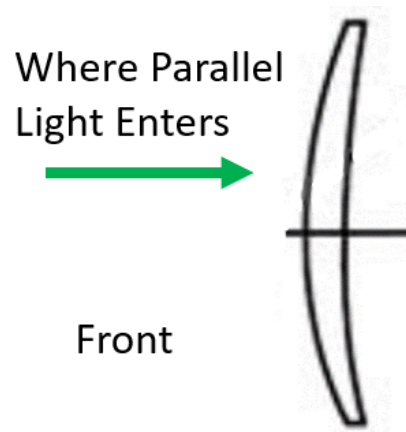
of light on a surface and is measured in units of lumens per square meter (lm/m^2).

EX1007, 34.

32. Lenses are often utilized in conjunction with LEDs to control the distribution of light that illuminates a given surface. For example, in many lighting applications, uniformly illuminating a region is desirable. EX1009, p. 237. Many different lenses exist that can bend the light in a desired manner. The terms “convex” and “concave” are often utilized in lens design to refer the surface shape with respect to a reference direction. For example, in the classic lens design reference “Lens Design Fundamentals” [Kingslake, R., & Johnson, R. B., Academic Press (2009) (EX1025)], the authors refer to the meniscus shape of the landscape lens in the figure below [Fig. 12.2a, edited] as “concave to the front where parallel light enters” for both surfaces.



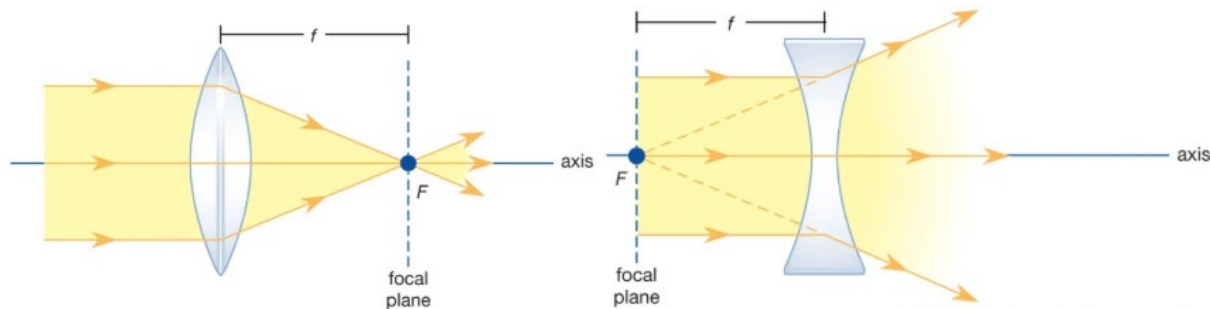
33. Conversely, the landscape lens shown in figure below [Fig 12.2d, edited] is referred to as having a “convex side to the front.”



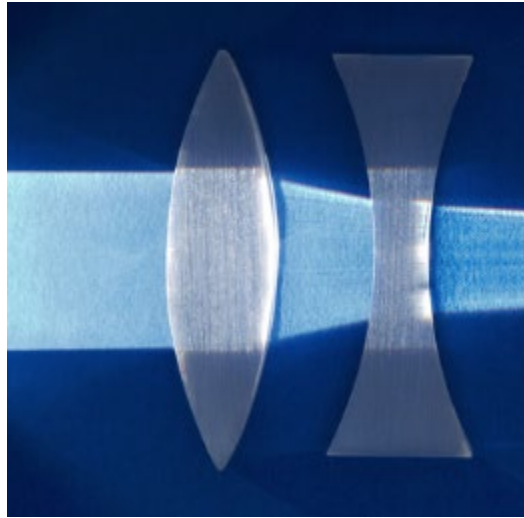
34. Even though the two lenses above look nearly identical if they are turned in the same direction, the impact of how well the lens works depends

significantly on the orientation of convex and concave surfaces with respect to a particular direction.

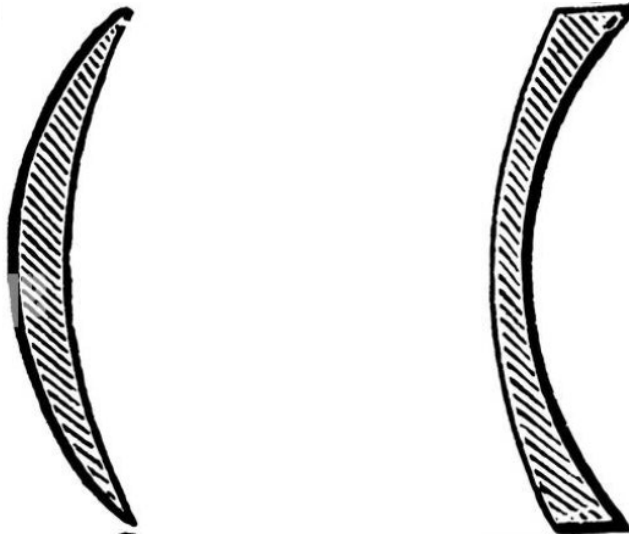
35. These concave and convex surfaces can be shaped as desired to achieve a desired performance. For example, a double-convex lens, which has two outwardly curved surfaces, can be utilized to focus light rays so that the light converges toward a point, as shown in the diagram below (left). In contrast, a double-concave lens, which has two surfaces that curve inward, can be utilized to spread out the light rays, causing them to diverge from a central axis (*see* the diagram below on the right).



36. These and other lenses can be combined in different ways to achieve desired light output characteristics. For example, double-convex and double-concave lenses can be assembled in sequence, such as shown below.



37. In some cases, these combinations of lens shapes can be integrated into a single lens design. For instance, the two exemplary lenses shown below can either converge light or diverge light, depending on the relative radii of curvature of the first and second surfaces from the direction where parallel light enters from the left. Both lenses are convex-concave lenses because they have convex-to-the-front first surfaces and concave-to-the-back second surfaces. However, the lens on the left can converge parallel light, and the lens on the right can diverge parallel light.



38. Designing different lens shapes required simple knowledge of distribution of light incident on the lens surface, some simple material properties and how light bends as it passes these different materials, and the desired characteristics of the light that gets output by the lens. These modifications and design of desired lens shapes were well-known and routinely carried out by optical engineers long before the priority date of the '162 Patent.

V. Overview of the '162 Patent

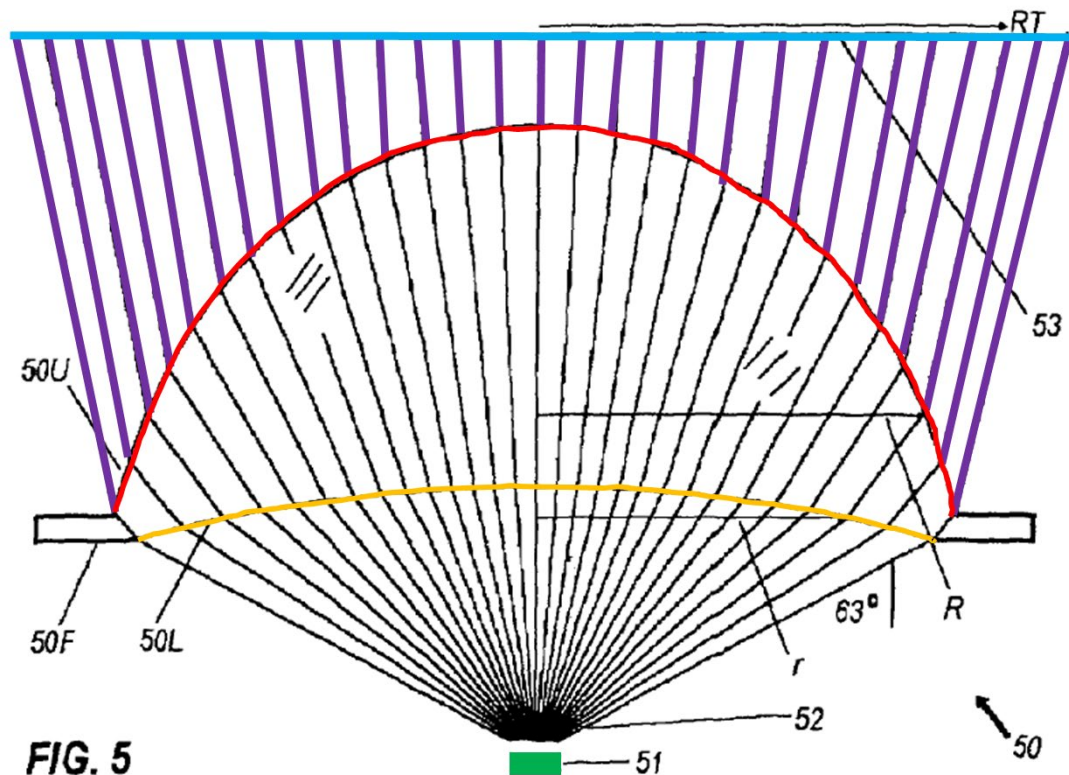
A. Summary of the '162 Patent

39. The '162 Patent describes a lens designed to evenly distribute light across a surface when used with a small light source, such as an LED, that normally outputs nonuniform distribution of light. *See* EX1001, 1:52-54 (“The

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present invention relates generally to illumination lenses, especially for LEDs, that produce uniform output-irradiance from highly nonuniform inputs.”).

40. As depicted in Figure 5 of the '162 Patent, the lens includes an “**entry surface**” (50L) and an “**exit surface**” (50U). The **entry surface** receives the **light emitted** from the **light emitting diode (LED)**, and the **exit surface** allows the light to leave the lens. *See* EX1001, 3:60-64 (“Figure 5 shows a preferred embodiment in profile 50 of a 35mm-diameter circularly symmetric illumination-redistribution lens formed of polycarbonate and comprising concave lower surface 50L, upper exit-surface 50U, and optically inactive flange 50F.”).

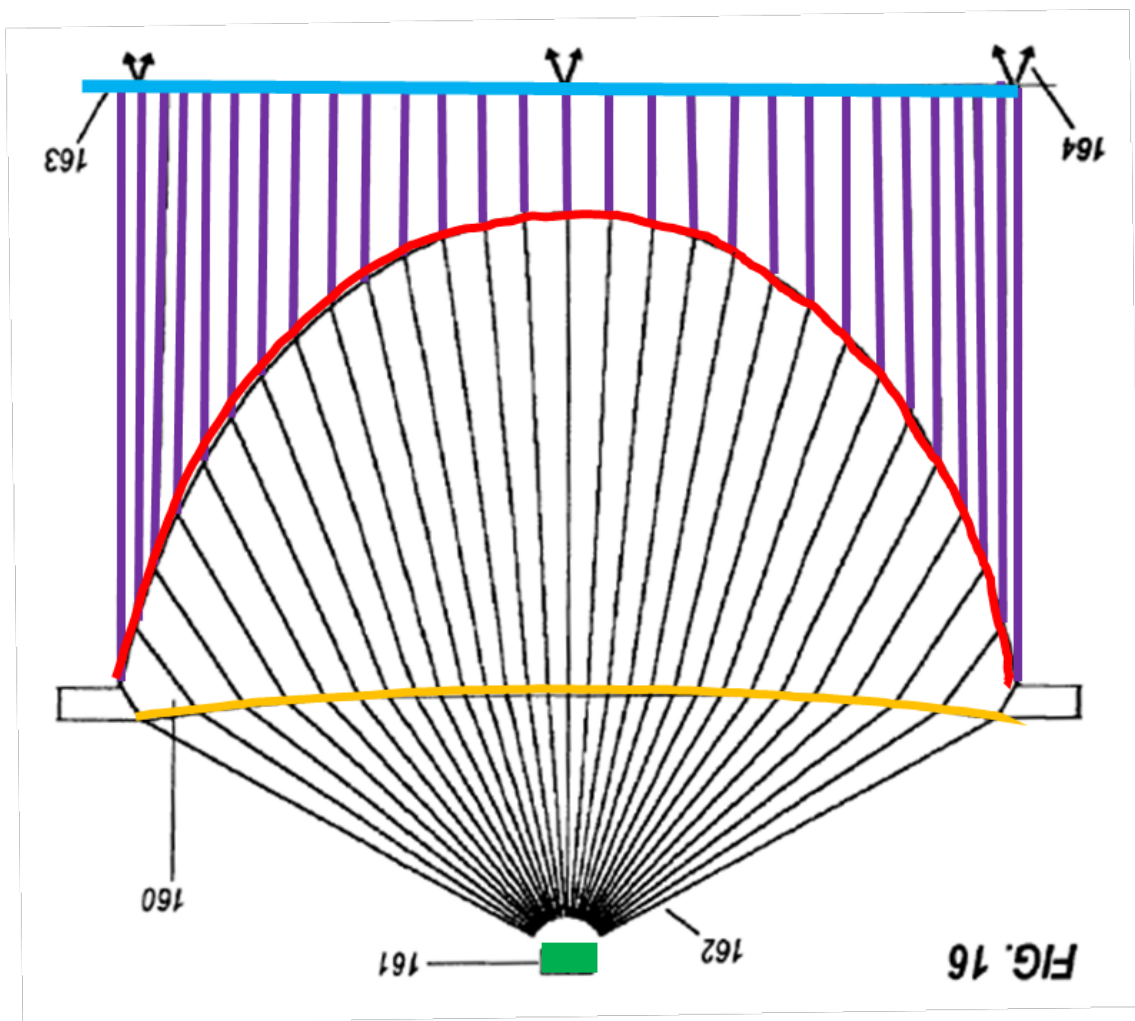


EX1001, Figure 5.

41. According to the '162 Patent, the **lower surface (50L)** refracts the incoming light from **LED 51** such that the light has a uniform distribution by the time it reaches the **upper surface (50U)**. See EX1001, 1:60-65. The **rays emerging** from the **upper surface (50U)** are then “refractively deflected therefrom toward radius RT on **target surface 53**” to produce a “uniform illuminance” on the **target surface 53**. EX1001, 4:4-10.

42. The '162 Patent explains that “[o]ne preferred embodiment of this new lens produces a very tightly collimated beam with uniform irradiance.”

EX1001, 1:66-2:3. For example, this is shown in Figure 16, which “shows a collimating irradiance-redistribution lens.” EX1001, 2:43-44.



EX1001, Figure 16.

B. Summary of the Prosecution History of the '162 Patent

43. The application for the '162 Patent was filed on November 9, 2005. EX1001, Cover. The application that was issued as the '162 Patent claims priority to U.S. Provisional Application No. 60/627,287, which was filed on November 12, 2004. EX1001, Cover.

44. The Examiner issued a restriction requirement, and Applicant elected claims 1-13 for prosecution. EX1003, 78-98. Subsequently, claims 1-13 were rejected in a Non-final Office Action under 35 U.S.C §112 as being indefinite and under 35 U.S.C §103 as being obvious over the following references:

- U.S. Patent No. 5,607,492 (“Doric”) and U.S. Patent No. 6,433,936 (“Carpenter”) (claims 1-3, 8);
- Doric, Carpenter and U.S. Patent No. 3,754,814 (“Leith”) (claims 4-7);
- Doric, Carpenter and U.S. Patent Application Publication No. 2007/0109615 (“Wunderer”); and
- U.S. Patent No. 4,655,539 (“Caufield”) (claims 11-13).

EX1003, 108-109.

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45. The applicant submitted claim amendments and arguments to overcome the rejections and added new claims 39 and 40. EX1003, 122-138.

46. In a Final Office Action, the Examiner objected to claims 1, 4, 8, and 39. EX1003, 144-145. Furthermore, the Examiner rejected claims 1, 4-6, 8, 11-13 and 39 under 35 U.S.C §112 as being indefinite. EX1003, 145.

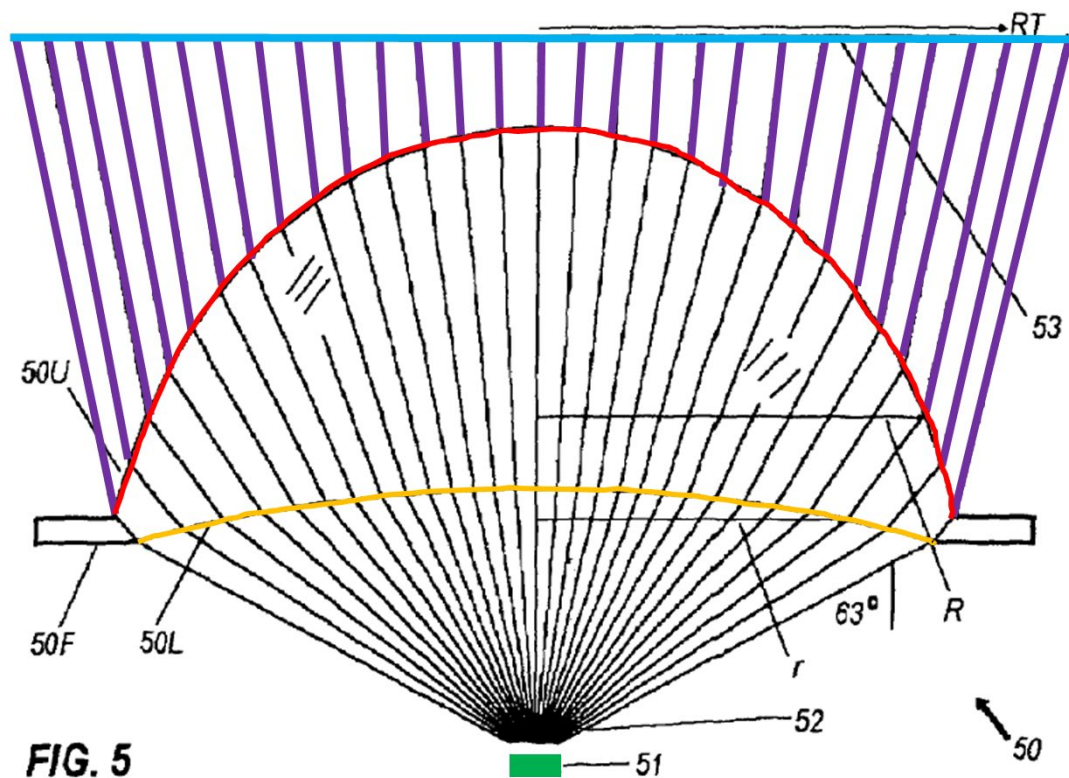
47. Additionally, the Examiner rejected claims 1, 4-6, 8, 11-13 and 39 under 35 U.S.C §102 over U.S. 2004/0228131 (“Minano”). EX1003, 146-147. The Examiner also rejected claims 2, 3, 7, 10, and 40 under 35 U.S.C §103 over Minano and U.S. 5,924,788 (“Parkyn”) (claims 2, 3), Minano alone (claims 7, 10) and Minano in view of U.S. 5,600,487 (“Kiyomoto”) (claim 40). EX1003, 148-151.

48. In Response, the Applicant amended independent claims 1 and 39 to recite:

said **entry surface** having first concavity facing toward said **light source**, and second concavity facing toward the **entry surface**, said second concavity being substantially greater than said first concavity.

EX1003, 169-170, 181-182.

49. The Applicant also explained that “the **entry** and **exit** concave surfaces are ... **50L** and **50U** in Fig. 5, the **light source being at 51.**” EX1003, 187.



EX1001, Figure 5, EX1003, 37.

50. The Examiner issued a Notice of Allowance on July 16, 2009.
EX1003, 267-273.

51. The '162 Patent issued on November 17, 2009. EX1003, 280, EX1001, Cover.

VI. Level of Ordinary Skill in the Art

52. 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.

53. I considered the factors I noted in the Paragraphs 17-18. I have looked at the education level of the named inventors, and was able to find what appears to be the biography of one of the named inventors – William Parkyn – who according to LinkedIn had (as of 2004) at least a bachelor of science degree coupled with at least several years in the field of optics. EX1026. I have not found anything more concrete on the other named inventor David Pelka, (other than that he appears to have been the Chairman and Chief Innovation Officer of InteLED in 2011). EX1027. One webpage suggests he may have received a doctor of philosophy from University of California, Riverside in 1971. *See* EX1028. Assuming these biographies are accurate, and based on my experience and understanding, the named inventors somewhat exceeded the skill of the people typically working in the areas of lens design around 2004, who usually had some higher-level education (e.g., bachelor of science) in a discipline, such as engineering or physics or some

related field. Often, these 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 '162 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 any groundbreaking inventions by 2004. Certainly, Nobel Prizes were not being awarded for coming up with desired lens designs that met desired performance characteristics.

54. Accordingly, based on my analysis, a POSITA as of the earliest claimed priority date of the '162 Patent (i.e., November 12, 2004) would have at least 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 calculate lens shapes applying the well-known principles of how light rays reflect and refract off different material surfaces as enter and exit the lens surfaces. I note that a higher

level of education or specific skills in the industry may make up for less experience and vice versa.

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

VII. Overview of the Primary Prior Art References

A. Overview of Tawa

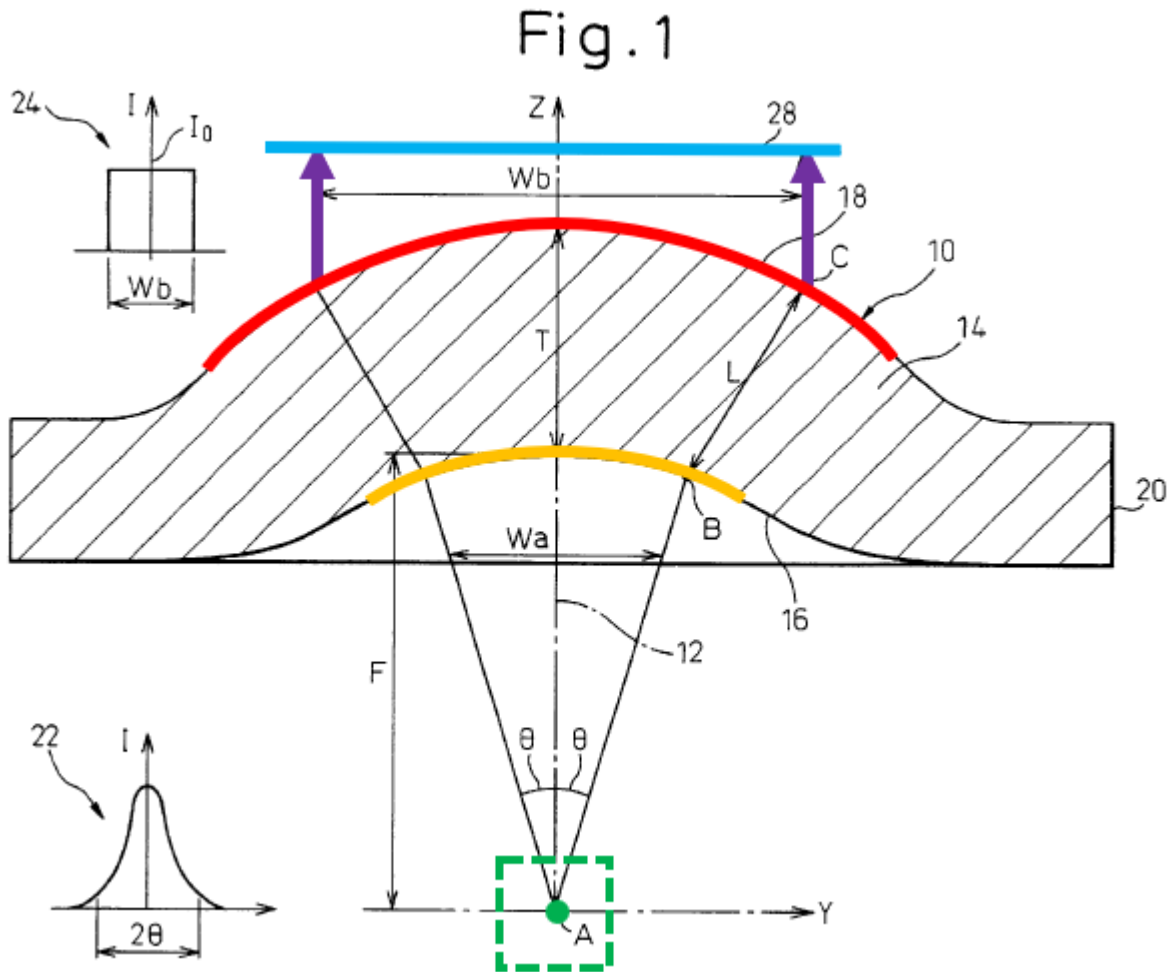
56. Tawa is a U.S. Patent issued on March 12, 2002. EX1004, Cover. I have been informed that Tawa is prior art to the '162 Patent.

57. Tawa describes a “light intensity distribution converting device” designed to modify the intensity distribution of light emitted from a source. EX1004, Abstract. This device can function as a collimator lens. EX1004, 7:6-14 (“The light intensity distribution converting device 10 of the present invention can convert a given light intensity distribution into an optional continuous light intensity distribution ... Also, if the device 10 has a lens function, it can be used as a collimator lens.”). Moreover, Tawa states that “emerging light having a uniform intensity distribution can be obtained from incident light having a Gaussian intensity distribution.” EX1004, 2:41-44 (“Using this light intensity distribution

converting device, emerging light having a uniform intensity distribution can be obtained from incident light having a Gaussian intensity distribution.”).

58. As illustrated in Figure 1 of Tawa, the device includes a “**first curved surface**” (16) that receives light emitted from a **light source at point A** having a non-uniform Gaussian intensity distribution 22, and a “**second curved surface**” (18) through which the light exits with a uniform light intensity distribution 24. *See* EX1004, 3:66-4:2 (“In FIGS. 1 and 2, **point A** represents a radiation point, point B represents an incident point of light onto the **first curved surface 16**, and point C represents a light emerging on the **second curved surface 18**.”), 4:35-38 (“In the embodiment, diverging light having a Gaussian light intensity distribution 22 is made incident to the body 14 at the **first curved surface 16**, and passes through the body 14.”), 4:38-41 (“The **light emerges** the body 14 from the **second curved surface 18** as parallel light having a uniform light intensity distribution 24.”).

Tawa notes that the light source at **point A** can be a laser or a **light-emitting diode (LED)**. *See* EX1004, 4:9-12 (“**Point A** can be, for example, a laser, which radiates diverging light having Gaussian light intensity distribution 22 which is in rotation-symmetry with respect to the Z-axis.”), 10:33-37 (“[T]his lighting apparatus can be used when an **LED array** or the like is used for a lighting device...”).



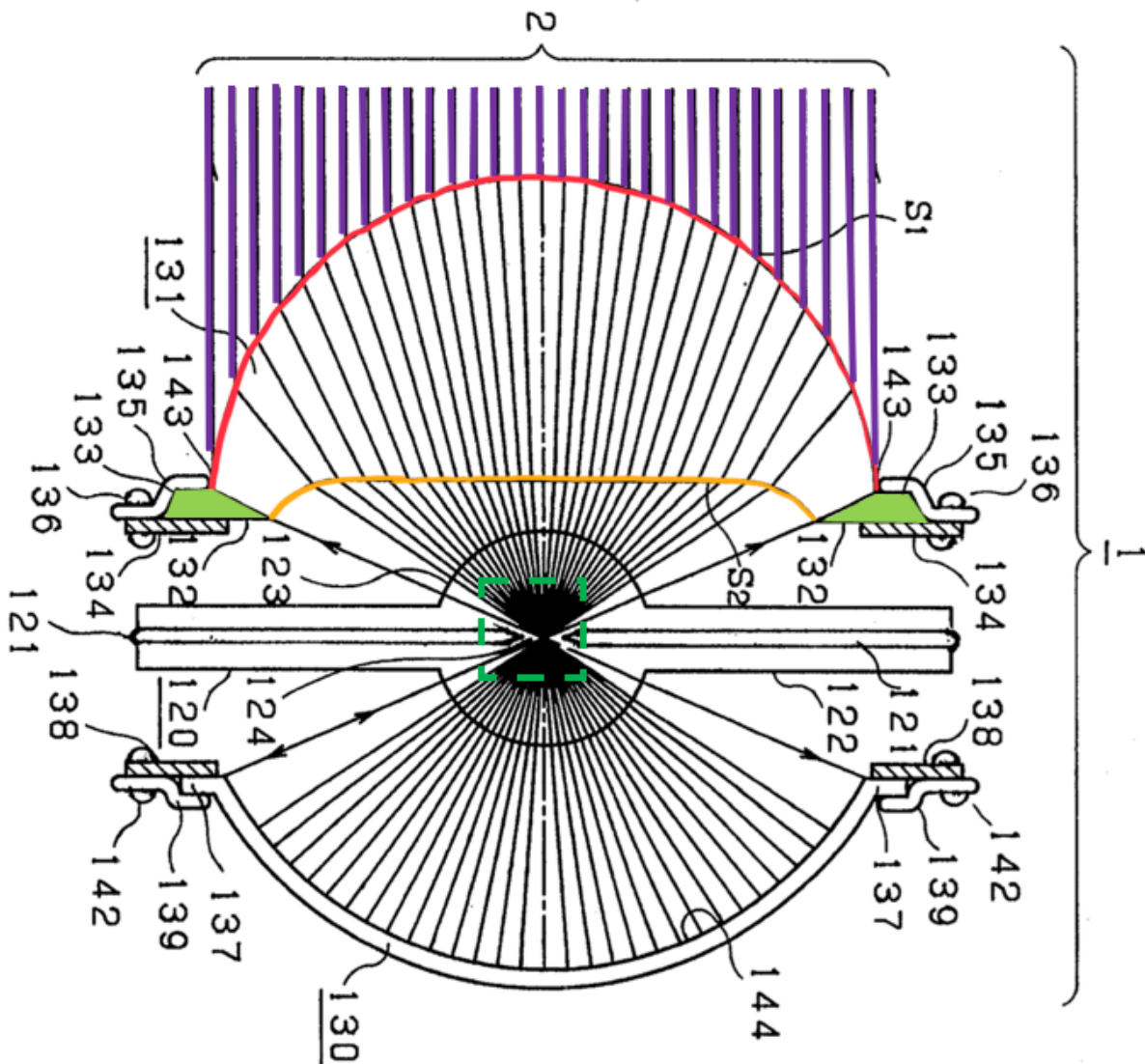
EX1004, Figure 1.

B. Overview of Shikama

59. Shikama is a U.S. Patent issued on January 24, 1995. EX1005, cover.

I have been informed that Shikama is prior art to the '162 Patent.

60. Shikama describes a “condenser lens” designed to manipulate light emitted from a source. EX1005, Title. The condenser lens, labeled as element 143 in Figure 13, has a **first surface (S1)**, a **second surface (S2)**, and a **flange (133)** that forms part of its structural design. These components are described in detail as follows: “FIG. 13 shows the construction of a light source apparatus according to Example 1 of Embodiment 2, wherein the reference numeral 131 is a condenser lens, 143 is a first plane face formed around the periphery of the effective diameter of the **first surface S1** of the condenser lens 131, 132 is a second plane face formed around the periphery of the **second surface S2** of the condenser lens 131, and **133 is a flange** consisting of the first and second plane faces 143 and 132 on both sides and formed integrally with the condenser lens 131.” EX1005, 14:58-68.



EX1005, Figure 13.

61. Shikama further explains that “[t]he **first surface S1** is of aspherical form having a convex curvature, while the **second surface S2** is also of aspherical form having a strongly concave curvature on the outermost circular zone thereof.”

EX1005, 10:62-65. Further, Shikama notes that “in the case of the **first surface S1**, the angle of incidence tends to increase toward its periphery.” EX1005, 17:3-4.

62. “[T]he beam of light ... is passed through the condenser lens 131 and emerges as a **parallel beam of light 2**.” EX1005, 15:42-45.

VIII. Claim Construction

63. 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 interpreted by applying the ordinary and customary meaning as understood by a POSITA as of November 2004.

64. I will note, however, that there may be some ambiguities associated with certain claim terms, such as “diverging” recited in [1c] and “said entry surface having first concavity facing toward said light source, and a second concavity facing toward the entry surface, said second concavity being substantially greater than said first concavity” recited in [1h]-[1j]. I have applied the possible different interpretations associated with those terms, as more fully explained below in the different Grounds below.

IX. Specific Grounds

65. As I explained in Paragraph 29, I conclude that claims 1, 4-6, 8, 9, 31, 39, and 43 of the '162 Patent are anticipated and/or rendered obvious by the prior art. In the sections below, I explain in detail how claims 1, 4-6, 8, 9, 31, 39, and 43 of the '162 Patent are not patentable over prior art.

A. Ground I: Tawa In Combination With Shikama Renders Obvious Claims 1, 4-6, 8, 9, 31, 39, And 43.

66. In my opinion, claims 1, 4-6, 8, 9, 31, 39, and 43 are all rendered obvious by the combination of Tawa and Shikama.

1. Independent Claim 1

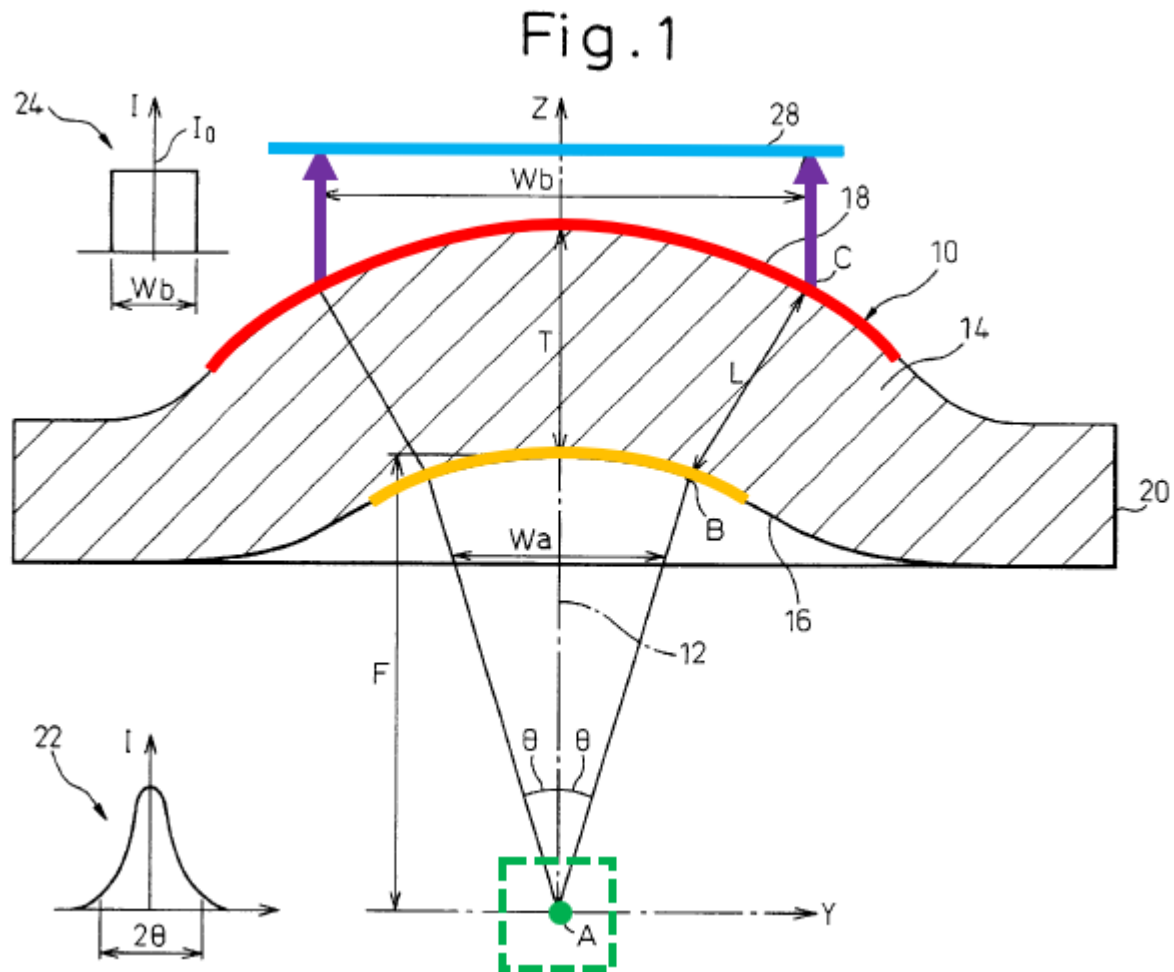
i. [1pre] An irradiance-redistribution illumination lens comprising:

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

68. Tawa discloses a “**lens**.” For instance, Tawa explains that the device shown in Figure 1 “serves as a collimator **lens**.” EX1004, 4:48-50; *see also* EX1004, 3:55-58 (“In FIGS. 1 and 2, the light intensity distribution converting device 10 comprises a transparent body 14 having a central axis 12. The body 14 is

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made of a transparent material, such as glass, having an isotropic refractive index.”).



EX1004, Figure 1.

69. Tawa further describes how the lens receives light from a **point light source located at point A**, redistributes the light using the **curved surface 16**

toward the **curved surface 18**. This configuration ensures that the light beams emitted toward the target surface (28) have a uniform light intensity distribution (24), resulting in uniform illumination. *See* EX1004, 3:66-4:2 (“In FIGS. 1 and 2, **point A represents a radiation point**, point B represents an incident point of light onto the **first curved surface 16**, and point C represents a light emerging point on the **second curved surface 18**.”), 4:20-22 (“The **first curved surface 16** is defined by a generally shallow rounded concave surface and the **second curved surface 18** is defined by a generally rounded convex surface.”).

70. The **light emerging** from the **second curved surface 18** travels as parallel rays, forming a beam with uniform intensity that reaches the target **surface 28**. EX1004, 4:38-40 (“The light emerges the body 14 from the **second curved surface 18** as parallel light having a uniform light intensity distribution 24.”).

Tawa explains that the inclination of the **second curved surface 18** is determined to ensure that light emerging from point C propagates parallel to the Z-axis. This precise optical alignment is achieved by ensuring identical optical path lengths for rays from the radiation point (A) to a plane perpendicular to the Z-axis located beyond point C. *See* EX1004, 4:41-47 (“The inclination of the **second curved surface 18** is determined such that the light emerging the body from the point C

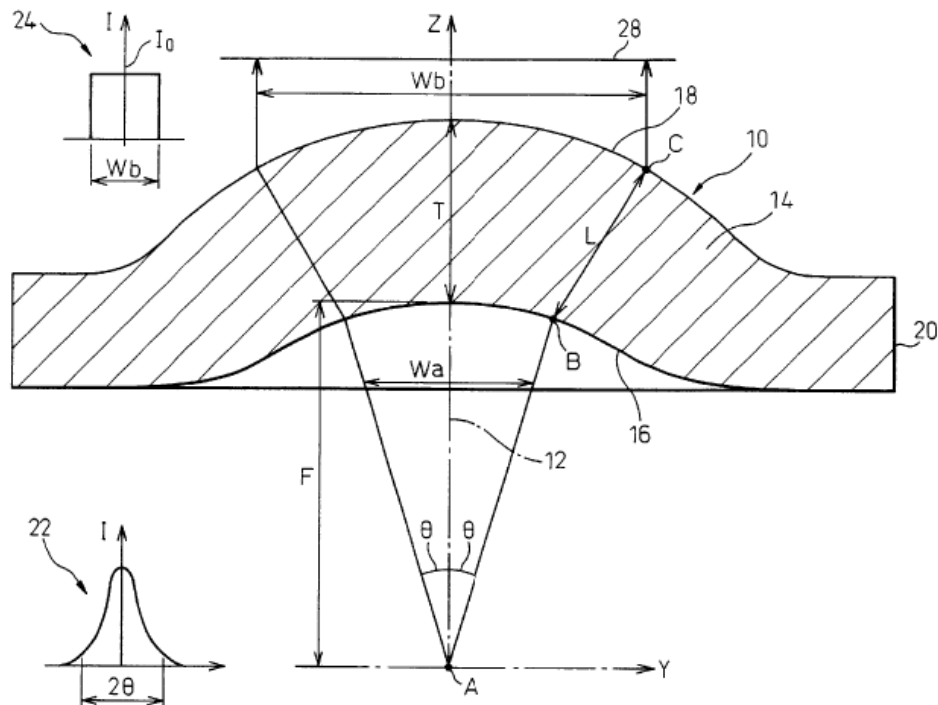
travels in parallel with the Z-axis. The optical path lengths, taken for small optical paths of the light from the **radiation point A** to the **surface 28** which lie in a plane perpendicular to the Z-axis and which is located beyond the point C are identical to each other.”).

ii. [1a] a transparent dielectric solid of revolution with external surface area predominantly comprised of

71. In my opinion, Tawa teaches [1a].

72. Tawa describes a “light intensity distribution converting device 10” that includes a transparent body (14) with a central axis (12). The transparent body is made from a material such as glass and is characterized by an isotropic refractive index. *See* EX1004, 3:55-58 (“In FIGS. 1 and 2, the light intensity distribution converting device 10 comprises a transparent body 14 having a central axis 12. The body 14 is ***made of a transparent material, such as glass***, having an isotropic refractive index.”).

Fig.1



EX1004, Figure 1.

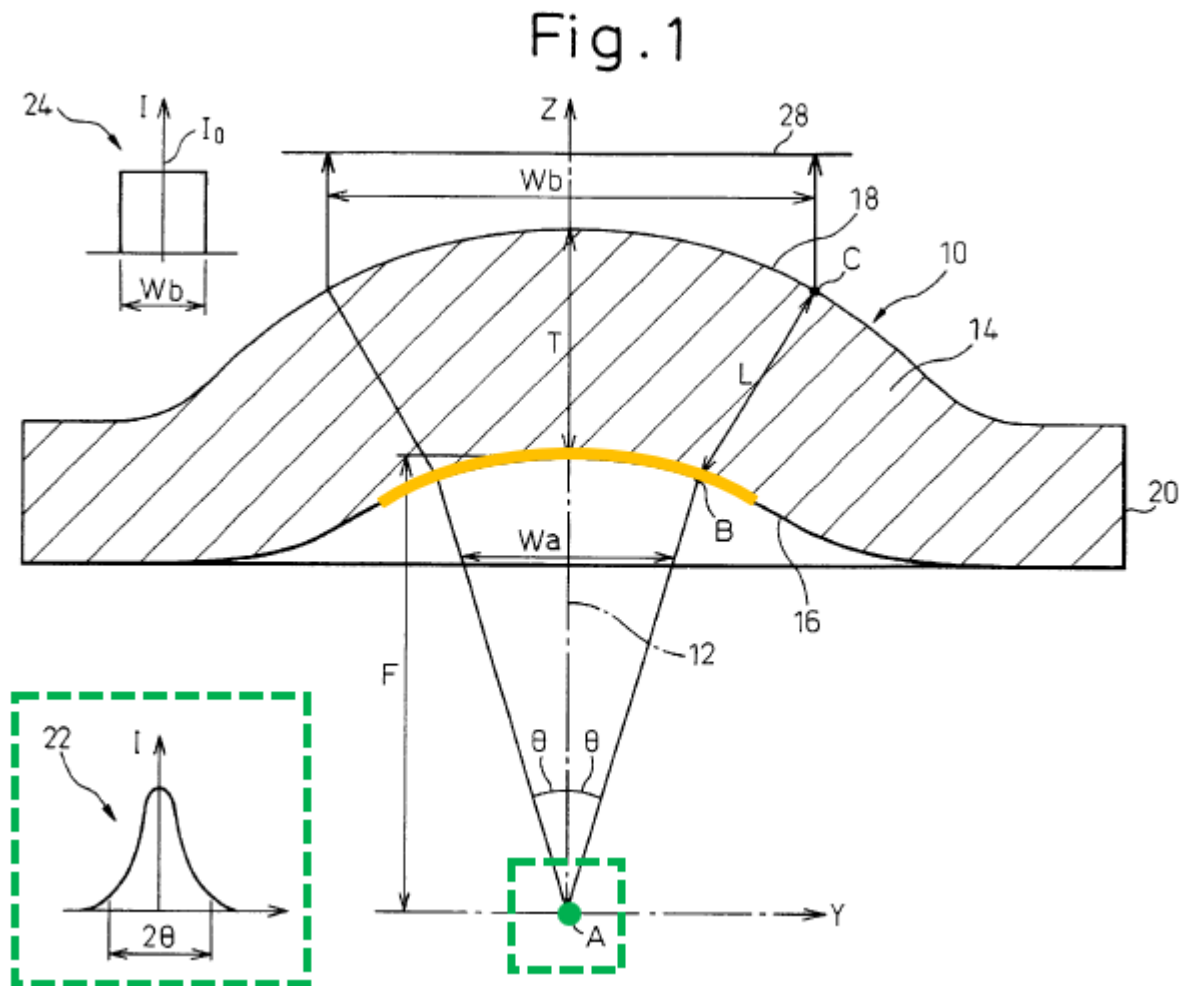
73. The transparent body 14 meets the claimed “***solid of revolution with external surface area***” because it includes external curved surfaces (16 and 18) that extend transversely with respect to the central axis (12) and the transparent body 14 is rotationally symmetric about the optical axis in the Z- direction. Specifically, Tawa explains that “[t]he body 14 has a first curved surface 16 ***transversely extending with respect to the central axis 12***, a second curved surface 18 located on the side opposite to the first curved surface 16 and ***transversely***

extending with respect to the central axis 12, and an outer circumferential surface 20 extending between the first curved surface 16 and the second curved surface 18.” EX1004, 3:59-65. Tawa further explains that “[t]he light intensity distribution converting device 10 is an optical device, having a rotation-symmetric shape regarding the Z-axis, and a refractive index n.” EX1004, 4:12-15.

iii. [1b] **an entry surface** that receives light of nonuniform irradiance from **a nearby compact light source** and

74. In my opinion, Tawa teaches [1b]. At a minimum, Tawa renders obvious [1b].

75. Tawa describes a “**first curved surface 16**” as shown in Tawa’s Figure 1 below.



EX1004, Figure 1; *see also* EX1004, 3:59-65.

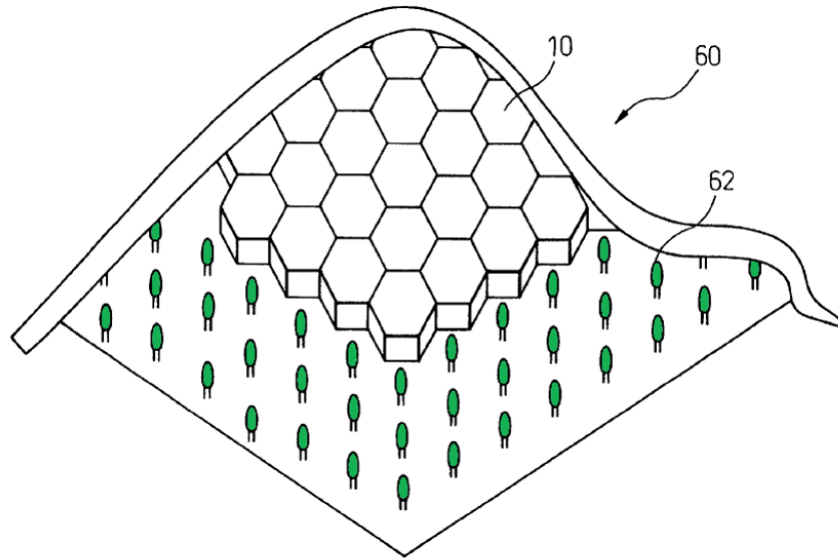
76. Tawa's **first curved surface 16** "receives light of nonuniform irradiance" from the **light source at point A**. As Tawa explains, the light from **point A** is nonuniform because it is a "diverging light having Gaussian light intensity distribution 22". EX1004, 4:9-12 ("**Point A** can be, for example, a laser,

which radiates diverging light having Gaussian light intensity distribution 22 which is in rotation-symmetry with respect to the Z-axis.”). As shown above in Figure 1, the Gaussian light intensity distribution 22 is nonuniform because the intensity $I(\theta)$ is highest at the center ($\theta=0$) and decreases as the θ increases.

77. Tawa distinguishes this nonuniform Gaussian light intensity distribution (22) from the uniform light intensity distribution (24) that results after the light passes through the device. Specifically, Tawa states: “In the embodiment, diverging light having a Gaussian light intensity distribution 22 is made incident to the body 14 at the **first curved surface 16**, and passes through the body 14. The light emerges the body 14 from the second curved surface 18 as parallel light having a uniform light intensity distribution 24”. EX1004, 4:35-40

78. The **light source at point A** satisfies the claimed “**compact light source**.” Tawa teaches that “[p]oint A can be, for example, a laser.” EX1004, 4:9-10. Tawa also teaches that the light source may include “light emitters, such as **light emitting diodes**.” EX1004, 10:18-37. This is shown in Figure 20, which is reproduced below.

Fig. 20



EX1004, Figure 20.

79. These light sources at **point A** are substantially smaller than the light intensity distribution converting device 10. For example, as Tawa itself explains, lasers are considered point light sources and the LEDs shown in Figure 20 are drawn to be substantially smaller than the light intensity distribution converting devices 10. *See* EX1004, 4:9-10 (“Point A can be, for example, a laser”); EX1004, 10:20-24 (“In this embodiment, the light source 62 composed of light emitters, such as light emitting diodes, is a two-dimensional arrangement, and the light intensity distribution converting devices 10 of a honeycomb shape are arranged

corresponding to the light emitters. Each light intensity distribution converting device 10 receives diverging light from the light emitters, and outputs light having a uniform light intensity distribution.”). This is just like the ’162 Patent, which discusses the size relationship between the light source and the lens, noting that “[t]he ratio shown in FIG. 4 of the width of emitter 41 to that of receiving surface 44 is ... less than $\frac{1}{5}$.” EX1001, 3:53-59. Similarly, the prosecution history emphasizes that the alleged invention includes “a separate lens that is much larger than its light source.” *See* EX1003, 189-190 (“The present invention teaches a separate lens that is much larger than its light source, whereas Minano [EX1018] teaches at attached body about the same size as the light source, which therefore is the opposite of ‘compact’.”); EX1001, 3:53-59 (“The ratio shown in FIG. 4 of the width of emitter 41 to that of receiving surface 44 is ... less than $\frac{1}{5}$.”).

80. Moreover, the **light source at point A** is located nearby the **first curved surface 16**, as it is positioned merely millimeters away from the light intensity distribution converting device 10. For instance, Tawa explains with Figure 3 that the distance “F” is measured between the radiation point (A) and the light intensity distribution converting device 10. *See* EX1004, 5:14-29 (“the distance F [is measured] between the radiation point A and the light intensity

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distribution converting device 10"). And Tawa's Figures 9A-9C and 10A-10C illustrate distances between **light source at point A** and the **first curved surface 16** that range from approximately 3.0 mm to 8.0 mm. See EX1004, 7:47-8:18.

Fig. 3

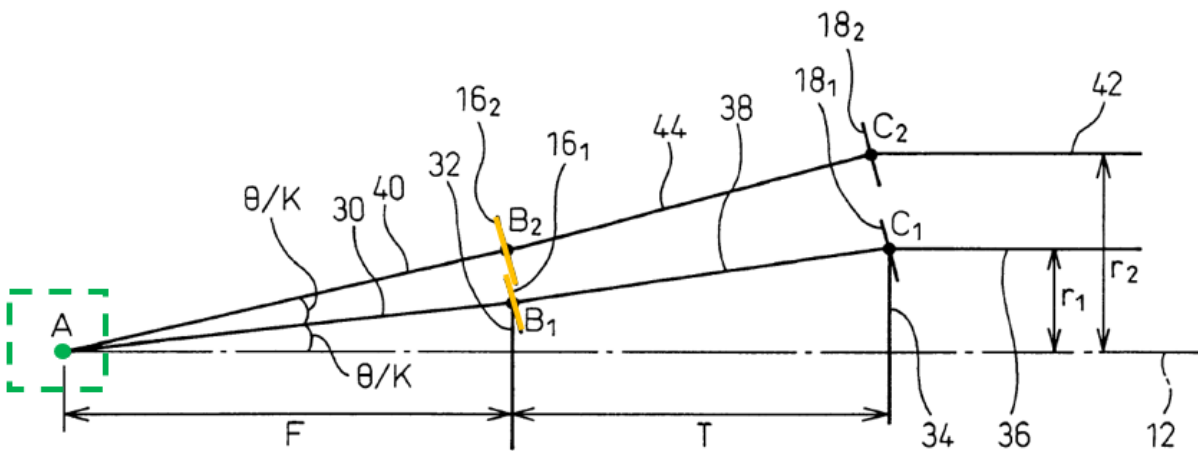
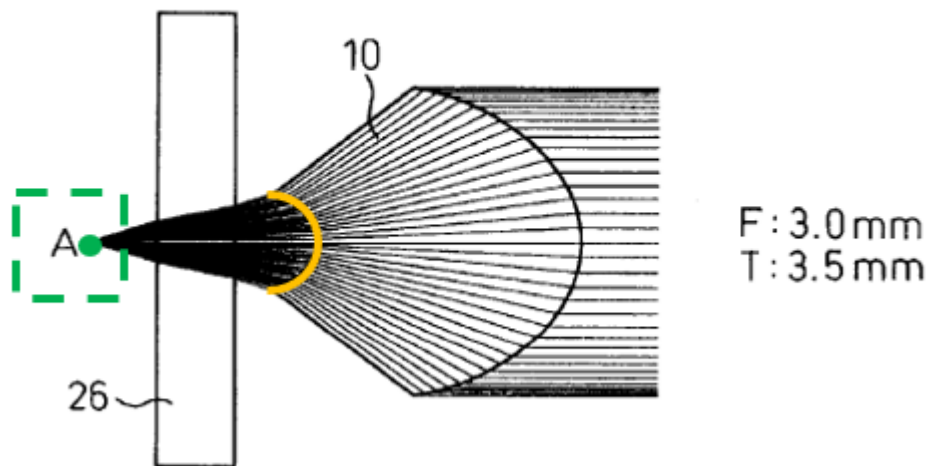


Fig. 9A



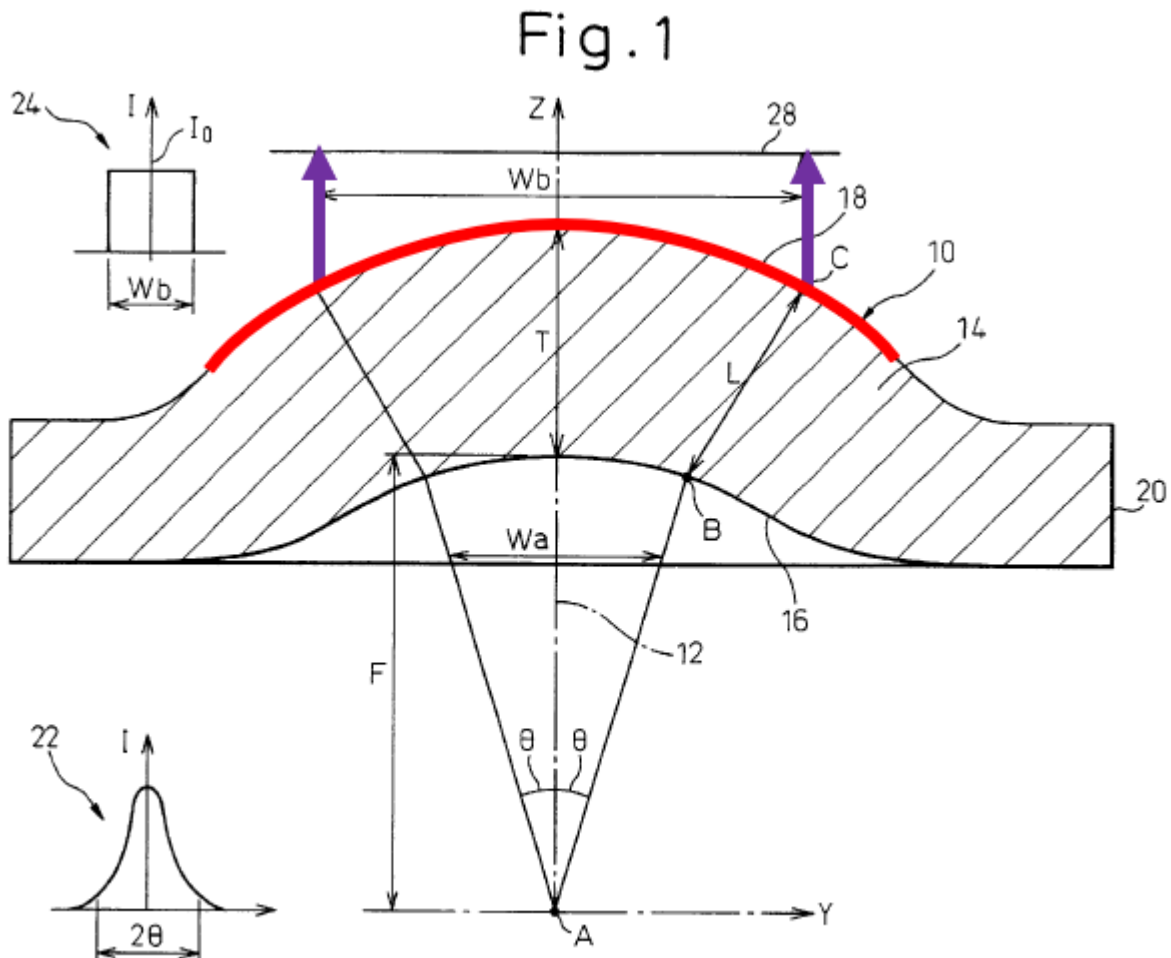
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EX1004, Figures 3 and 9A.

iv. [1c] of **an opposing exit surface** that forms from said
received light a pre-specified diverging **output beam**;

81. In my opinion, Tawa teaches [1c]. At a minimum, Tawa renders
obvious [1c].

82. As shown in Figure 1, Tawa teaches a “**second curved surface 18**
located on the side opposite to the first curved surface 16.” *See* EX1004, 3:59-65.

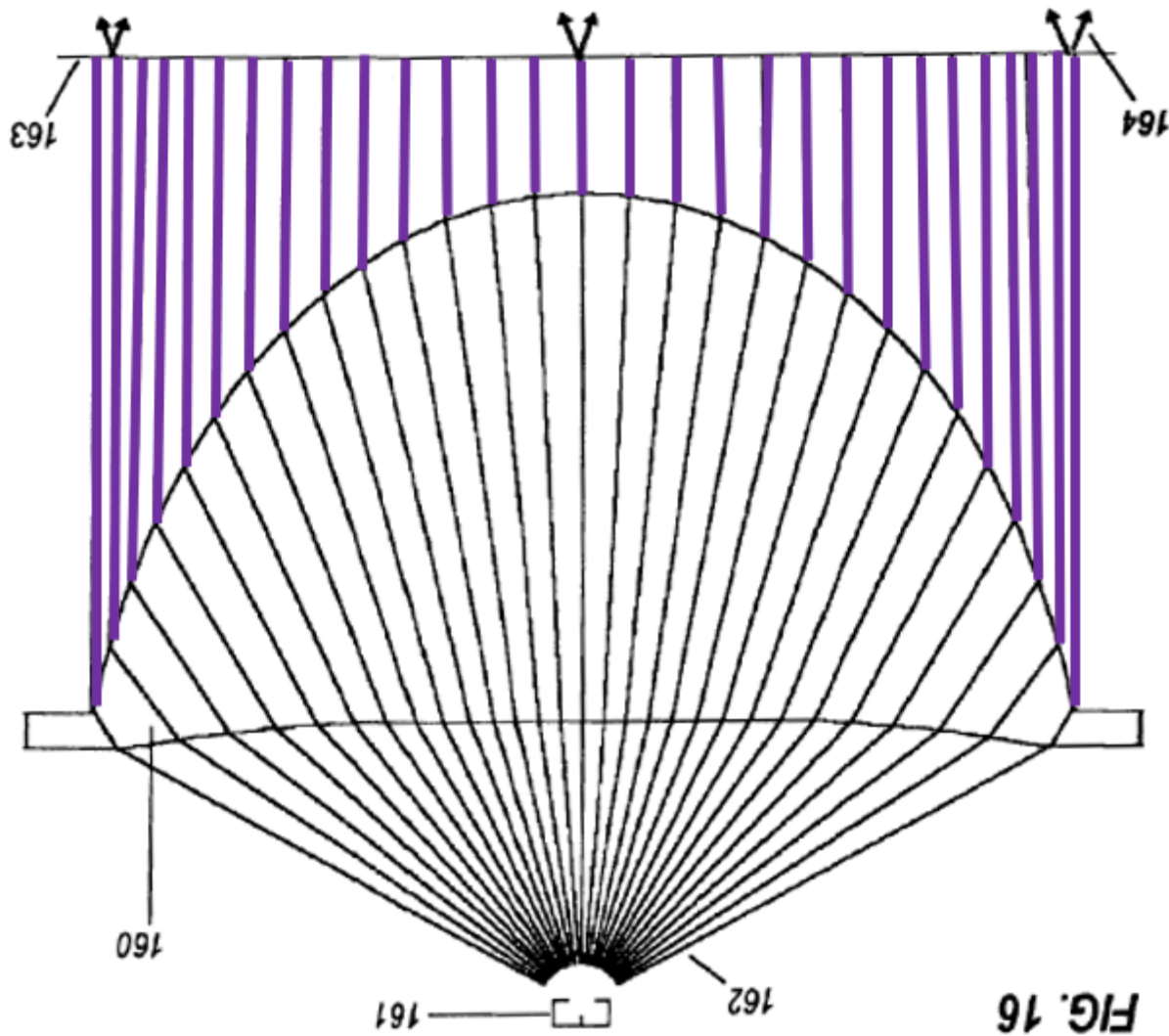


EX1004, Figure 1.

83. Tawa further teaches the **second curved surface 18** forms an “**output beam**” that is “pre-specified” because it is parallel to the optical Z-axis. Tawa teaches that the “**light emerges** the body 14 from the **second curved surface 18** as parallel light having a uniform light intensity distribution 24.” EX1004, 4:31-40; *see also* EX1004, 4:41-43. (“The inclination of the **second curved surface 18** is

determined such that the light emerging the body from the point C travels in parallel with the Z-axis.”). As Tawa teaches, the net effect of the rays being parallel to each other is that it serves as a “collimator lens.” EX1004, 4:47-50.

84. The fact that the light converting device 10 serves as a collimator lens means that it is producing a “diverging” beam, based at least on the preferred embodiment of the ’162 Patent. For instance, the ’162 Patent states that “[o]ne preferred embodiment of this new lens produces a very tightly collimated beam with uniform irradiance.” EX1001, 1:66-67; *see also* EX1001, 6:1-3 (“FIG. 16 shows the profile of collimating irradiance-redistribution lens 60, illuminated by LED 161 with rays 162 that uniformly illuminate target 163.”). As I explained in Paragraph 22, I understand that interpreting a claim term to exclude a preferred embodiment is rarely correct.



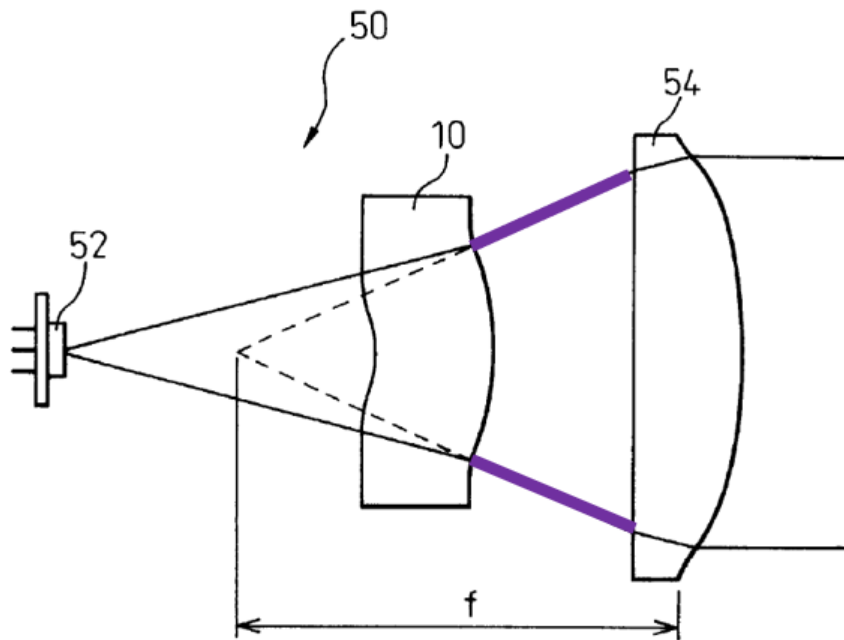
EX1001, Figure 16.

85. This is also consistent with dependent claim 11, which states that “[t]he lens of claim 1, wherein said [diverging] output beam is collimated....”

EX1001, claim 11.

86. At a minimum, Tawa renders obvious [1c] because Tawa describes other embodiments where the light being emitted from the light converting device 10 is not parallel, but instead increases outwardly. *See* EX1004, 9:48-55 (“In FIG. 18A, the light intensity distribution converting device 10 is arranged so that the diverging light, which enters the light intensity distribution converting device 10, is emitted therefrom at an increased divergent angle. In FIG. 18B, the light intensity distribution converting device 10 is arranged so that the diverging light, which enters the light intensity distribution converting device 10, is emitted therefrom at a reduced diverged angle.”).

Fig. 18A



EX1004, Figure 18A.

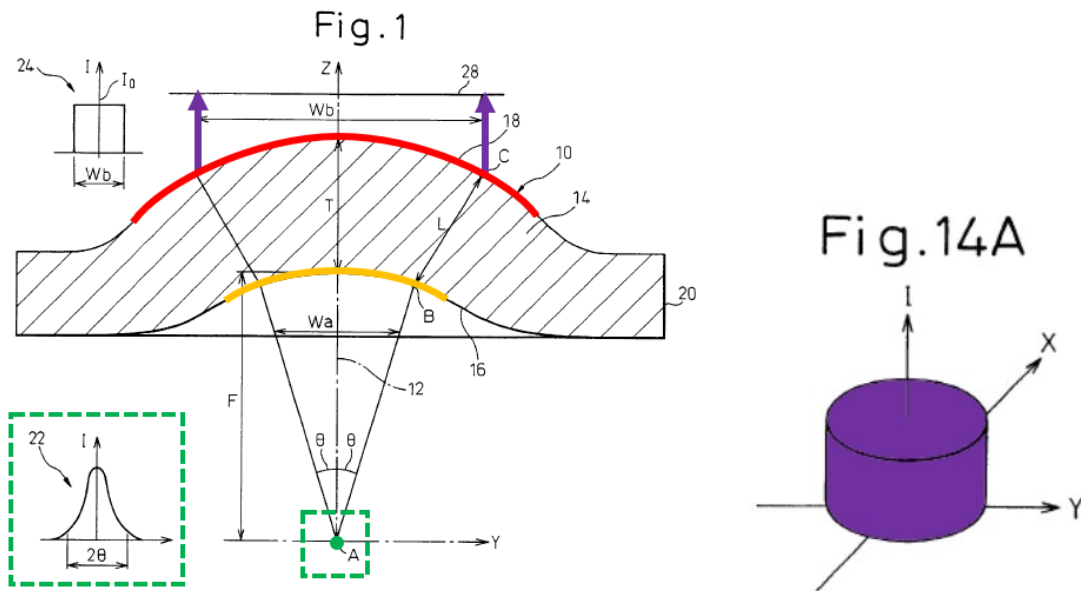
- i. [1d] **said entry surface** given a specific profile that refractively deflects said received light into a different solid angle,

87. In my opinion, Tawa teaches [1d].

88. Tawa explains that **first curved surface 16** is “*design[ed]*” to be shaped such that it “refractively deflects said received light into a different solid angle,” allowing the light to be redistributed as it travels through the device. *See*

EX1004, 5:4-5 (“The *design* of the **first ... curved surface[] 16** will be explained below.”).

89. As illustrated in Figure 1 below, the light entering the **first curved surface 16**, which is symmetric about the Z-axis, is refracted into a new solid angle as it passes into the transparent body (14). See EX1004, 4:9-12 (“Point A can be, for example, a laser, which radiates diverging light having Gaussian light intensity distribution 22 which is in rotation-symmetry with respect to the Z-axis.”), 4:31-40 (“[T]he light intensity distribution of light emitted therefrom is different from that of light made incident thereupto, due to refractions of light caused at the **first curved surface 16** and the **second curved surface 18**.”). This refraction is designed to ensure that, by the time the light exits through the **second curved surface 18**, it has been redistributed into a uniform light intensity I_0 across the aperture W_b , such as the cylindrical uniform light intensity distribution shown in Figure 14A below. See EX1004, 8:44-46 (“A cylindrical uniform light intensity distribution is shown in FIG. 14A.”).



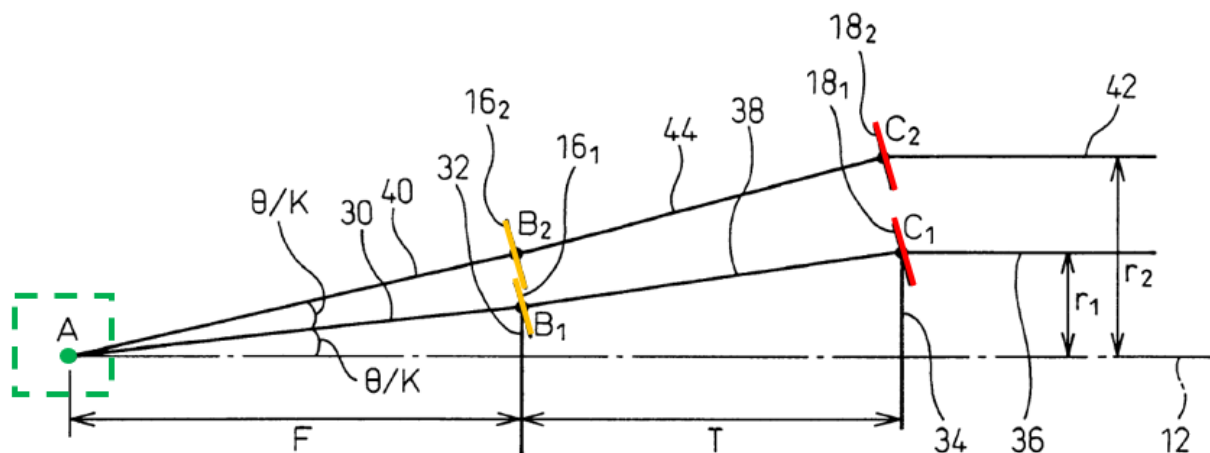
EX1004, Figures 1 and 14A.

90. Limitation [1d] does not specify how the “different solid angle” should be formed as light refracts at the entry surface. For example, Figure 1 of Tawa shows a change to a different solid angle by refracting away from the optical axis. In contrast, Figure 5 of the '162 Patent shows a change to a different solid angle by refracting towards the optical axis.

91. Figure 3 below shows the iterative process by which the profiles of the **first curved surface 16** and **second curved surface 18** are determined. Particularly, Tawa divides the incoming light θ into small angular segments θ/k , and the beam is redirected at each interval to achieve a uniform output by matching the light incident on small angular segments of the **first curved surface 16** with that the light exiting from corresponding segments of the **second curved surface 18**. Tawa's calculations ensure that the amount of light per unit area exiting the

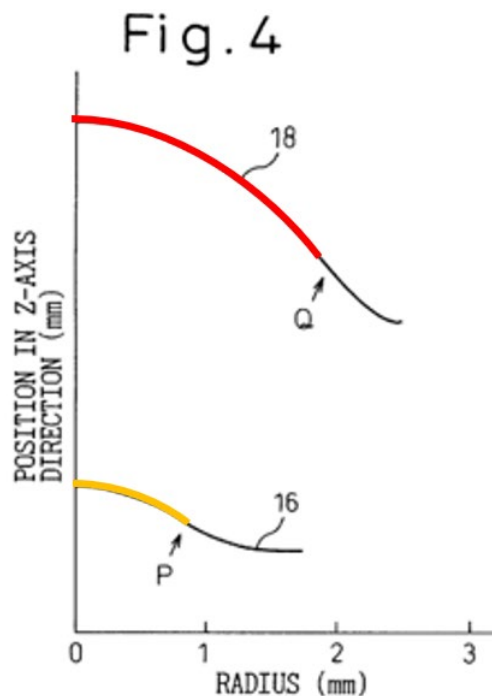
small angular segments across the **second curved surface 18** is the same for each of them. By carrying these steps iteratively at small enough segments, smooth and continuous surface geometries can be obtained for both the **first curved surface 16** and the **second curved surface 18**. entry and exit surfaces. *See* EX1004, 5:5-56.

Fig. 3



EX1004, Figure 3.

92. The result of these calculations is shown in Figure 4, which illustrates the final shapes of the **first** and **second** curved surfaces. EX1004, 6:12-31 (“FIG. 4 shows the shape of the [resulting] **first** and **second** curved surface[s] **16** and **18** of the light intensity distribution converting device 10 shown in FIG. 2.”).



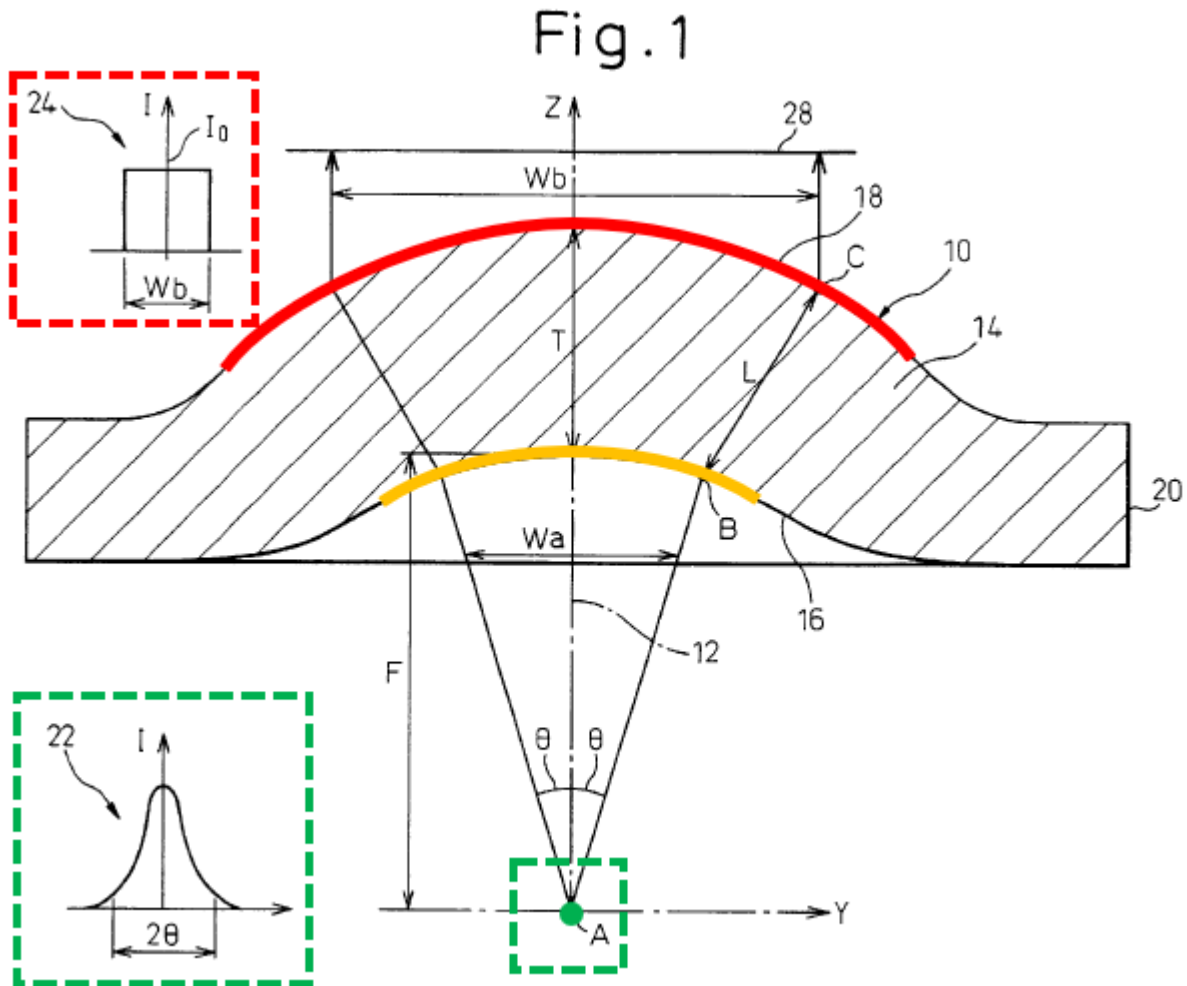
EX1004, Figure 4.

- i. [1e] **said entry surface** spatially distributed such that **said exit surface** receives said deflected light with **predominantly uniform irradiance**,

93. In my opinion, Tawa teaches [1e]. At a minimum, Tawa by itself or together with Shikama renders obvious [1e].

94. As I already explained in Paragraphs 88-92, the **first curved surface 16** has the shape shown in Figure 1 that is “spatially distributed” because it is “symmetric” and “transversely extend[s]” about the optical Z-axis. EX1004, 3:37-65 (“The body 14 has a **first curved surface 16** transversely extending with

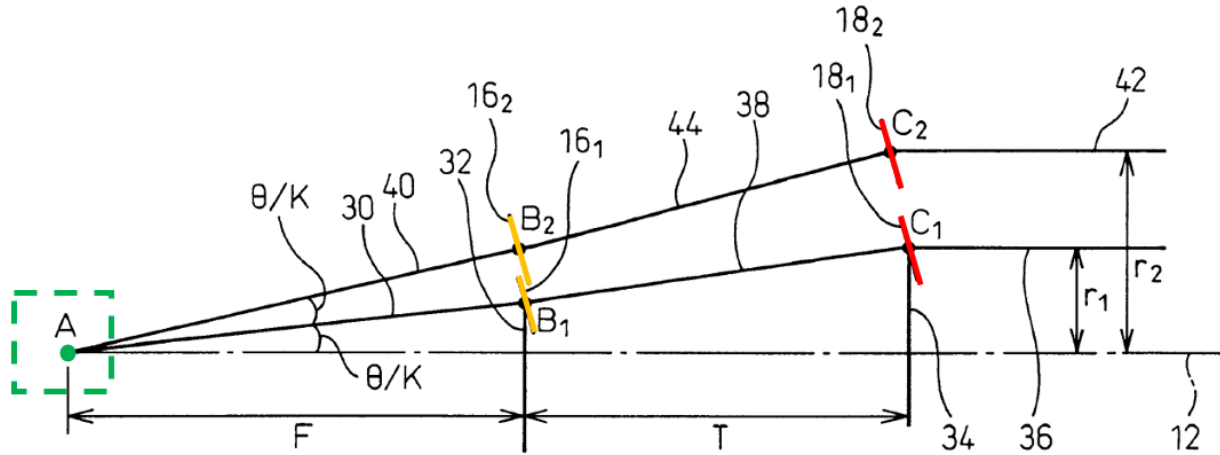
respect to the central axis 12, a second curved surface 18 located on the side opposite to the **first curved surface 16** and transversely extending with respect to the central axis 12, and an outer circumferential surface 20 extending between the first curved surface 16 and the second curved surface 18.”), 4:12-15 (“The light intensity distribution converting device 10 is an optical device, having a rotation-symmetric shape regarding the Z-axis, and a refractive index n .”). As shown below in Figure 1, the light having a nonuniform distribution of intensity arrives at the **first curved surface 16** and is deflected towards the **second curved surface 18**.



EX1004, Figure. 1.

95. Tawa further teaches that the light being received at the **second curved surface 18** has a “predominantly uniform irradiance.” Tawa describes the redistribution of the light by first splitting the radiation angle θ into equal parts, θ/k , as shown in Figure 3, below. EX1004, 5:5-9.

Fig. 3



EX1004, Figure 3. Each such segment corresponds to a concentric area on the **first curved surface 16** of the lens, which Tawa identifies as $\Delta I_1, \Delta I_2 \dots \Delta I_k$. EX1004, 5:5-9. The total light quantity in each of these concentric areas is represented as $Q_1, Q_2 \dots Q_k$. EX1004, 5:5-9. On the **second curved surface 18**, Tawa ensures that the concentric areas $\Delta O_1, \Delta O_2 \dots \Delta O_k$ contain the same light quantities as their corresponding incident areas. This relationship is described mathematically by the equation:

$$Q_k = I_0 \times \pi(r_k^2 - r_{k-1}^2),$$

where I_0 is the uniform intensity of the emitted light, as shown in Figure 1, and $\pi(r_k^2 - r_{k-1}^2)$ is the area of the corresponding output concentric area. EX1004, 5:9-

14. In other words, Tawa's calculations ensure that the total light in each of the successive concentric areas (e.g., k , and $k-1$) on the **second curved surface 18** has the same constant light intensity I_0 .

$$\frac{Q_k}{\pi(r_k^2 - r_{k-1}^2)} = I_0$$

And because light rays arriving at the **second curved surface 18** are nearly parallel to the local normal direction of **second curved surface 18**, such as shown in Figures 2 and 3, the light being received by the **second curved surface 18** has a "predominantly uniform irradiance."

96. In fact, this calculation described by Tawa is essentially what the '162 Patent performs as well as it designs its lens surfaces, by taking an iterative approach to calculating the profile of the entry and exit surfaces to ensure that the target receives a uniform illumination. *See* EX1001, 4:61-5:50. The underlying physics of redistributing the light having a nonuniform intensity to emit light that has a uniform illumination using the lens's surface profile is nearly identical to one another in Tawa and the '162 Patent.

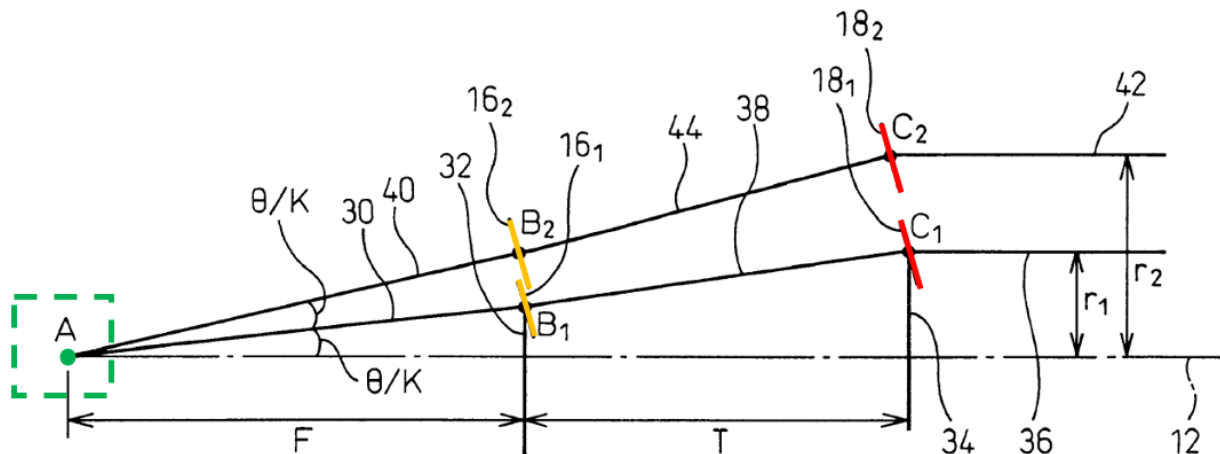
97. What results from these calculations is that the "light emerges the body 14 from the **second curved surface 18** as parallel light having a uniform

light intensity distribution 24.” EX1004, 4:35-40; *see also, e.g.*, EX1004, 4:59-65 (“Since the total quantity of incident light is equal to the total quantity of emission light, and since the *emission light has a uniform light intensity distribution...*”), 5:14-65 (showing the iterative calculations to design the shapes of the **first curved surface 16** such that the **second curved surface 18** such that the emitted beam of light has uniform intensity distribution), 10:23-30 (“Each light intensity distribution converting device 10 receives diverging light from the light emitters, and *outputs light having a uniform light intensity distribution.*”). See also Figure 2 of Tawa. It should be noted that Shikama provides a similar disclosure of such a lens producing a uniform light distribution. Particularly, Shikama teaches that the components in its system are arranged such that they “attain a uniform distribution of the projected image brightness.” EX1005, 6:2-7, 6:39-48, 18:51-54, 19:7-12, 26:45-50, 27:18-26. And it is the design of the **second surface S2**, which “serves to improve the uniformity of the transmittance characteristic.” EX1005, 16:60-67.

98. Therefore, at a minimum, a POSITA would have found it obvious that the light arriving at the **second curved surface 18** is “predominantly uniform” because both Tawa and ’162 Patent relies on the same boundary condition of conservation of the amount of light in equal light out at each of the small intervals

with the goal of outputting a uniform distribution of light being refracted out of the **exit surface**. To the extent that there are minor variations of light intensity that may occur as the light refracts out of the **second curved surface 18**, a POSITA would have found it obvious to design the shape of the **first curved surface 16** and the **second curved surface 18** such that light arriving at the **second curved surface 18** has “predominantly uniform irradiance,” as that would have facilitated design of a lens that can output “parallel light having a uniform light intensity distribution 24.” EX1004, 4:38-40. The fact that light being output by the **second curved surface 18** is a collimated beam (i.e., light rays that are parallel) with a uniform light intensity distribution means that a POSITA would have found it obvious to design the lens shape so that light arriving at the **second curved surface 18** is predominantly uniform as well because the refraction that occurs at the **second curved surface 18** merely alters the light rays to become parallel to each other. And, as noted above, such a teaching would have also been supported by the combination of Tawa and Shikama.

Fig. 3



EX1004, Figure 3.

- ii. [1f] **said exit surface** given a specific shape that refractively deflects said uniform irradiance into **said output beam**;

99. In my opinion, Tawa teaches [1f].

100. As I already explained in Paragraphs 88-92, Tawa teaches “design[ing] of ... the **second curved surface**] ... **18**” to give it a “specific shape.” EX1004, 5:4-5. I already explained in detail in Paragraphs 91-92 how the shape of the **second curved surface 18** is determined, using inclinations at multiple points to ensure the refracted **light emerges** as light rays that are parallel to the central axis with a uniform intensity. *See generally* EX1004, 5:5-56; *see also*

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EX1004, 4:20-40 (“The light emerges the body 14 from the **second curved surface 18** as parallel light having a uniform light intensity distribution 24.”), 4:59-65 (“Since the total quantity of incident light is equal to the total quantity of emission light, and since the emission light has a uniform light intensity distribution...”), 6:12-31, 10:23-30 (“Each light intensity distribution converting device 10 receives diverging light from the light emitters, and outputs light having a uniform light intensity distribution.”).

iii. [1g] **said light source** being sufficiently compact for said specific shapes to be calculated by mathematical integration of the slope distributions required by said refractive deflections,

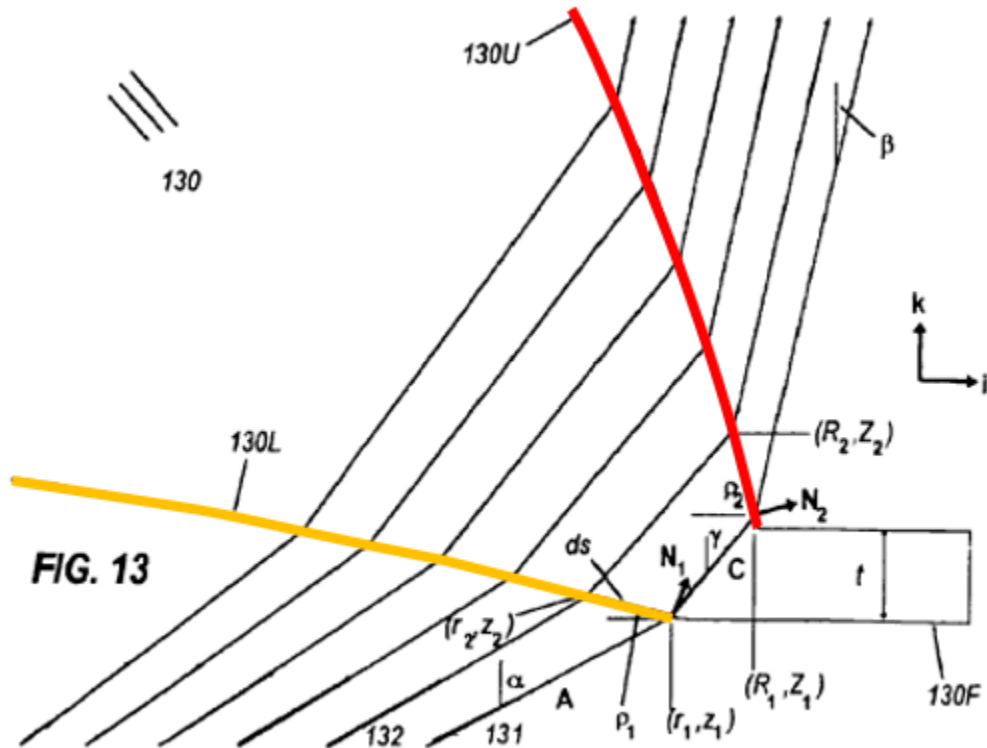
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102. As I already explained in Paragraphs 78-79, the **light source** in Tawa is a “**compact light source**.”

103. Furthermore, this **light source** is also “sufficiently compact for said specific shapes to be calculated by mathematical integration of the slope distributions required by the said refractive deflections,” because both the ’162 Patent and Tawa use iterative calculations of the refractive deflections occurring at the entry surface and the exit surface to determine the specific shapes of the lens. *See generally* EX1001, 5:5-49; EX1004, 5:14-56. I explain below the similarities between the ’162 Patent’s and Tawa’s calculation methods.

104. The ’162 Patent uses small intervals (ds) to iteratively refine the lens profile, as illustrated in Figure 13. This iterative process involves adding discrete steps, starting from one edge of the lens, which are then integrated over the whole surface to produce the lens surfaces **130L** and **130U**, while ensuring that the resulting surfaces are smooth. These surfaces are designed to emit light with uniform intensity, and thereby achieve even illumination across a target area. *See* EX1001, 5:9-54 (“The mathematical generation of lower surface 130L begins with its outer edge, at defined point (r,z) ... By using small intervals ds , smooth surfaces 130L and 130U can thus be mathematically iterated from the periphery to the

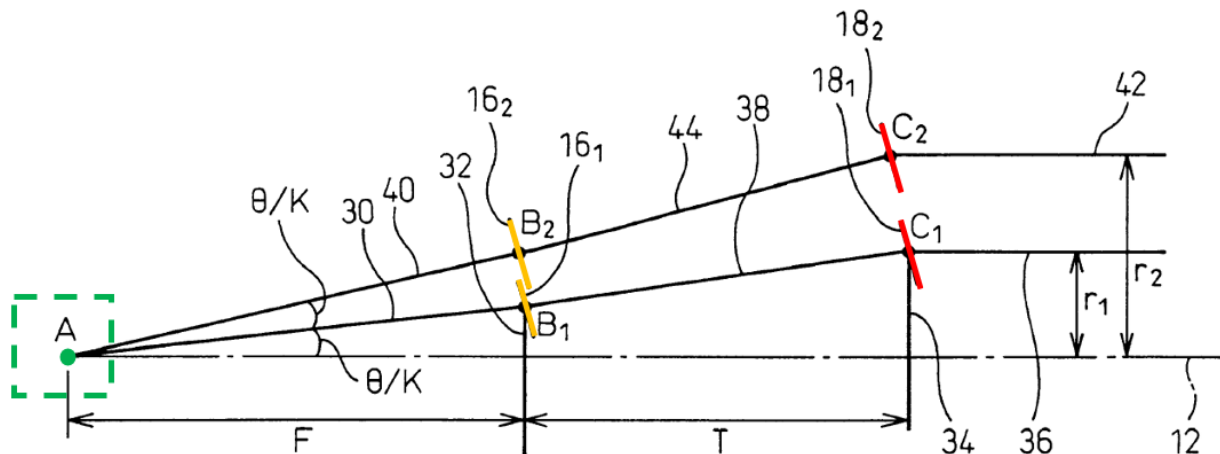
center, with different resultant shapes dependent upon the size and distance of the illumination target, such as target 63 of FIG. 6.”). Figure 13 further illustrates this method, showing the progression from the outer edge towards its center by calculating the positions of points (r_1, z_1) , (r_2, z_2) ... on the entry surface and (R_1, Z_1) , (R_2, Z_2) ... on the exit surface.



EX1001, Figure 13.

105. Similar to the iterative process described in the '162 Patent, Tawa discloses a method of iteratively calculating the deflections that occur as the light enters and exits the lens, except Tawa runs this calculation starting from the center of the lens along the optical axis and moving outwards toward the periphery of the lens. Specifically, Tawa states that “[t]he inclination 16_1 of a micro part of the **first curved surface 16**, which passes through the point B_1 is determined so that the optical path of the incident light corresponds to the line 30, and the optical path of the refracted light corresponds to the line 38. Thereafter, the inclination 18_1 of a micro part of the **second curved surface 18**, which passes through the point C_1 is determined so that the optical path of the incident light corresponds to the line 38, and the optical path of the refracted light corresponds to the line 36 and is parallel with the central axis line 12.” EX1004, 5:30-39. And the “inclination of the **second curved surface 18** is determined such that the light emerging the body from the point C travels in parallel with the Z-axis.” EX1004, 4:41-43. Figure 3 of Tawa illustrates this method, showing the progression from points $B_1, B_2 \dots$ on the entry surface and $C_1, C_2 \dots$ on the exit surface.

Fig. 3



EX1004, Figure 3. As such, in my opinion, because both Tawa and the '162 Patent utilize nearly identical methods for calculating the shape of its lenses, although the '162 Patent does not explicitly define what “mathematical integration of the slope distribution” means, Tawa teaches [1g]. At a minimum, Tawa renders obvious [1g] because Tawa is utilizing nearly identical methods for calculating the shape of its lens.

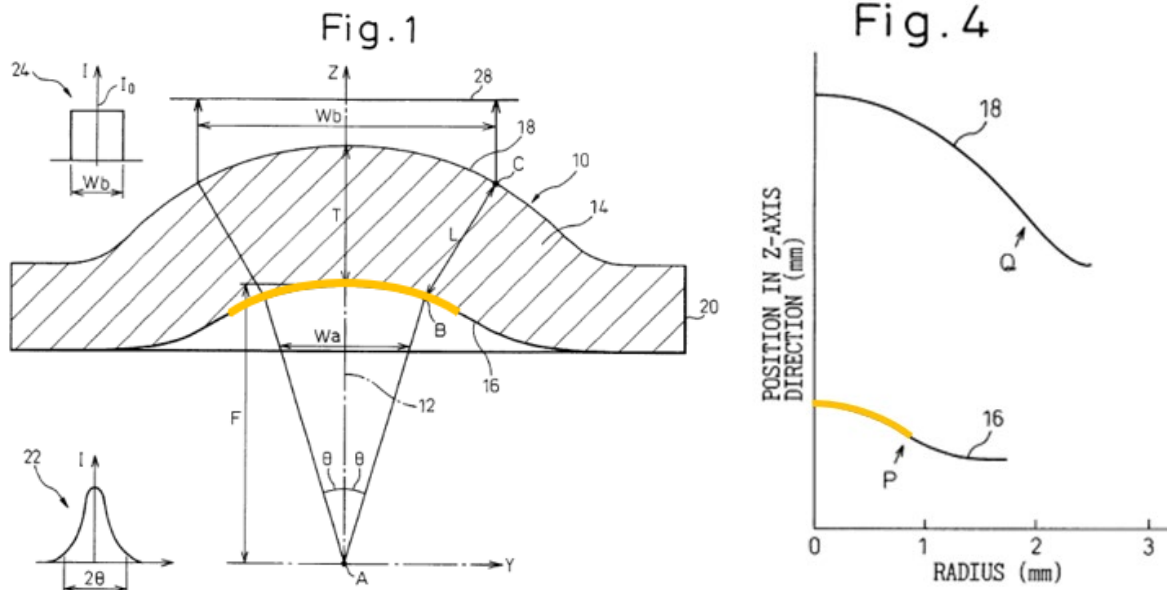
iv. [1h] **said entry surface** having first concavity facing toward **said light source**,

106. As I explain further below in Paragraphs 127-130 and Paragraphs 206-207, while Tawa alone may teach or render obvious [1h] (depending on how

the term is interpreted), at a minimum Tawa in combination with Shikama renders obvious [1h].

107. The '162 Patent does not explicitly define what “having first concavity” requires. For example, it is unclear whether “having first concavity” requires the entire **entry surface** to have a single shape (i.e., only concave and not convex) or just a portion of the **entry surface** can be concave (i.e., with other portions being convex). Here, my opinion is based on the first possible interpretation where it requires the entire **entry surface** must be concave.

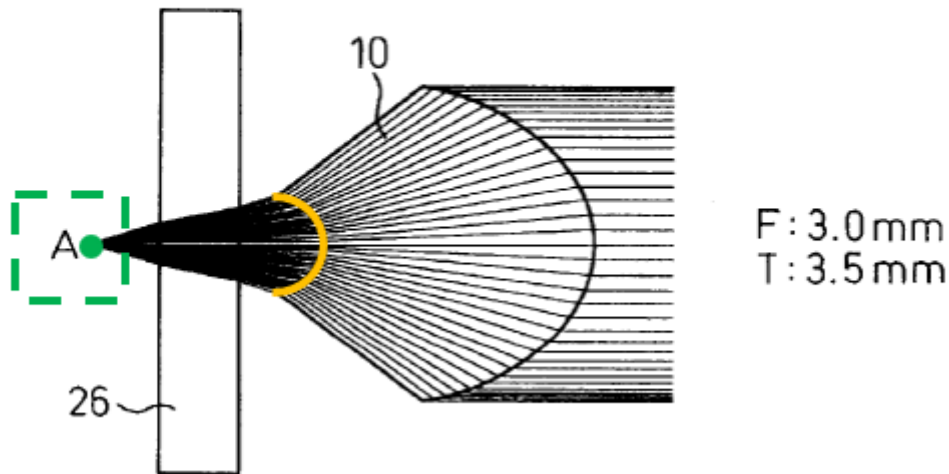
108. Under this interpretation, Tawa does not explicitly teach [1h] because the **first curved surface 16** has a portion that is concave (portion colored in orange below) facing toward the **light source at point A** but another portion that is convex (uncolored portion below) facing toward the **light source at point A**.



EX1004, Figures 1 and 4

109. Nevertheless, a lens where the entire **curved surface** has a single shape (i.e., only concave) toward the **light source at point A** was well-known in the art. In fact, Tawa teaches that this is one possible modification, as shown below in Figure 9A.

Fig.9A



EX1004, Figure 9A.

110. As another example, Shikama shows in Figure 13 a condenser lens 131 that has a **second surface S2** having a concavity that is facing toward the **lamp 120**. See EX1005, 14:58-68 (“FIG. 13 shows the construction of a light source apparatus ... wherein the reference numeral 131 is a condenser lens, ... 132 is a second plane face formed around the periphery of the **second surface S2** of the condenser lens 131,...”), 15:12-19 (“The **lamp 120** is mounted facing the **second surface S2** of the condenser lens 131 ... placed perpendicularly to the optical axis

(indicated by a dashed line) of the condenser lens 131.”).

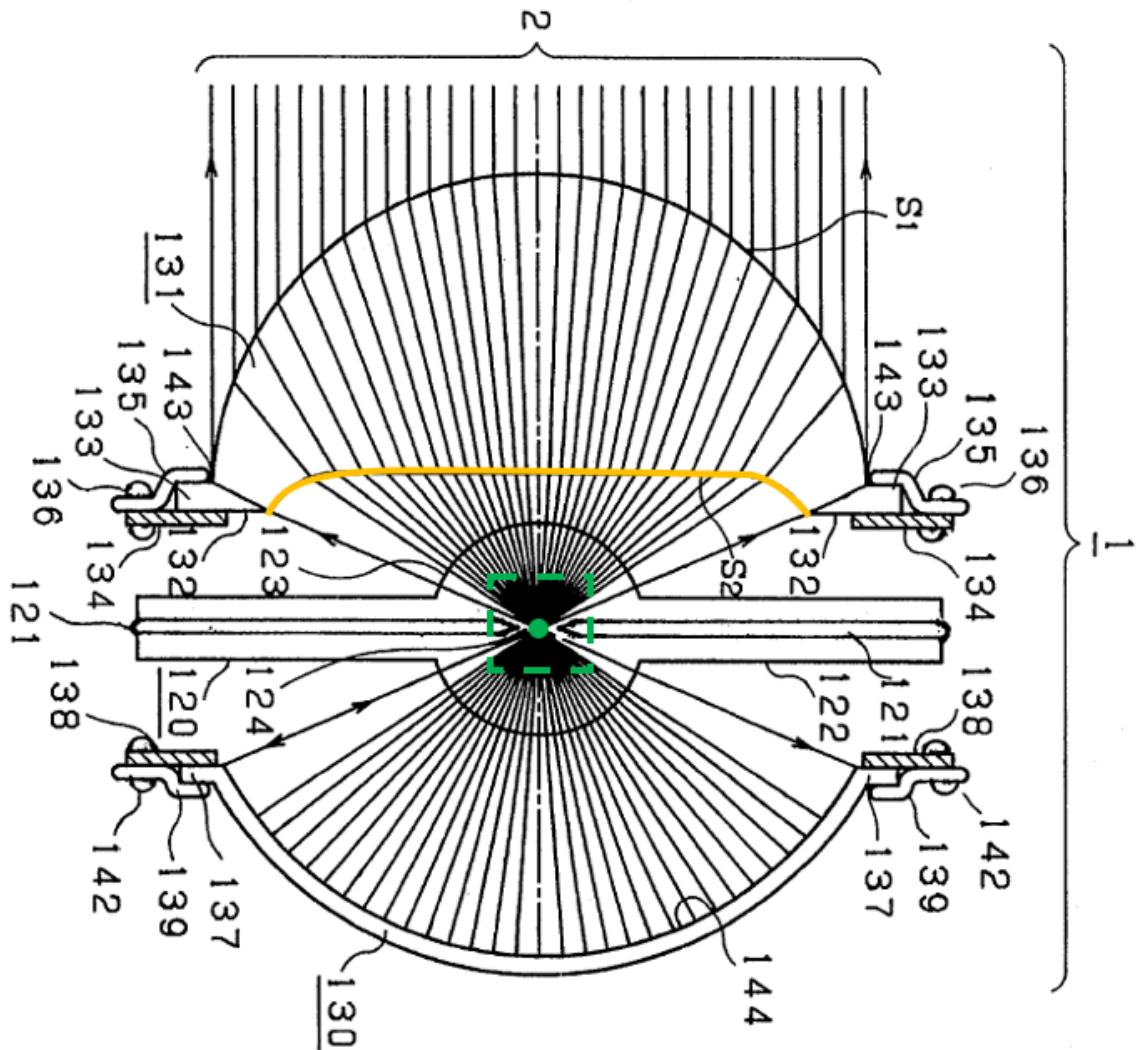


Fig. 13

EX1005, Figure 13.

111. There was nothing inventive about a lens shape in which the entire **entry surface** has a single shape (i.e., only concave) toward the **light source** and it

would have been obvious to modify the Tawa's lens shape similar to the shape taught by Shikama for the reasons I provide below in Paragraphs 131-136.

v. [1i] and [said **exit surface** having a] second concavity facing toward the **entry surface**,

112. As I explain further below in Paragraphs 127-130 and Paragraphs 208-209, while Tawa alone may teach or render obvious [1i] (depending on how the term is interpreted), at a minimum Tawa in combination with Shikama renders obvious [1i].

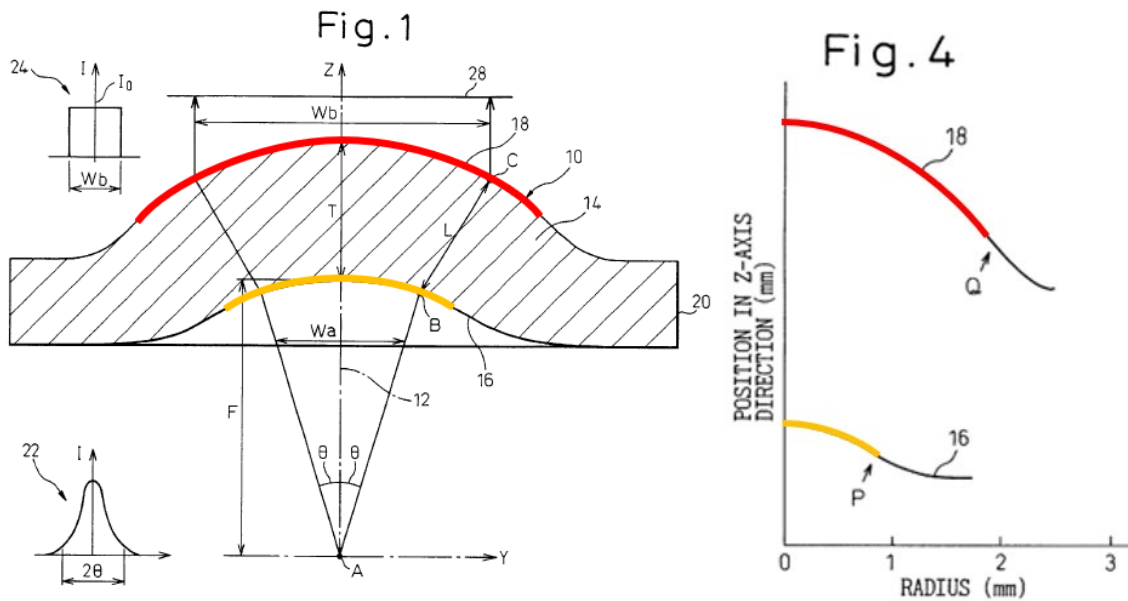
113. As an initial matter, it is unclear whether the applicant intended to recite “[**said exit surface** having a] second concavity facing toward **the entry surface**” or “[**said entry surface** having a] second concavity facing toward **the entry surface**.” As written, [1i] appears to require the latter whereas the prosecution history may suggest the former. *See* Paragraphs 48-49. In this Section, I am interpreting [1i] to require “[**said exit surface** having a] second concavity facing toward **the entry surface**.”

114. Moreover, similar to [1h], the '162 Patent does not explicitly define what “having” “second concavity” requires. For example, it is unclear whether “having” “second concavity” requires the entire **exit surface** to have a single shape

(i.e., only concave and not convex) or just a portion of the **exit surface** can be concave (i.e., with other portions being convex). Here, my opinion is based on the first possible interpretation where it requires the entire **exit surface** must be concave.

115. Under this interpretation, Tawa does not explicitly teach [1h] because the **second curved surface 18** has a portion that is concave (portion colored in red below) facing toward the **first curved surface 16** but another portion that is convex (uncolored portion of 18 below) facing toward the **first curved surface 16**. Just as a quick aside, I note here that Tawa says “the **second curved surface 18** is defined by a generally rounded convex surface.” EX1004, 4:21-22. The term “convex” here actually refers to the portion that is colored in red below because, as I explained in Paragraphs 32-34, the curvature is typically determined from the vantage point that is external to the surface it is being measured against. In other words, the curvature for the **second curved surface 18** is determined from the vantage point near surface 28 whereas the curvature for the **first curved surface 16** is determined from the vantage point near point A. *See* also Paragraphs 32-34. But Figures 1 and 4 clearly show that the **second curved surface 18** has a portion

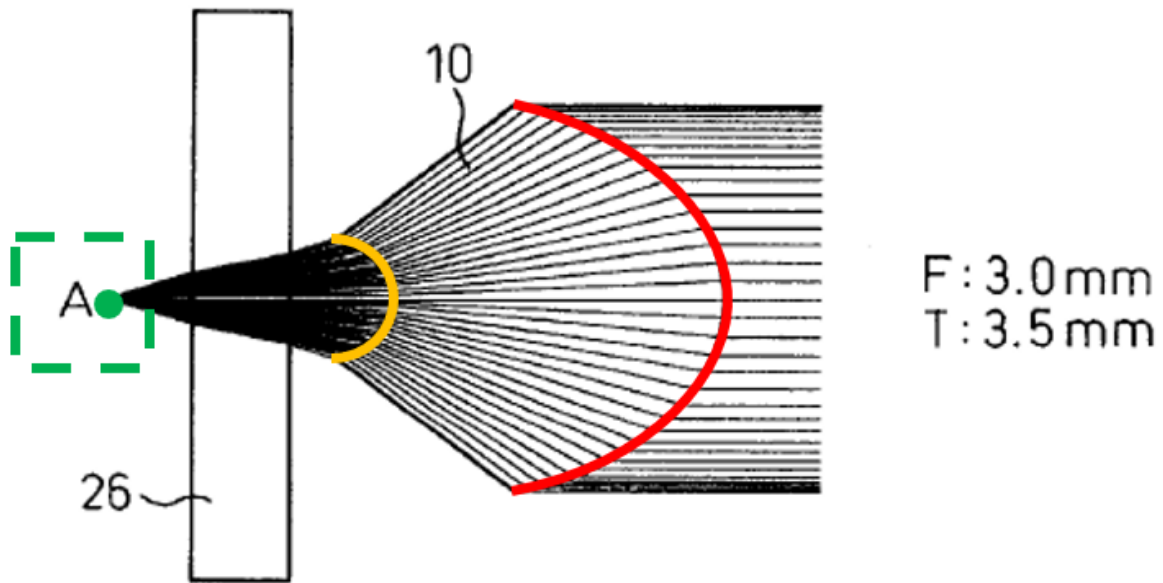
that is concave (portion colored in red below) facing toward the **first curved surface 16**.



EX1004, Figures 1 and 4.

116. Nevertheless, a lens where the entire **exit surface** has a single shape (i.e., only concave) toward the **entry surface** was well-known in the art. In fact, Tawa teaches that this is one possible modification, as shown below in Figure 9A.

Fig. 9A



EX1004, Figure 9A.

117. As another example, Shikama shows in Figure 13 a condenser lens 131 that has a **first surface S1** having a concavity that is facing toward the **second surface S2**. See EX1005, 14:58-68 (“FIG. 13 shows the construction of a light source apparatus according to Example 1 of Embodiment 2, wherein the reference numeral 131 is a condenser lens, 143 is a first plane face formed around the periphery of the effective diameter of the **first surface S1** of the condenser lens 131, 132 is a second plane face formed around the periphery of the **second surface**

118. There was nothing inventive about a lens shape in which the entire **exit surface** has a single shape (i.e., only concave) toward the **entry surface** and it would have been obvious to modify the Tawa's lens shape similar to the shape taught by Shikama for the reasons I provide below in Paragraphs 131-136.

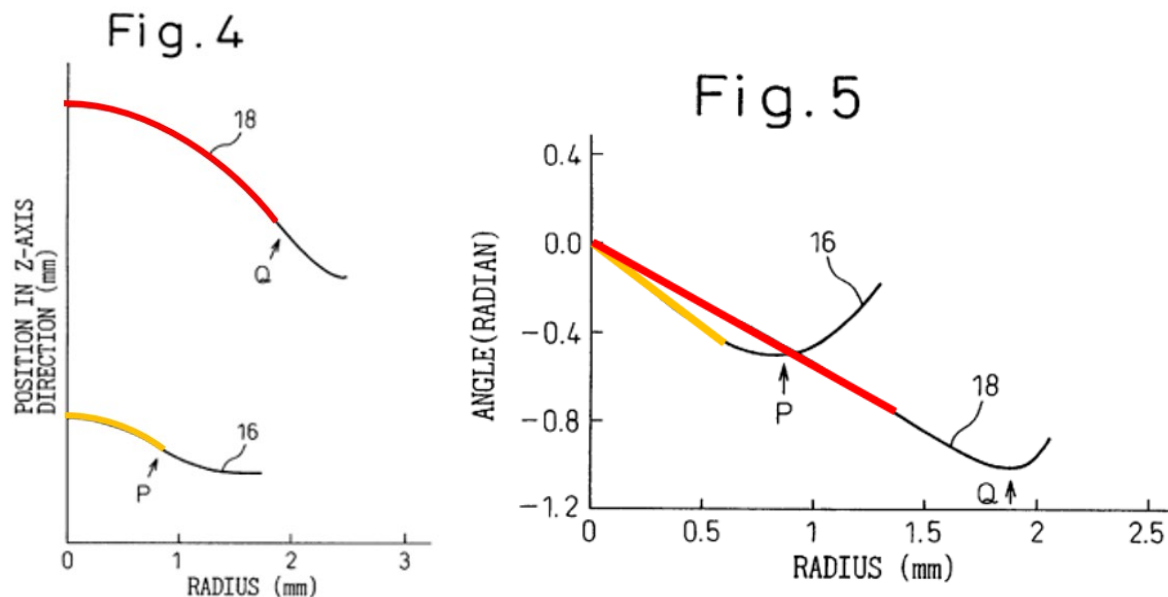
vi. [1j] said second concavity being substantially greater than said first concavity.

119. As I explain further below in Paragraphs 128-130 and Paragraphs 210-215, while Tawa alone may teach or render obvious [1j] (depending on how the term is interpreted), at a minimum Tawa in combination with Shikama renders obvious [1j].

120. The '162 Patent does not provide an explicit definition how to determine when "said second concavity" is "substantially greater than said first concavity." For example, concavity may refer to the curvatures of the entry and exit surfaces or it may refer to the dimensions (e.g., radius) spanned by the entry and exit surfaces. In this section, I apply the first interpretation. And under that interpretation, Tawa in combination with Shikama render obvious [1j].

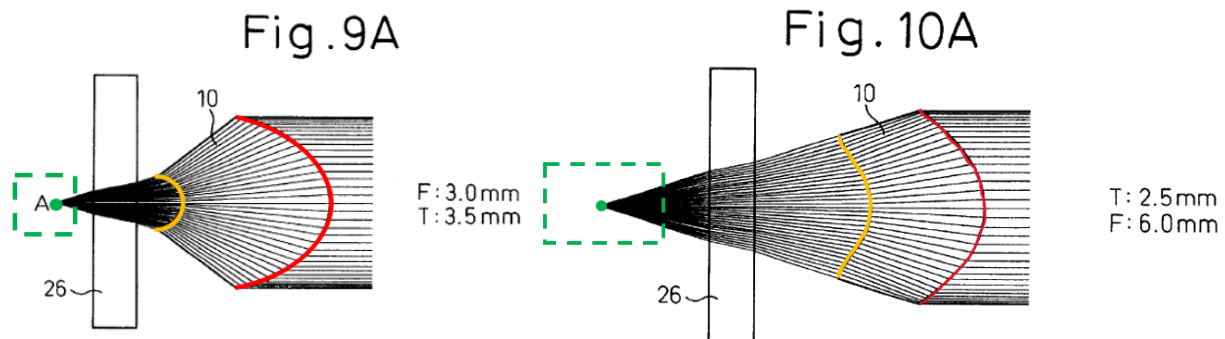
121. As an initial matter, Figures 4 and 5 of Tawa show a specific embodiment that is opposite to that claimed in [1j]. Namely, the **second curved**

surface 18 has a smaller concavity than that of the **first curved surface 16**. More specifically, Tawa describes the shapes of these surfaces in Figure 4, stating: “FIG. 4 shows the shape of the first and second curved surface **16** and **18** of the light intensity distribution converting device 10 shown in FIG. 2.” EX1004, 6:12-14. Figure 5 illustrates the slope (which is the first derivative) of the **first curved surface 16** and the **second curved surface 18**, which can in turn be used to determine the concavity of these curves by taking the second derivative of the curve shown in Figure 5. *See*, EX1024, 33 (explaining that concavity is the second derivative of the curve). As can be seen in Figure 5, the concavity of the **first curved surface 16** is slightly greater than that of the **second curved surface 18** up to the respective inflection points, denoted as P and Q because the slope of the first derivative of the **first curved surface 16** is slightly greater than the slope of the first derivative of the **second curved surface 18**.



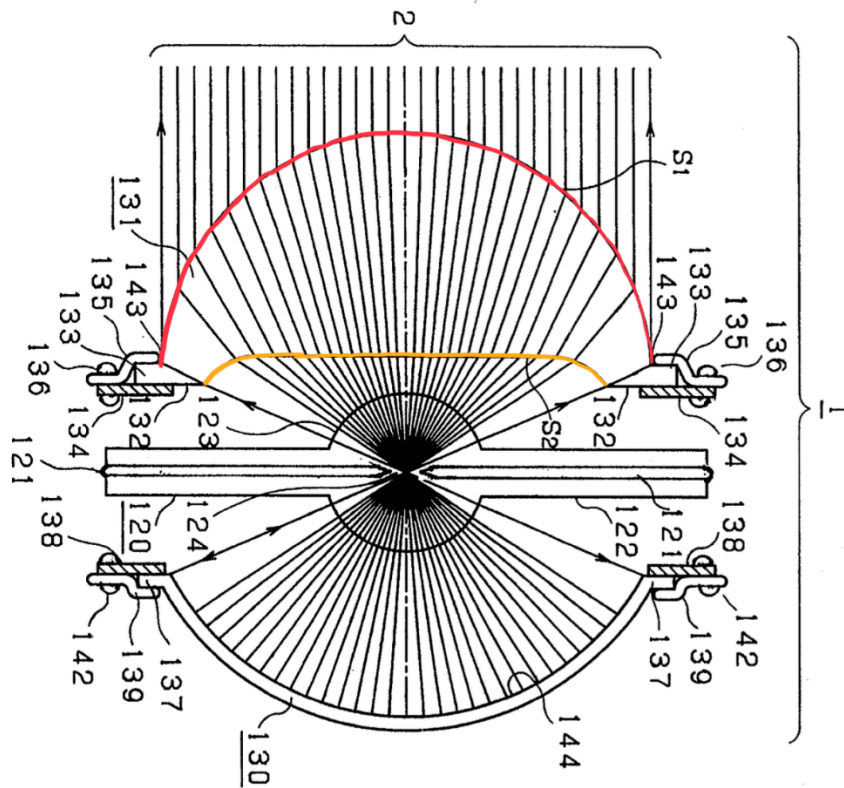
EX1004, Figures 4 and 5.

122. But there was nothing inventive about the **second curved surface 18** having a greater concavity than that of the **first curved surface 16**. In fact, Tawa discloses that these curvatures of the **first curved surface 16** and the **second curved surface 18** can vary, depending parameters such as distance F between the radiation point A and the lens and the thickness T of the lens. *See* EX1004, 7:47-60 (“FIGS. 9A to 9C show ... [t]he shape of the light intensity distribution converting device differs depending on the distance F between the radiation point A and the device 10. The shorter the distance F, the larger the curvatures of the first and second curved surfaces 16 and 18.”).



EX1004, Figures. 9A-10C.

123. Shikama is another example that demonstrates that a lens having the curvature of the **second surface S2** being substantially greater than that of the **first surface S1** was well-known, as illustrated in Figure 13 below. See EX1005, 10:62-65 (“The first surface S1 is of aspherical form having a convex curvature, while the second surface S2 is also of aspherical form having a strongly concave curvature on the outermost circular zone thereof.”), 17:3-4 (“In the case of the first surface S1, the angle of incidence tends to increase toward its periphery;...”), 11:3-8 (further explaining that “since the absolute value of the radius of curvature at the center of the **second surface S2** is extremely large compared with that of the **first surface S1**, the *center zone* [of the **second surface S2**] *appears almost flat* [i.e., has a small concavity].”).



EX1005, Figure 13.

124. In fact, Shikama provides numerical ranges of the radius of curvatures of the **first surface S1** and the **second surface S2** as follows:

$$0.42 < r1/nf < 0.45 \quad (2)$$

$$18 < |r2/nf| \quad (3)$$

$$-0.39 < K1 < -0.25 \quad (4)$$

$$0.11 < \Delta 2/f < 0.14 \quad (5)$$

where

f: focal length of the whole lens system

n: refractive index of the lens

r1: radius of center curvature of the **first surface S1**

r2: radius of center curvature of the **second surface S2...**” EX1005, 11:9-34.

125. And because it is well-known that curvature is inversely proportional to the radius of curvature, the curvature of the **first surface S1** (between approximately 2.2 and 2.4) is significantly greater than that of the **second surface S2** (less than approximately 0.056). EX1024, 78 (explaining that the “reciprocal of the curvature is called the radius of curvature.”). Shikama thus provides explicit guidance for designing a lens where the **second surface** has greater concavity than the **first**. Note that the refractive index of the lens (n) and the focal length of the whole lens system (f) is the same in equations (2) and (3) for a single lens.

126. There was nothing inventive about a lens shape in which the concavity of the **exit surface** is substantially greater than the concavity of the **entry surface** and it would have been obvious to modify the Tawa’s lens shape similar to the shape taught by Shikama for the reasons I provide below in Paragraphs 131-136.

- i. [1h]-[1j] **said entry surface** having first concavity facing toward **said light source**, and [said entry surface having] second concavity facing toward the **entry surface**, said second concavity being substantially greater than said first concavity.

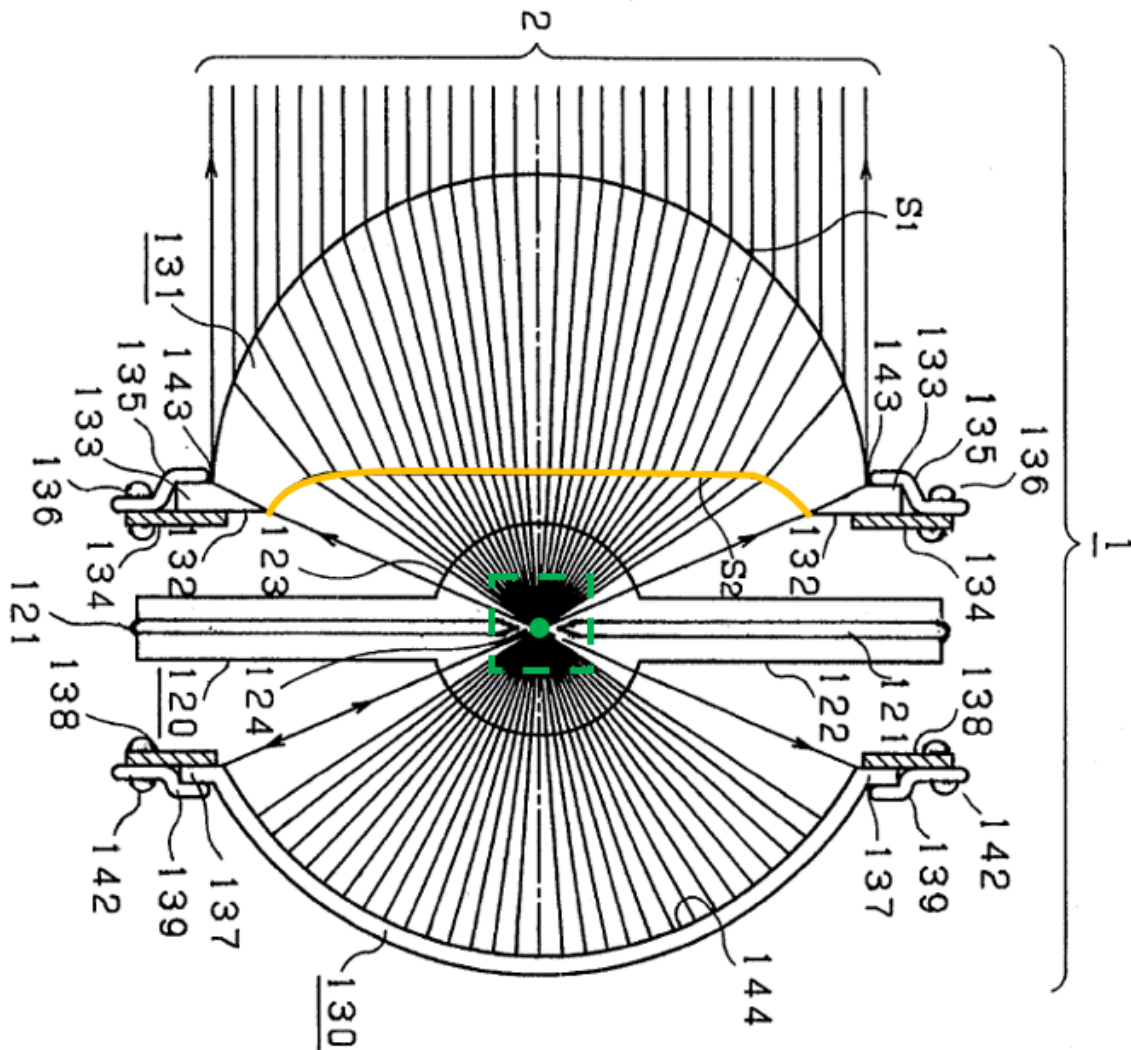
127. As I noted above in Paragraph 113, the above claim limitation is amenable to different interpretation. Another alternative interpretation that I apply in this section interprets [1h]-[1j] to require (1) “[**said entry surface** having] second concavity facing toward **the entry surface**,” (2) “having first concavity” and “having second concavity” requires just a portion of the **entry surface** to be concave (i.e., with other portions being convex), and (3) “concavity” refers to the curvatures on different portions of the **entry surface**.

128. Under this interpretation, Tawa with Shikama also render obvious [1h]-[1j].

129. Figure 13 of Shikama shows “the **second surface S2** is ... of aspherical form having a strongly concave curvature on the outermost circular zone thereof.” EX1005, 10:62-65. In contrast, Shikama discloses that “the radius of curvature at the center of the **second surface S2** is extremely large” because “the *center zone* [] *appears almost flat*.” EX1005, 11:3-8. In other words, Shikama teaches that the **second surface S2** has two different concavities at different

regions of the **second surface S2** that face toward itself where the outermost part has a concavity that is greater than the concavity near the center. The center portion faces toward the **lamp 20** and the outermost part faces toward the inner portion of the **second surface S2**.

Fig. 13



EX1005, Figure 13.

130. There was nothing inventive about a lens shape in which the concavity of the outer portion of the **entry surface** is substantially greater than the concavity of the inner portion of the **entry surface** and it would have been obvious to modify the Tawa's lens shape similar to the shape taught by Shikama for the reasons I provide below in Paragraphs 131-136.

2. Reasons To Combine The Embodiments Of Tawa With Shikama

131. In my opinion, a POSITA would have been able to combine Tawa with Shikama and have a reasonable expectation of success in doing so. Particularly, as I discussed in Paragraphs 88-92, Tawa provides guidance for how to modify the shapes of the **first curved surface 16** and the **second curved surface 18** such that the nonuniform light (e.g., light having Gaussian intensity), from the light source is projected with uniform distribution onto a target surface. A POSITA would readily recognize that such modifications would also be used to achieve shapes and curvatures similar to those of the **second surface S2** and the **first surface S1** of Shikama. The teachings of Tawa provide guidance that

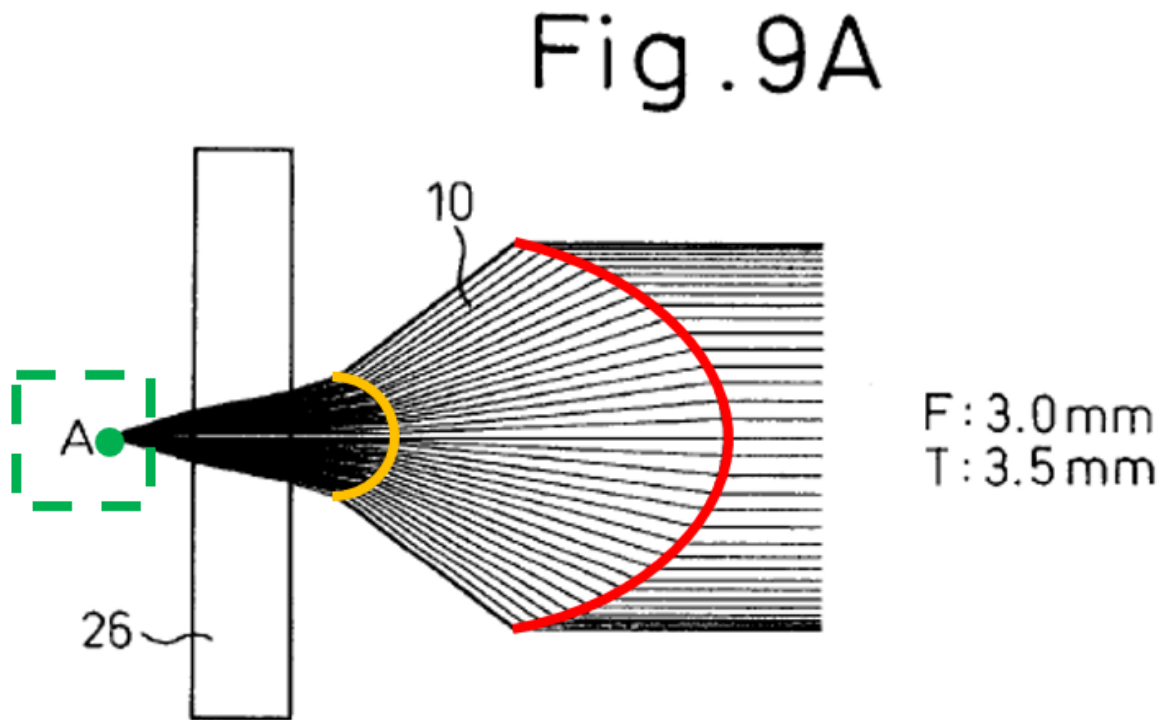
supports combining its features with those of other references, such as Shikama, to achieve the desired lens design.

132. A POSITA would have also understood that any embodiment of Tawa can be combined with other embodiments from Tawa itself or from other references, including Shikama. Tawa teaches that the shape of the lens (and hence the **first curved surface 16** and the **second curved surface 18**) is not limited to the examples provided in the figures, and can vary depending on specific requirements. For instance, Tawa states that “since the light intensity distribution converting device 10 has a freedom in shape to some extent, an optimum shape light intensity distribution converting device 10 according to the requirements of dimensional precision or an optical system to be used together therewith can be obtained.”. EX1004, 8:13-18. This means that the lens design can be adjusted to meet the needs of the optical system it is used with, such as changes in distance between the light source and the lens. Tawa illustrates this in Figures 9A-12C, where lenses with different curvatures are shown, all of which produce uniform light output. Therefore, depending on *e.g.*, the distance from the light source to the lens, the **first curved surface 16** and the **second curved surface 18** will have varying profiles. The curvatures of the **first curved surface 16** and the **second**

curved surface 18 will also depend on the desired distribution of the exit rays. In some cases, the rays exiting Tawa's lens are collimated. *See*, Figures 1, 2, 9A-10C, 14A. In other cases, the exit rays may be intended to produce uniform illumination on a wider surface and hence the rays might spread. *See*, Figures 18A-18B.

133. A POSITA would have also seen the specific reasons to combine Tawa's lens designs with the teachings of Shikama, which would have led to the alleged invention. Particularly, Tawa teaches that "since the light intensity distribution converting device 10 has a freedom in shape to some extent, an optimum shape light intensity distribution converting device 10 according to the requirements of dimensional precision or an optical system to be used together therewith can be obtained." EX1004, 8:13-18. In other words, other shapes of the **first curved surface 16** and the **second curved surface 18** are possible from those exemplified in the embodiment of Figures 1-5. Figures 9A-12C of Tawa, for example, illustrate a variety of possible shapes for the **first curved surface 16** and the **second curved surface 18**, all of which are designed to emit a collimated and uniform beam of light. Specifically, Tawa's Figure 9A, reproduced below, shows a lens in which a single type of concavity is utilized across both the **first curved**

surface 16 and the **second curved surface 18**, similar to the lens shape shown in Shikama.



EX1004, Figure 9A. Furthermore, Tawa teaches that the concavity of the **first curved surface 16** can decrease as the distance between the light source and the lens increases. EX1004, 7:47-60 (“The shape of the light intensity distribution converting device differs depending on the distance F between the radiation point A and the device 10. The shorter the distance F, the larger the curvatures of the first and second curved surfaces 16 and 18.”). *See also*, Figures 9A-10C and

Paragraph 122. A POSITA would have understood that Tawa's teachings could be readily adapted to incorporate the lens shapes disclosed in Shikama. A POSITA would have known that because the shapes for the **first curved surface 16** and the **second curved surface 18** would vary depending on the desired application, Shikama's shape of the lens (and thus curvatures of the first and second curved surfaces 16 and 18) is an obvious variant of Tawa's lens and would be achieved for specific dimensions, such as, focal length, or refractive index, or radius of the first and second curved surfaces 16 and 18. *See* EX1005, 11:9-34 (describing equations that control the shapes of the **first surface S1** and the **second surface S2**). And these shapes could have been calculated by doing the same calculations that I already discussed in Paragraph 105. *See also* EX1004, 4:41-43, 5:30-39. A POSITA would have readily combined the teachings of Tawa and Shikama, using Shikama's specific lens shape to achieve the uniform light distribution described by Tawa. This modification represents a straightforward application of known lens shapes and calculation methods, yielding the predictable result of converting nonuniform light intensity from a point light source into a uniform distribution on the target surface.

134. Furthermore, the modification of Tawa's lens with that of Shikama would only involve an application of a known technique to a known device. And, in my opinion, this combination would yield predictable results. As I already discussed in Paragraph 105, Tawa describes how the shapes of its **first curved surface 16** and the **second curved surface 18** can be calculated based on system parameters such as the distance between the lens and the light source. By applying this same method using Shikama's constraints—for example, a different distance between the light source and the target surface—a POSITA would have been able to calculate lens shapes similar to those in Shikama. For instance, Tawa explains that “[t]he shape of the light intensity distribution converting device differs depending on the distance F between the radiation point A and the device 10.” EX1004, 7:47-60. Shikama further teaches that a condenser lens satisfying specific mathematical conditions can achieve advantages such as reduced spherical aberration and a long back focal length. For example, by satisfying Shikama's Equations 2 and 3, a lens with high image brightness, good color uniformity, and reduced thermal stress on the condenser lens can be created. A POSITA would have recognized that combining Tawa's method with Shikama's design parameters

would predictably result in a lens emitting collimated light with a uniform intensity distribution. EX1005, 4:35–39, 11:9–34, 24:46–62.

135. I should note that a POSITA would have understood that Tawa's light distribution device is suitable for various small light sources, including LEDs and lasers. For Example, Tawa demonstrates that embodiments like the one associated with Figure 20 can be integrated with others, such as the embodiments shown in Figures 1–5, without difficulty. For example, Figure 20 adapts Tawa's earlier designs initially disclosed with a laser as a light source for use in a specific lighting apparatus that has LEDs. A POSITA would have recognized that the lens would operate the same way regardless of whether the light source was a laser or an LED.

136. Lastly, a POSITA would have a reasonable expectation of success when making the described modifications. The modification involves performing straightforward optical calculations, which were well understood at the time. Tawa itself provides detailed guidance on how to perform such calculations to adjust the shapes of the curved surfaces. For instance, Tawa explains how the curvature of the lens can be tailored to achieve the desired optical output. EX1004, 4:41-6:31. In my opinion, this modification would have led to the same predictable result of a

condenser lens that emits collimated light having a uniform intensity distribution.

See EX1004, 2:40-47; EX1005, 24:46-62.

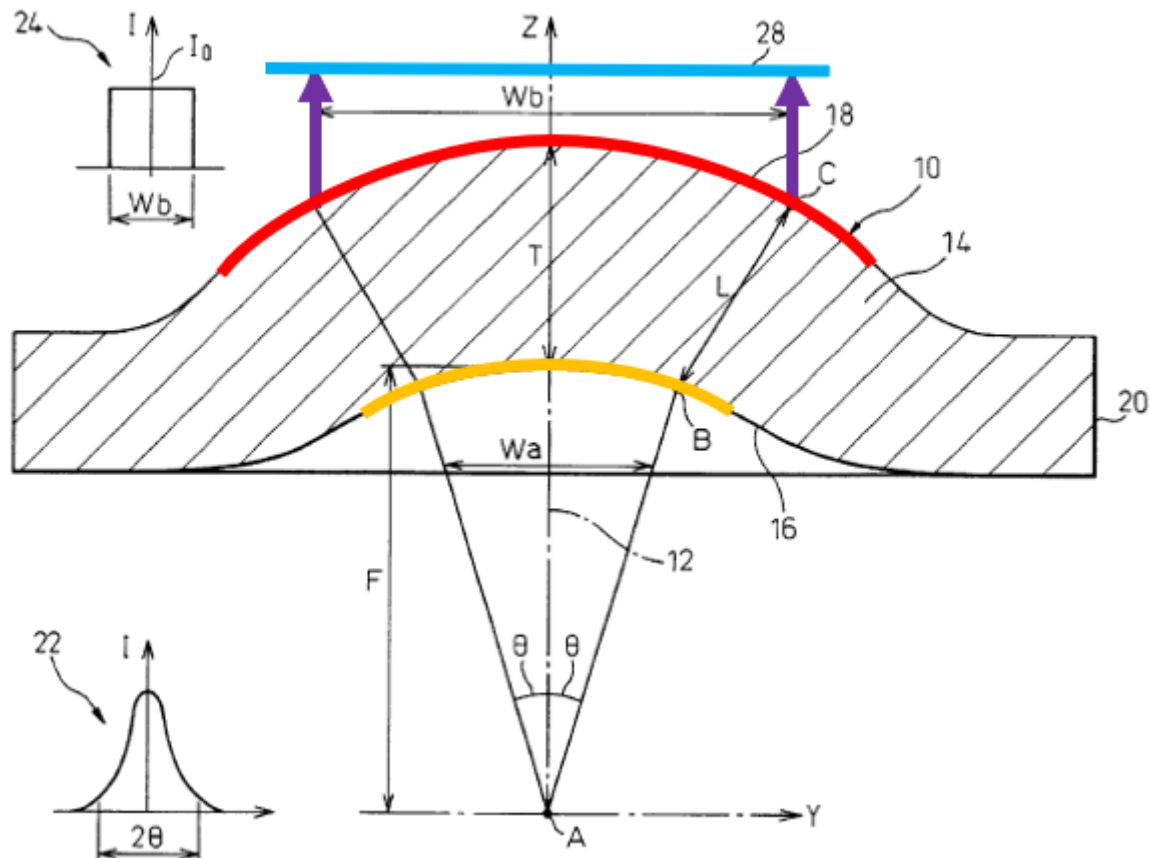
3. Dependent Claim 4

- i. [4] The lens of claim 1 wherein **said output beam has predominantly uniform intensity within a predetermined angular limit.**

137. In my opinion, Tawa teaches [4].

138. As I already discussed in Paragraph 100, Tawa discloses that once the light reaches the **second curved surface 18**, it is deflected by refraction and exits device 10 at a different angle with a *uniform intensity*. See EX1004, 4:38-40 (“The light emerges the body 14 from the **second curved surface 18** as parallel light having a *uniform light intensity distribution 24*.”), 4:59-65 (“Since the total quantity of incident light is equal to the total quantity of emission light, and Since the *emission light has a uniform light intensity distribution...*”), 10:23-30 (“Each light intensity distribution converting device 10 receives diverging light from the light emitters, and outputs light having a *uniform light intensity distribution*.”).

Fig. 1



EX1004, Figure 1.

139. Furthermore, Tawa also shows in Figure 1 above that the **output beam** is emitted as collimated light within predetermined angular limit shown by Wb. For instance, Tawa teaches that “Wa represents the aperture diameter of incident light upon the light intensity distribution converting device 10, and **Wb** represents the aperture diameter of the light emerging therefrom.”). EX1004, 4:51-

54; *see also* EX1004, 6:6-10 (“the emission aperture diameter *W_b*,” can be a factor considered when designing the lens).

4. Dependent Claims 5-6

i. [5] The lens of claim 1 wherein said output beam uniformly illuminates a **target zone**.

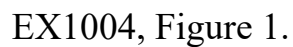
[6] The lens of claim 5 wherein said **target zone** is on a plane facing said lens.

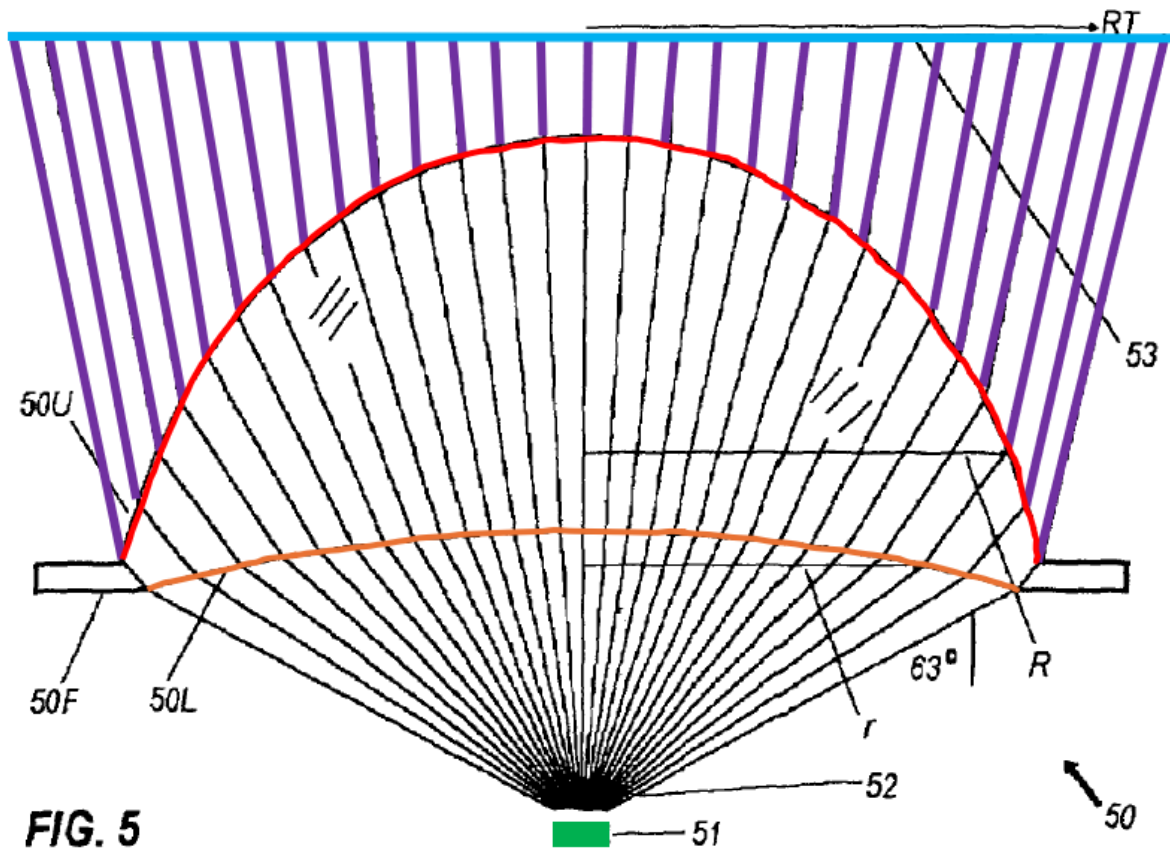
140. In my opinion, Tawa teaches [5] and [6].

141. As I already discussed in Paragraph 100, Tawa discloses that once the light reaches the **second curved surface 18**, it is deflected by refraction and exits device 10 at a different angle with a *uniform intensity*. *See* EX1004, 4:38-40 (“The light emerges the body 14 from the second curved surface 18 as parallel light having a *uniform light intensity distribution 24*.”), 4:59-65 (“Since the total quantity of incident light is equal to the total quantity of *emission light*, and since the *emission light has a uniform light intensity distribution*...”), 10:23-30 (“Each light intensity distribution converting device 10 receives diverging light from the light emitters, and outputs light having a *uniform light intensity distribution*.”).

142. Furthermore, as Tawa shows in Figure 1, the *emission light* illuminates “**surface 28**, which lies in a plane perpendicular to the Z-axis and

which is located beyond the point C” and faces the lens. EX1004, 4:41-47; *see also* EX1004, 5:57-67. **Surface 28** meets the claimed “**target zone**” because it is just like the **target surface 53** shown in Figure 5 of the ’162 Patent.





EX1001, Figure 5.

5. Dependent Claim 8

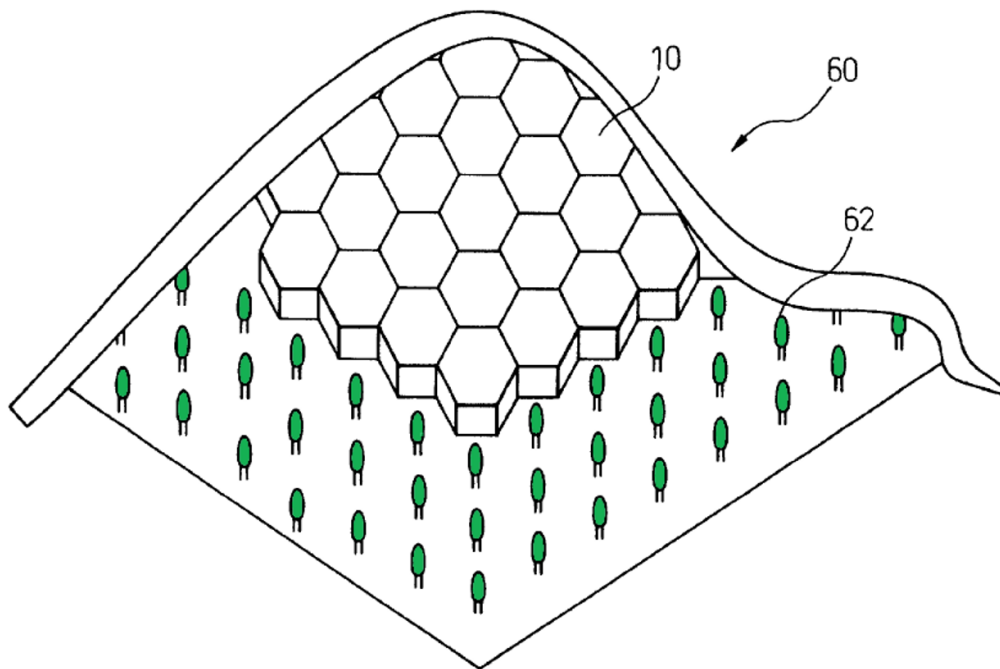
- i. [8] The lens of claim 1 wherein said **light source** is a **light emitting diode**.

143. In my opinion, Tawa teaches [8].

144. As I noted in Paragraphs 76-80, Tawa discloses that that the light source can be a laser. EX1004, 4:9-10 (“**Point A** can be, for example, a laser.”).

However, Tawa also discloses that the that the **light source** can be “composed of light emitters, such as **light emitting diodes**.” EX1004, 10:18-37. *See also*, Paragraph 79. As I already explained in Paragraph 135, a POSITA would have readily been able to use a light emitting diode instead of the laser because Tawa teaches that either of these light sources can be used with the light intensity distribution converting device 10. *See, e.g.*, EX1004, 3:47-6:31, 10:17-37.

Fig. 20



EX1004, Figure 20

6. Dependent Claim 31

- i. [31pre] A light redistribution system comprising, in combination with a lens as defined in claim 1,**

145. In my opinion, Tawa teaches [31pre].

146. Tawa discloses “an embodiment of a lighting apparatus 60 using a light source 62 and the **light intensity distribution converting device 10.**”

EX1004, 10:18-20, Figure 20. *See also* e.g., Paragraphs 68-70.

- ii. [31a] LED means,**

147. In my opinion, Tawa teaches [31a].

148. At the outset, I have been asked to interpret [31a] to recite an LED or any equivalents of an LED.

149. In my opinion, Tawa’s disclosure of “light source 62 composed of light emitters, such as **light emitting diodes**” reads on the claimed “LED means.” EX1004, 10:20-23. *See also* 10:35-37 (explaining “this lighting apparatus can be used when an **LED** array or the like is used for a lighting device...”). *See also* Paragraph 144, discussing claim 8.

iii. [31b] the lens having **a concave lower refracting surface** receiving rays from **said LED means**,

150. In my opinion, Tawa alone or in combination with Shikama teaches [31b].

151. Particularly, if “**a concave lower refracting surface**” refers to the “**entry surface**” as opposed to an additional surface in addition to the “**entry surface**” claimed in claim 1, Tawa alone or in combination with Shikama discloses this limitation for at least the reasons I already discussed in Paragraphs 75-80, 106-111, and 127-130.

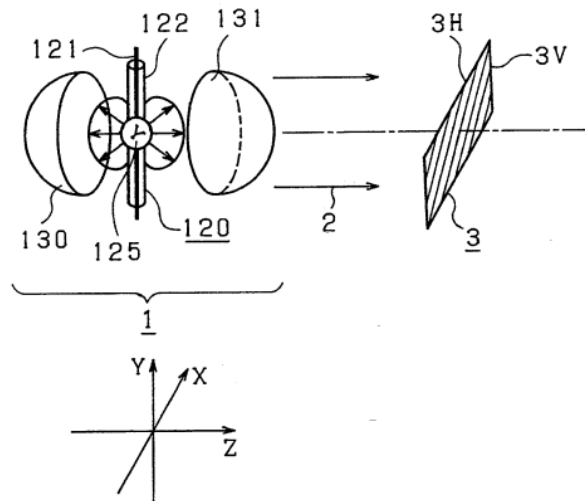
iv. [31c] the lens having **a dome-shaped refracting upper surface**, the curvature of which is one of the following: i) exceeds the curvature of **the lower surface**, ii) is less than the curvature of **the lower surface**,

152. In my opinion, Tawa alone or in combination with Shikama teaches [31c].

153. If the claim term “**a dome-shaped refracting upper surface**” refers to the “**exit surface**” identified in claim 1 as opposed to a separate additional surface), and “**the lower surface**” refers to the “**entry surface**” described in claim 1, then, in my opinion, Tawa alone or in combination with Shikama discloses [31c]. *See also* Paragraphs 72-73, 82-86, 94-95, 100, 107-111, 128-130 and

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EX1005, Figure 17 illustrating a condenser lens with a curved upper portion, i.e., dome-shaped upper surface.



EX1005, Figures 17, 13.

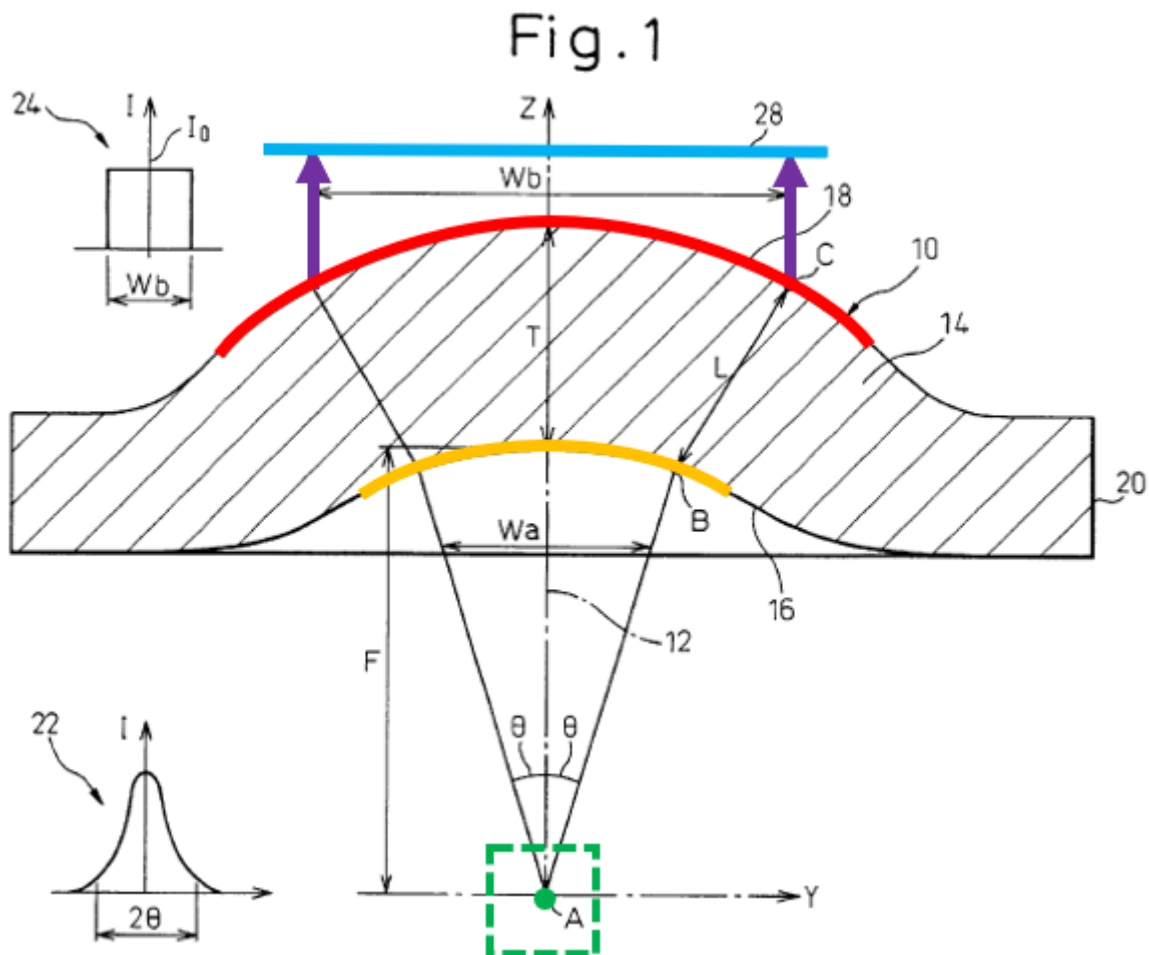
- i. [31d] a target surface receiving rays refracted by said upper surface,

154. In my opinion, Tawa teaches [31d] for at least the same reasons I already discussed in Paragraphs 100, and 141-142.

- ii. [31e] said LED means and said upper and lower surfaces configured to produce a profile of bounded flux at said target surface that provides substantially uniform illuminance.

155. In my opinion, Tawa alone or in combination with Shikama teaches [31e].

156. Tawa discloses that the flux of the *emitted light* is bounded by W_b because the output rays are parallel to the Z-axis. For instance, Tawa discloses that the “inclination of the second curved surface 18 is determined such that the light emerging the body from the point C travels in parallel with the Z-axis.” EX1004, 4:41-43. *See also* Paragraphs 138-139, 141-142, and 144.



EX1004, Figure 1.

7. Independent Claim 39

i. [39pre] An irradiance-redistribution lens comprising

157. In my opinion Tawa teaches [39pre] for at least the same reasons I already discussed in Paragraphs 67-70.

ii. [39a] a transparent dielectric formed as a solid of revolution with an axis about which a planar curved profile-line is swept,

158. In my opinion, Tawa discloses [39a].

159. As I already discussed in Paragraphs 72-73, Tawa teaches “a transparent dielectric formed as a solid of revolution.” Tawa also teaches that this transparent dielectric is “with an axis about which a planar curved profile-line is swept.” Specifically, Tawa discloses that “the light intensity distribution converting device 10 is an optical device, having a rotation-symmetric shape regarding the Z-axis.” EX1004, 4:12–15; *see also* EX1004, 3:55–57. This indicates that Tawa’s lens incorporates a central axis (the Z-axis) around which a planar curved profile-line is rotated, thereby forming the solid of revolution.

160. Additionally, Tawa explains that “[t]he body 14 has a first curved surface 16 transversely extending with respect to the central axis 12” and “a second

curved surface 18 located on the side opposite to the first curved surface 16.”

EX1004, 3:59-65. Together, these curved surfaces define the claimed “planar curved profile-line,” which, when rotated about the central axis 12, produces the solid of revolution described in [39a].

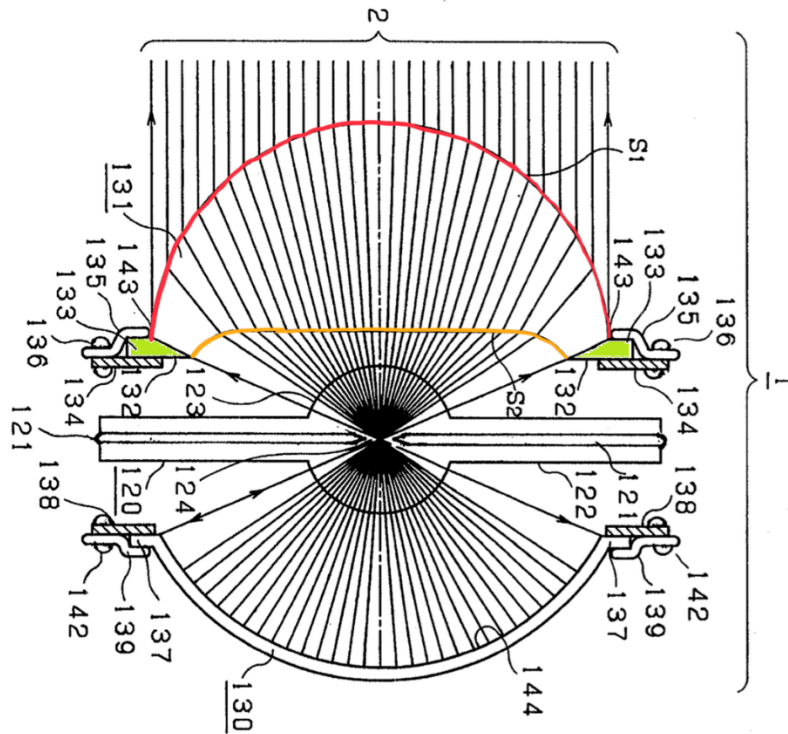
iii. [39b] with external surface area comprised of **an optically active entry surface, an optically active exit surface, and an optically inactive mounting surface;**

161. In my opinion, Tawa alone or in combination with Shikama teaches [39b].

162. As I already disclosed in Paragraphs 72-73, and 75-80, Tawa discloses an “external surface area comprised of **an optically active entry surface**[and] **an optically active exit surface.**”

163. Figure 1 of Tawa illustrates **flange portions** (annotated below). These **flange portions** are positioned in such a way that they do not interact with or influence the optical path of the light traveling through the device from **light source A**. Hence, they are “optically inactive” for the purposes of this light distribution system.

164. Shikama also discloses similar **flange portions**. Particularly, Shikama teaches “**flange 133** integrally formed around the peripheral of the effective diameter thereof.” EX1005, 16:10-12. Furthermore, Shikama expressly teaches that the **flange** is used for mounting, thereby meeting the “optically inactive mounting surface” of [39b]. EX1005, 14:28-32 (“**flange** for holding the lens in



165. In my opinion, a POSITA would have found it obvious to use the side portions of Tawa's lens, which do not receive any incoming light as mounting surfaces, similar to those taught by Shikama. Since the similarly shaped region would be used for to merely mount the lens onto a particular system, a POSITA would have a reasonable expectation of success.

- iv. [39c] **said entry surface** receiving light of nonuniform irradiance from **a compact light source** situated on said axis in a nearby focal zone;

166. In my opinion, Tawa teaches [39c].

167. As an initial matter, I already discussed in Paragraphs 75-80, Tawa teaches that “**said entry surface** receiving light of nonuniform irradiance from **a compact light source**.”

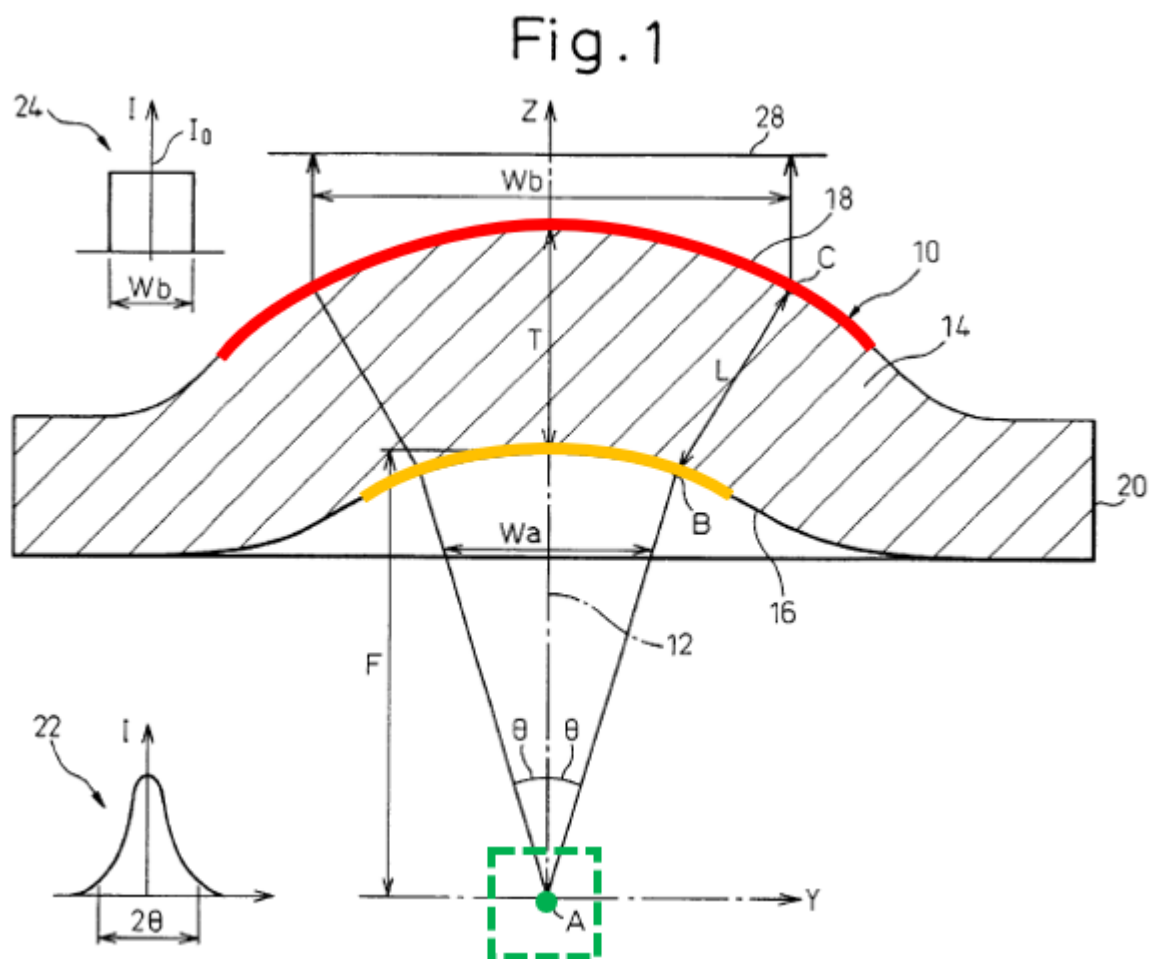
168. Additionally, Tawa teaches that “**point A** is the object focal point,” And therefore is “situated on said axis in a nearby focal zone.” EX1004, 6:39-40; *see also* EX1004, Figures 18A-18B. Similarly, Tawa teaches that the “focal length of the collimator lens 54 is represented by f' ” which is near “the light source 52”). EX1004, 9:48-65. *See also* EX1004, 4:2-6 (“In these figures, the Z-axis passing through the point A defines the optical axis direction...”).

- v. [39d] **said entry surface** having a specific profile that produces refractive deflection of said received light into interiorly propagating light of a different solid angle;

169. In my opinion, Tawa teaches [39d].

170. Specifically, as illustrated in Figure 1 of Tawa, light emitted from source A refracts at the first curved surface 16. The refracted light is directed toward the interior portion of the lens, altering its propagation path to a different

solid angle. Tawa explains this process, stating that “light emitted from the point A passes through the first curved surface 16, refracts at this surface toward the interior portion of the lens at a different solid angle, and propagates therethrough the interior portion of the lens.” EX1004, 4:29–40. *See also* Paragraphs 88-92.



EX1004, Figure 1.

- vi. [39e] **said exit surface** opposing **said entry surface** and receiving **said internally propagating light therefrom**;

171. In my opinion, Tawa teaches [39e] for at least the reasons I already discussed in Paragraphs 82-86, and 94-95.

- vii. [39f] **said exit surface** forming a **pre-specified diverging output beam** from **said internally propagating light**;

172. In my opinion, Tawa teaches [39f] for at least the reasons I already discussed in Paragraphs 82-86.

- viii. [39g] **said entry-surface** deflection spatially distributed such that **said exit surface** receives **said deflected light with predominantly uniform irradiance**,

173. In my opinion, Tawa teaches [39g] for at least the reasons I already discussed in Paragraphs 94-95.

- ix. [39h] **said exit surface** given a specific shape that refractively deflects **said uniform irradiance** into **said output beam**;

174. In my opinion, Tawa teaches [39h] for at least the reasons I already discussed in Paragraph 100.

- x. **[39i] said light source** being sufficiently compact for said specific shapes to be calculated by mathematical integration of the slope distributions required by said refractive deflections,

175. In my opinion, Tawa teaches [39i] for at least the reasons I already discussed in Paragraphs 102-105.

- xi. **[39j] said entry surface** having first concavity facing toward said **light source**,

176. In my opinion, Tawa teaches [39j] for at least the reasons I already discussed in Paragraphs 107-111.

- xii. **[39k] and second concavity facing toward the entry surface**,

177. In my opinion, Tawa teaches [39k] for at least the reasons I already discussed in Paragraphs 113-118.

- xiii. **[39l] said second concavity being substantially greater than said first concavity.**

178. In my opinion, Tawa teaches [39k] for at least the reasons I already discussed in Paragraphs 120-126.

- xiv. [39j]-[39l] **said entry surface** having first concavity facing toward **said light source**, and [said entry surface having] second concavity facing toward the **entry surface**, said second concavity being substantially greater than said first concavity.

179. In my opinion, to the extent it is argued that [39j]-[39l] requires the **entry surface** to have a second concavity facing toward itself, (as opposed to the **exit surface** having the second concavity), Shikama teaches this limitation. Specifically, as I already discussed in Paragraphs 127-129 Shikama's **second surface S2** meets this limitation.

8. Dependent Claim 43

- i. [43pre] A light redistribution system comprising, in combination with a lens as defined in claim 1,

180. In my opinion, Tawa teaches [43pre] for at least the reasons I already discussed in Paragraph 146.

- ii. [43a] **said light source comprising LED means**,

181. In my opinion, Tawa teaches [43a] for at least the reasons I already discussed in Paragraphs 148-149.

- iii. [43b] the lens **concave lower refracting surface** receiving rays from **said LED means**,

182. In my opinion, Tawa teaches [43b] for at least the reasons I already discussed in Paragraph 151.

- iv. [43c] the lens having **a dome-shaped refracting exit surface**, the curvature of which is one of the following:
i) exceeds the curvature of the lower surface, ii) is less than the curvature of **the lower surface**,

183. In my opinion, Tawa teaches [43c] for at least the reasons I already discussed in Paragraph 153.

- v. [43d] there being **a target surface** receiving rays refracted by **said exit surface**,

184. In my opinion, Tawa teaches [43d] for at least the reasons I already discussed in Paragraph 154.

- vi. [43e] **said LED means** and **said entry and exit surfaces** configured to produce a profile of bounded flux at **said target surface** that provides substantially uniform illuminance.

185. In my opinion, Tawa teaches [43e] for at least the reasons I already discussed in Paragraph 156.

**B. Ground II: Tawa In Combination With Shikama And Scharf
Renders Obvious Claim 9**

1. Dependent Claim 9

**i. [9a] Multiple lenses as defined in claim 8 laterally
arrayed in proximity, above multiple light sources,**

186. In my opinion, Tawa teaches [9a].

187. In Figure 20, Tawa shows “an embodiment of a lighting apparatus 60 using a light source 62 and the **light intensity distribution converting device 10**. In this embodiment, the light source 62 composed of light emitters, such as **light emitting diodes**, is a two-dimensional arrangement, and the **light intensity distribution converting devices** of a honeycomb shape are arranged corresponding to the light emitters.” EX1004, 10:18-23. *See also* the generation discussion in Sections IX.A.1 (regarding claim 1) and IX.C.5 (regarding claim 8).

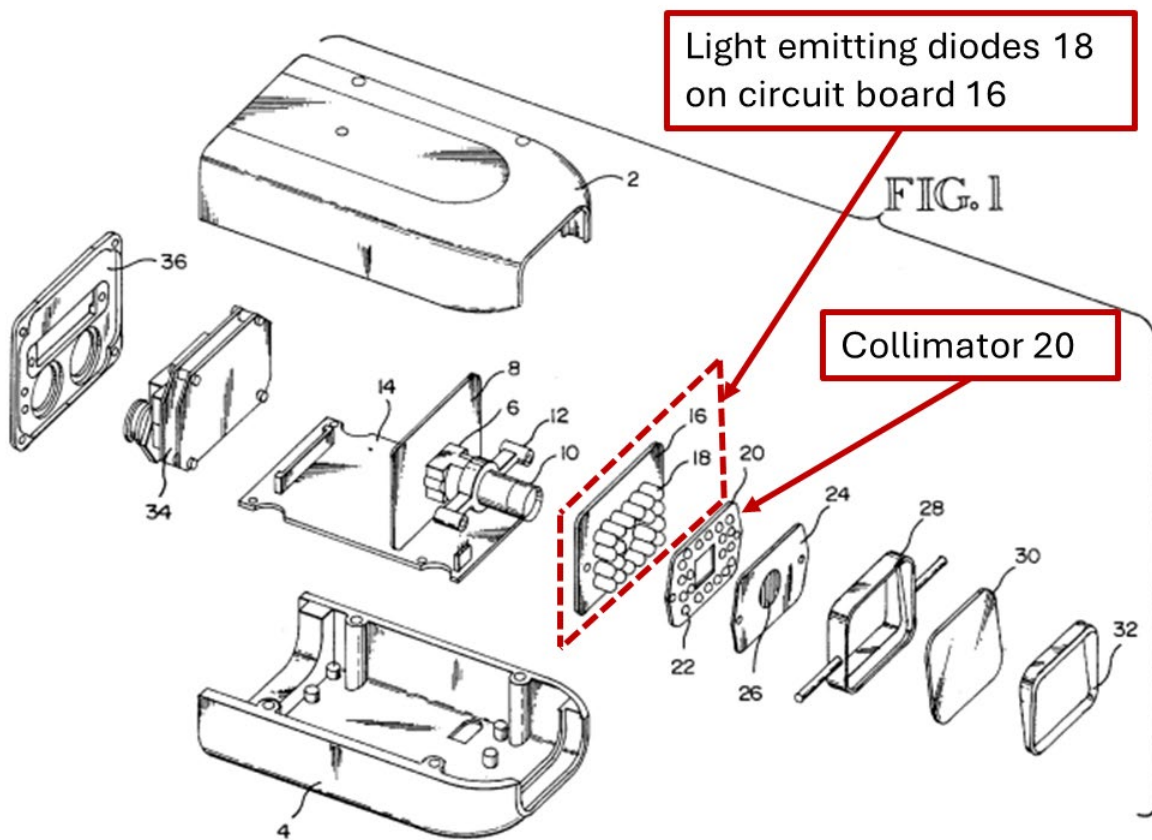
ii. [9b] in association with a common circuit board, and

188. In my opinion, Tawa and Scharf teach [9b].

189. Although Tawa does not explicitly state that its **light emitting diodes (LEDs)** are associated with a common circuit board, a POSITA would have considered this to be an obvious implementation. Scharf provides just one such example. Scharf teaches a two-dimensional array of **LEDs** arranged in alignment

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with collimating lenses to produce uniform, high-intensity illumination on a target surface. EX1006, 2:58-60 (“The light emitted from the **LEDs** is passed through a collimator and an optical diffuser in order to provide a uniform high intensity illumination of the target symbol.”), 3:64-4:36 (“In the present invention collimator 20 is comprised of an array of collimating lenses arranged in the same pattern and in one-to-one alignment with the **LEDs** of array 18.”). Additionally, Scharf specifies that the LEDs are mounted on a common printed circuit board, stating that the “array of light-emitting diodes 18 are arranged in a generally rectangular pattern on LED printed *circuit board 16*.” EX1006, 4:2-4.



EX1006, Figure 1 (annotated).

iii. [9c] having their output beams illuminating the same target.

190. In my opinion, Tawa teaches or at minimum renders obvious [9c].

191. Tawa teaches that its lens can “increase the illuminance in a given direction without light quantity loss” and is useful for applications such as “backlights of a display,” or a lighting device for a microscope.” EX1004, 10:30–

33, 10:35–37. Therefore, Tawa’s lighting apparatus is designed to illuminate specific targets, such as a display surface or a microscope sample, with their respective output beams.

2. Reasons To Combine Tawa And Shikama With Scharf

192. In my opinion, and for at least the following reasons, a POSITA would have been motivated to arrange the light-emitting diodes (LEDs) in Tawa’s lighting apparatus on a common circuit board, as taught by Scharf, with a reasonable expectation of success.

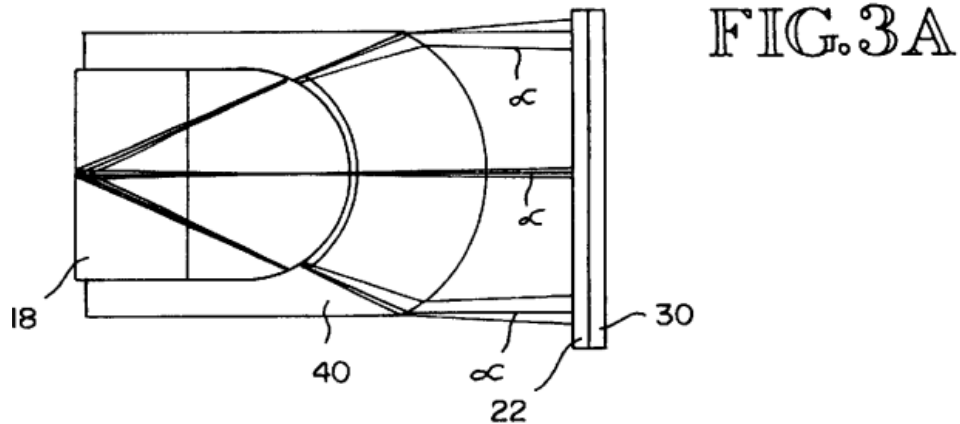
193. As an initial matter, both Tawa and Scharf describe arrays of LEDs with lenses positioned over each LED to manage light output. For instance, Tawa teaches that “the light source 62 composed of light emitters, such as light emitting diodes, is a two-dimensional arrangement, and the light intensity distribution converting devices of a honeycomb shape are arranged corresponding to the light emitters.” EX1004, 10:20-27, Fig. 20. Similarly Scharf teaches that “collimator 20 is comprised of an array of collimating lenses arranged in the same pattern and in one-to-one alignment with the LEDs of array 18.”). A POSITA would have readily recognized that the LEDs in Tawa, just like the LEDs in Scharf, need electrical connections to operate. To achieve this, a POSITA would recognize that arranging

the LEDs on a circuit board, as described in Scharf, is a practical and commonly used method. This approach is straightforward and relies on established techniques that ensure the LEDs are properly connected and able to function. Setting up the LEDs in this way is one of a limited number of predictable configurations that would allow for the creation of a working LED array capable of emitting light.

194. Furthermore, both Tawa and Scharf are directed to devices that produce uniform illumination on a target surface. For instance, Tawa teaches that “[t]he light emerges the body 14 from the second curved surface 18 as parallel *light having a uniform light intensity distribution* 24.”). EX1004 4:38-40. *See also* EX1004, 4:59-65, and 10:23-30 where Tawa explains that “the emission light has a uniform light intensity distribution.” And Scharf also clearly states that “[t]he light emitted from the LEDs is passed through a collimator and an optical diffuser in order to provide a *uniform high intensity illumination of the target symbol*.” A POSITA would have known that the LEDs may be arranged on a circuit board, because such configurations were well-known for systems where uniform light distribution is desired. A combination of Tawa and Shikama would therefore be a straightforward combination of known elements that would achieve the expected outcome of producing uniform illumination. Such a combination would not require

any nonobvious step, as it uses established methods and known designs to create a predictable result.

195. I already explained in Paragraphs 131-136, why a POSITA would have been combined the disclosures of Tawa and Shikama. Moreover, Scharf, like Tawa and Shikama, uses lenses that collimate light to create uniform and directed illumination. EX1004, 4:47-50 (“Consequently, this light intensity distribution converting device 10 ... serves as a collimator lens.”); EX1005, 4:29-30 (“It is an object of the invention to provide a condenser lens...”), 10:55-58 (“The numeral 2 indicates a parallel beam of light which was ... collimated by the condenser lens 131.”); EX1006, 4:11-14 (“In the present invention collimator 20 is comprised of an array of collimating lenses arranged in the same pattern and in one-to-one alignment with the LEDs of array 18.”). Scharf further specifies that its collimating lenses have shapes comparable to those described in Tawa and Shikama. EX1006, 4:56-62 (“FIG. 3A illustrates the method utilizing a meniscus-shaped collimator lens segment 40 to capture the illumination from the LED array 18 and collimate the rays α ... The mathematical description of the collection optic is a cubic spline, a spherical, or conical surface that is rotationally symmetric about the optical axis of the LED.”).



EX1006, Figure 3A.

196. Given these similarities, using Scharf's circuit board configuration in Tawa's lighting device would simply involve applying a known technique to improve a similar device in the same manner, leading to predictable results.

197. Lastly, arranging LEDs on a circuit board, as disclosed in Scharf, is one of a limited number of well-known solutions for integrating LED arrays in a lighting device. This arrangement ensures electrical connections and power delivery, both of which were standard and widely understood in the field of LED-based lighting systems. A POSITA would have reasonably expected success in making such a modification to Tawa's device.

C. Grounds III and IV: Tawa Anticipates And/Or Renders Obvious Claims 1, 4-6, 8, 9, 31, 39, And 43.

i. [1pre]: An irradiance-redistribution illumination lens comprising

198. Tawa teaches [1pre] for at least the same reasons I already discussed in Paragraphs 67-70.

ii. [1a] a transparent dielectric solid of revolution with external surface area predominantly comprised of

199. Tawa teaches [1a] for at least the same reasons I already discussed in Paragraphs 71-73.

iii. [1b] an entry surface that receives light of nonuniform irradiance from a nearby compact light source and

200. Tawa teaches and/or renders obvious [1b] for at least the same reasons I already discussed in Paragraphs 74-80.

iv. [1c] of an opposing exit surface that forms from said received light a pre-specified diverging output beam;

201. Tawa teaches and/or renders obvious [1c] for at least the same reasons I already discussed in Paragraphs 81-86.

- v. [1d] **said entry surface** given a specific profile that refractively deflects said received light into a different solid angle,

202. Tawa teaches [1d] for at least the same reasons I already discussed in Paragraphs 87-92.

- vi. [1e] **said entry surface** spatially distributed such that **said exit surface** receives said deflected light with predominantly uniform irradiance,

203. Tawa teaches and/or renders obvious [1e] for at least the same reasons I already discussed in Paragraphs 93-95.

- vii. [1f] **said exit surface** given a specific shape that refractively deflects said uniform irradiance into **said output beam**;

204. Tawa teaches [1f] for at least the same reasons I already discussed in Paragraphs 99-100.

- viii. [1g] **said light source** being sufficiently compact for said specific shapes to be calculated by mathematical integration of the slope distributions required by said refractive deflections,

205. Tawa teaches [1g] for at least the same reasons I already discussed in Paragraphs 101-105.

207. As is clearly illustrated in Figures 1 and 4, the **first curved surface 16** includes a portion with a concavity that faces the light source i.e., the **light source at point A**. This is further supported by Tawa's disclosure that "[t]he first curved surface 16 is defined by a generally shallow rounded concave surface...").

EX1004, 4:20-21.

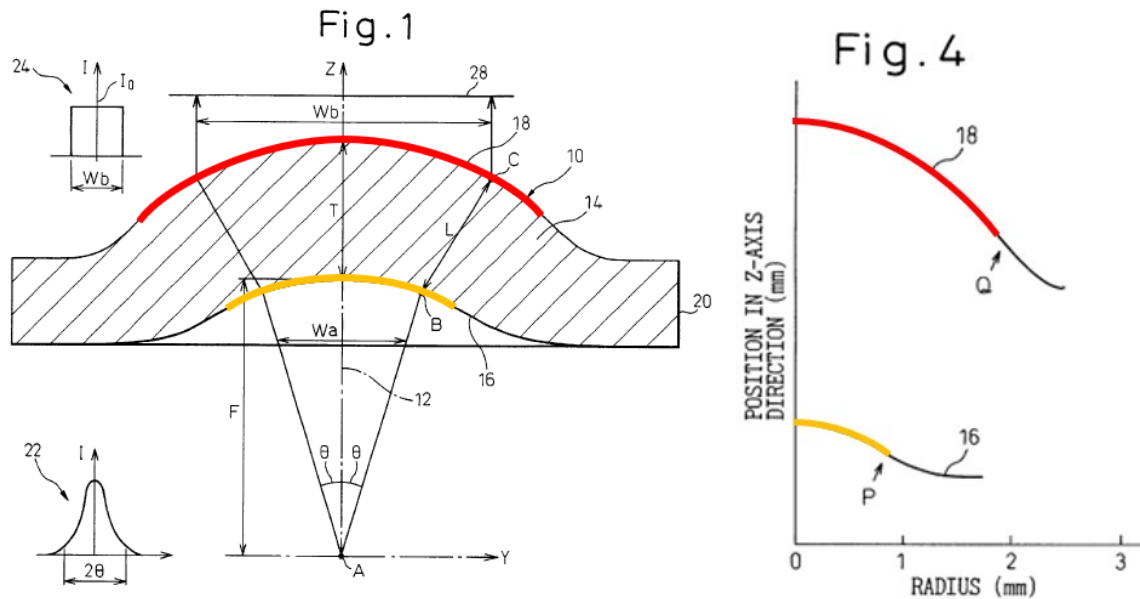


EX1004, Figures 1, 4.

- i. [1i] and [said **exit surface** having] second concavity facing toward the **entry surface**,

208. In my opinion, if it is argued that the “second concavity” can exist on any portion of the “**exit surface**,” Tawa teaches [1h].

209. As is clearly illustrated in Figures 1 and 4, the **second curved surface 18** includes a portion where the concavity faces the **first curved surface 16**. And Tawa teaches that “the **second curved surface 18** is defined by a generally rounded convex surface.” EX1004, 4:21-22. Note that as I discussed in Paragraph 37, lenses like the one shown in Tawa are sometimes referred to as “convex-concave lenses” because their shape is defined from the “outside” of the lens. This naming convention explains why Tawa describes the **second curved surface 18** as having a “convex surface” when viewed from the “top of the lens,” while the same surface appears concave when observed from the perspective of the **first curved surface 16**.



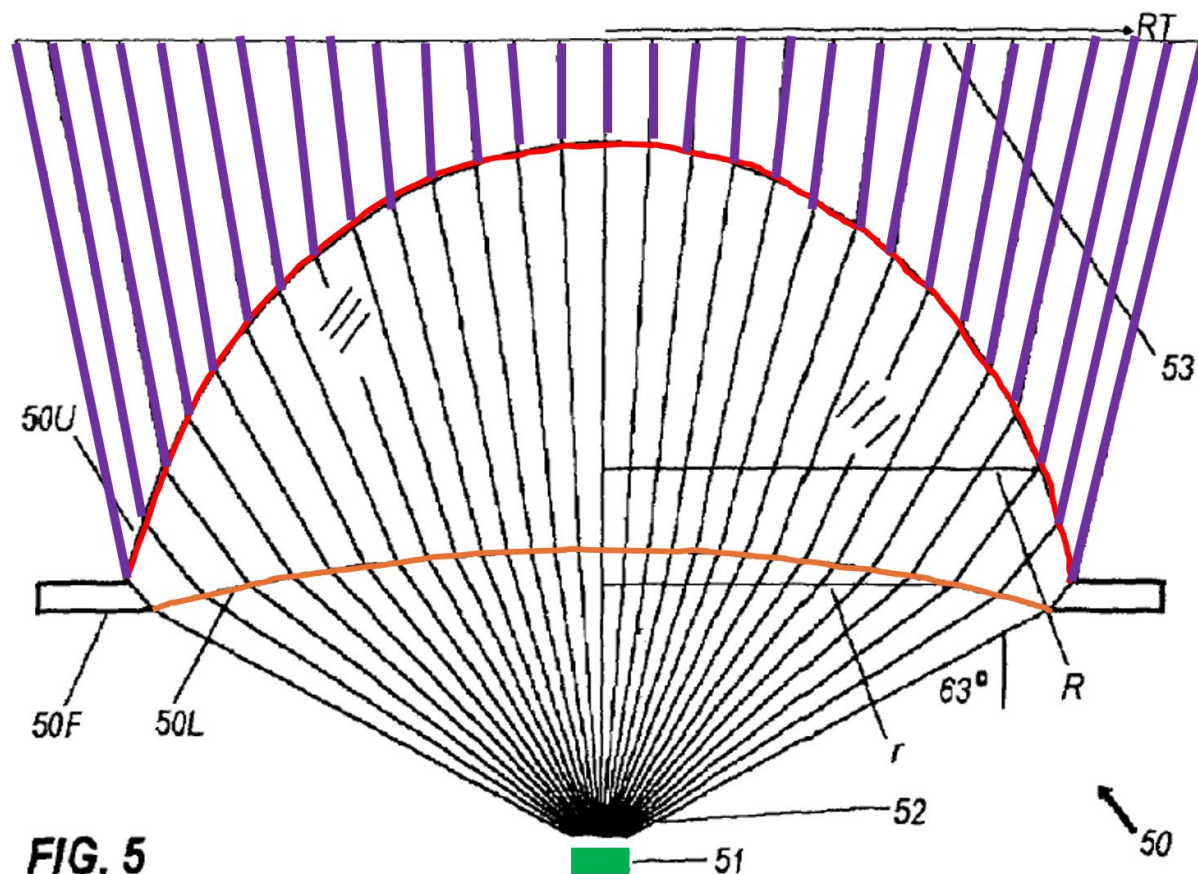
EX1004, Figures. 1, 4.

i. **[1j] said second concavity being substantially greater than said first concavity.**

210. In my opinion, if it is argued that the term “concavity” does not refer to the curvature of the surfaces of the lens, but instead to the portion of the lens along the radial direction, Tawa teaches [1j].

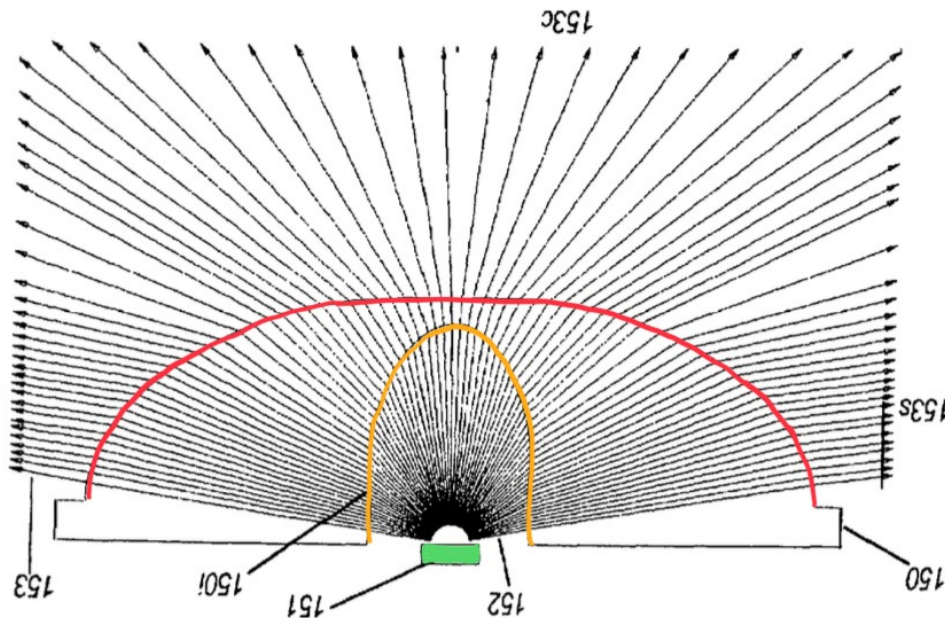
211. As an initial matter, limitations [1j]-[1i] were added during prosecution of the '162 Patent by an amendment to overcome cited prior art. EX1003, 169-170. In particular, the Applicant pointed to Figure 5 of the '162 Patent and argued that the prior art “lack suggestion of such lesser and greater concave surfaces.” EX1003, 186. Specifically, the Applicant stated that “Base

claim 1 now further defines over the art, including Minano.... In this regard, the entry and exit concave surfaces are for example seen at 50L and 50U in Fig. 5, the light source being at 51. Note also beam refractions. Minano configurations lack suggestion of such lesser and greater concave surfaces, as claimed, ...”). EX1003, 186.



EX1001, Figure 5.

212. The File History of the '162 Patent does not indicate whether any other embodiments read on these claim limitations. Nevertheless, in Figure 15A, there is an embodiment where the **exit surface** has a smaller concavity than the **entry surface**, if the size of the concavity is measured by the “curvature.



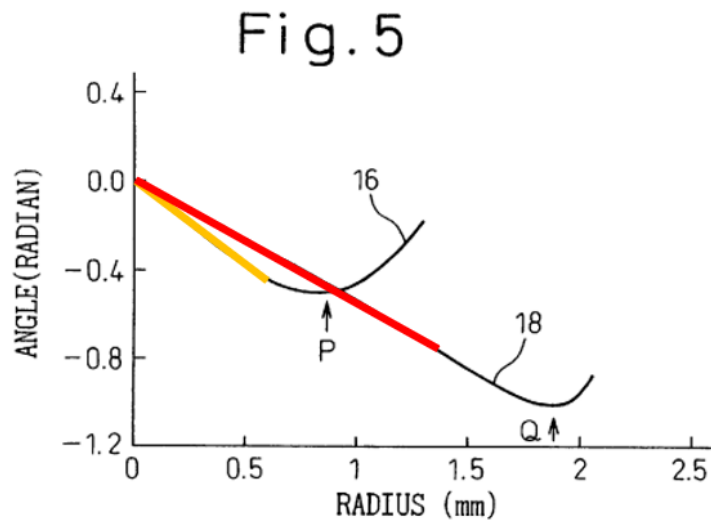
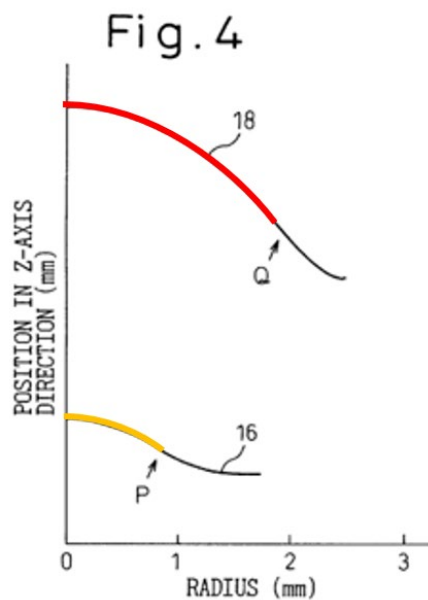
EX1001, Figure 15A.

213. I recognize that the noted amendment might exclude the lens shown in Figure 15. However, to the extent that it is argued that the independent claim 1 reads on the lens shown in Figure 15A, Tawa teaches [1j].

214. Specifically, Tawa, like the embodiment in Figure 15A, provides an embodiment where the concave portion of the “**second concavity**” spans a greater

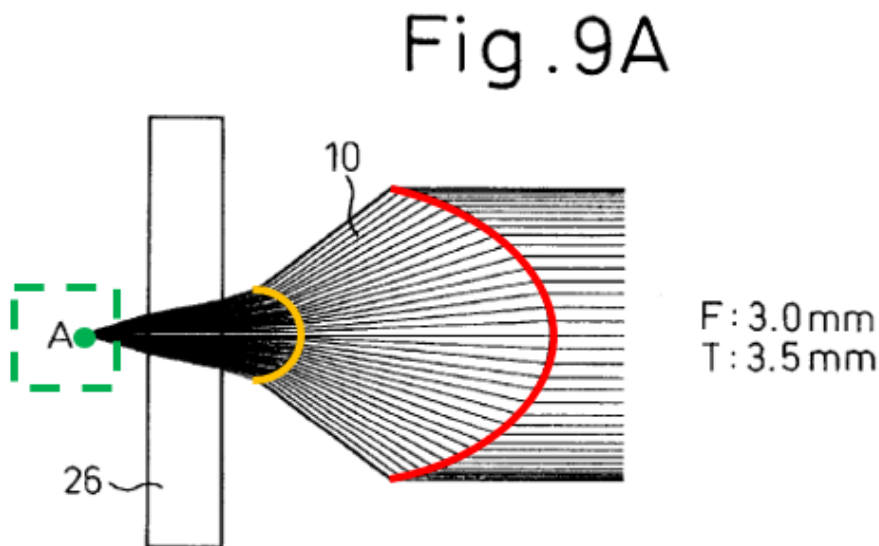
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portion of the lens along the radial direction than the concave portion of the “**first concavity**.” In Figure 4, Tawa “shows the shape of the first and second curved surface **16** and **18** of the light intensity distribution converting device 10 shown in FIG. 2.” EX1004, 6:12-14. Figure 4 also provides the inflection points for the **first curved surface 16** and the **second curved surface 18**, marked as P and Q, respectively. As shown in Figures 4 and 5, the concave portion of the **second curved surface 18** extends over a larger area of the lens, with a radius of approximately 1.8 mm, compared to the concave portion of the **first curved surface 16**, which has a smaller radius of approximately 0.8 mm.



EX1004, Figures 4 and 5.

215. Additionally, or alternatively Tawa in Figure 9A shows an embodiment where the entirety of the **first curved surface 16** and the **second curved surface 18** represent the concavity and the “**second concavity**” spans a greater portion of the lens along the radial direction than the concave portion of the “**first concavity**.”



EX1004, Figure 9A.

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

216. In my opinion, a POSITA would have understood that any of Tawa's embodiments could be combined with one another, with the expectation that such

combinations would work effectively and achieve the intended results for at least the reasons I already discussed in Paragraph 132.

3. Dependent Claim 4

- i. [4] The lens of claim 1 wherein **said output beam** has **predominantly uniform intensity within a predetermined angular limit.**

217. Tawa teaches the added limitation of [4] for at least the same reasons I already discussed in Paragraphs 137-139.

4. Dependent Claims 5-6

- i. [5] The lens of claim 1 wherein said output beam **uniformly illuminates a target zone.**

[6] The lens of claim 5 wherein said **target zone** is on a plane facing said lens.

218. Tawa teaches the added limitation of [5] for at least the same reasons I already discussed in Paragraphs 140-142.

5. Dependent Claim 8

- i. [8] The lens of claim 1 wherein said **light source** is a **light emitting diode.**

219. Tawa teaches and/or renders obvious the added limitation of [8] for at least the same reasons I already discussed in Paragraphs 143-144.

6. Dependent Claim 31

- i. [31pre] A light redistribution system comprising, in combination with a lens as defined in claim 1,

220. Tawa teaches [31pre] for at least the same reasons I already discussed in Paragraphs 145-146.

- ii. [31a] LED means,

221. Tawa teaches and/or renders obvious [31a] for at least the same reasons I already discussed in Paragraphs 147-149.

- iii. [31b] the lens having a concave lower refracting surface receiving rays from said LED means,

222. Tawa teaches and/or renders obvious [31b] for at least the same reasons I already discussed in Paragraphs 150-151.

- iv. [31c] the lens having a dome-shaped refracting upper surface, the curvature of which is one of the following:
i) exceeds the curvature of the lower surface, ii) is less than the curvature of the lower surface,

223. Tawa teaches and/or renders obvious [31c] for at least the same reasons I already discussed in Paragraphs 152-153, and 206-215.

- v. [31d] **a target surface** receiving rays refracted by **said upper surface**,

224. Tawa teaches [31d] for at least the same reasons I already discussed in Paragraph 154.

- vi. [31e] **said LED means** and **said upper** and **lower surfaces** configured to produce a profile of bounded **flux** at **said target surface** that provides substantially uniform illuminance.

225. Tawa teaches and/or renders obvious [31e] for at least the same reasons I already discussed in Paragraphs 155-156.

7. Independent Claim 39

- i. [39pre] **An irradiance-redistribution lens comprising**

226. Tawa teaches [39pre] for at least the same reasons I already discussed in Paragraph 157.

- ii. [39a] **a transparent dielectric formed as a solid of revolution with an axis about which a planar curved profile-line is swept,**

227. Tawa teaches [39a] for at least the same reasons I already discussed in Paragraphs 158-160.

- iii. [39b] with external surface area comprised of **an optically active entry surface, an optically active exit surface, and an optically inactive mounting surface;**

228. Tawa teaches and/or renders obvious [39b] for at least the same reasons I already discussed in Paragraphs 161-165.

- iv. [39c] **said entry surface** receiving light of nonuniform irradiance from **a compact light source** situated on said axis in a nearby focal zone;

229. Tawa teaches and/or renders obvious [39c] for at least the same reasons I already discussed in Paragraphs 166-168.

- v. [39d] **said entry surface** having a specific profile that produces refractive deflection of said received light into interiorly propagating light of a different solid angle;

230. Tawa teaches [39d] for at least the same reasons I already discussed in Paragraphs 169-170.

- vi. [39e] **said exit surface** opposing **said entry surface** and receiving said internally propagating light therefrom;

231. Tawa teaches and/or renders obvious [39e] for at least the same reasons I already discussed in Paragraph 171.

- vii. [39f] **said exit surface** forming a **pre-specified diverging output beam** from said internally propagating light;

232. Tawa teaches and/or renders obvious [39f] for at least the same reasons I already discussed in Paragraph 172.

- viii. [39g] **said entry-surface** deflection spatially distributed such that **said exit surface** receives said deflected light with predominantly uniform irradiance,

233. Tawa teaches and/or renders obvious [39g] for at least the same reasons I already discussed in Paragraph 173.

- ix. [39h] **said exit surface** given a specific shape that refractively deflects said uniform irradiance into **said output beam**;

234. Tawa teaches [39h] for at least the same reasons I already discussed in Paragraph 174.

- x. [39i] **said light source** being sufficiently compact for said specific shapes to be calculated by mathematical integration of the slope distributions required by said refractive deflections,

235. Tawa teaches and/or renders obvious [39i] for at least the same reasons I already discussed in Paragraphs 175.

- xi. [39j] said entry surface having first concavity facing toward said light source,**

236. Tawa teaches [39j] for at least the same reasons I already discussed in Paragraphs 206-207.

- xii. [39k] and [said exit surface having] second concavity facing toward the entry surface,**

237. Tawa teaches [39k] for at least the same reasons I already discussed in Paragraphs 208-209.

- xiii. [39l] said second concavity being substantially greater than said first concavity.**

238. Tawa teaches [39l] for at least the same reasons I already discussed in Paragraphs 210-215.

8. Dependent Claim 43

- i. [43pre] A light redistribution system comprising, in combination with a lens as defined in claim 1,**

239. Tawa teaches [43pre] for at least the same reasons I already discussed in Paragraph 220.

- ii. [43a] said light source comprising LED means,**

240. Tawa teaches and/or renders obvious [43a] for at least the same reasons I already discussed in Paragraph 221.

- iii. [43b] the lens **concave lower refracting surface** receiving rays from **said LED means**,

241. Tawa teaches and/or renders obvious [43b] for at least the same reasons I already discussed in Paragraph 222.

- iv. [43c] the lens having **a dome-shaped refracting exit surface**, the curvature of which is one of the following:
i) exceeds the curvature of the lower surface, ii) is less than the curvature of **the lower surface**,

242. Tawa teaches and/or renders obvious [43c] for at least the same reasons I already discussed in Paragraph 223.

- v. [43d] there being **a target surface** receiving rays refracted by **said exit surface**,

243. Tawa teaches [43d] for at least the same reasons I already discussed in Paragraph 224.

- vi. [43e] **said LED means** and **said entry and exit surfaces** configured to produce a profile of bounded flux at **said target surface** that provides substantially uniform illuminance.

244. Tawa teaches and/or renders obvious [43e] for at least the same reasons I already discussed in Paragraph 225.

D. Ground V: Tawa In Combination With Scharf Renders Obvious Claim 9

1. Dependent Claim 9

- i. [9a] Multiple lenses as defined in claim 8 laterally arrayed in proximity, above multiple light sources,**

245. Tawa teaches and/or renders obvious [9a] for at least the same reasons I already discussed in Paragraphs 186-187.

- ii. [9b] in association with a common circuit board, and**

246. Tawa in combination with Scharf renders obvious [9b] for at least the same reasons I already discussed in Paragraphs 188-189.

- iii. [9c] having their output beams illuminating the same target.**

247. Tawa teaches and/or renders obvious [9c] for at least the same reasons I already discussed in Paragraphs 190-191.

2. Reasons To Combine Tawa With Scharf

248. A POSITA would have been able to and motivated to combine Tawa with Scharf for at least the reasons I already discussed in Paragraphs 192-197.

X. Availability for Cross-Examination

249. 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

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

XI. Right to Supplement

250. 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

251. 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.

January 27, 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
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CHRONOLOGY OF EDUCATION

Colleges and universities attended:

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

Institutions, degrees and dates awarded:

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

Title of doctoral dissertation and name of advisor:

“Design and construction of a modular gamma camera”

Advisor: Dr. Harrison Barrett

Major Fields:

Optical Sciences and Electrical Engineering

CHRONOLOGY OF EMPLOYMENT

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

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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

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- and Local Plasmons. J. Tominaga and D. P. Tsai, eds., (Springer-Verlag, Berlin, Germany 2003) pp. 119-39 (2003).
6. E. P. Walker and T.D. Milster, "Beam Shaping for Optical Data Storage," in Laser Beam Shaping Applications, F. M. Dickey, S. C. Holswade and D. L. Shealy, eds. (Marcel Decker, New York, 2005, 2014 and 2017).
 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).
 8. T. D. Milster and G. T. Sincerbox, "Future of Optical Data Storage," in McGraw-Hill 2002 Yearbook of Science and Technology, pp. 252-255 (2002).
 9. T. D. Milster, "Optical Data Storage," in Handbook of Laser Technology and Applications, Volume 3: Applications, C E Webb, University of Oxford, UK; J D C Jones, eds., (Institute of Physics Publishing, Bristol, UK, 2003). pp. 2391-2420 (2003).
 10. T.D. Milster and G. T. Sincerbox, "Optical Data Storage," in McGraw-Hill Encyclopedia of Science and Technology, Vol 12, pp. 457-461 (2001).
 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.
5. Apai, D., T. D. Milster, D. Kim, A. Bixel, G. Schneider, B. Rackham, and J. Arenberg. "A Search for Life in a Thousand Earths: The Nautilus Space Observatory." *Bulletin of the American Astronomical Society* 53, no. 3 (2021): 1206.
6. Milster, Tom D., Young Sik Kim, Zichan Wang, and Kira Purvin. "Multiple-order diffractive engineered surface lenses." *Applied Optics* 59, no. 26 (2020): 7900-7906.
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.

Peer-Reviewed Papers 2010s:

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

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

2. Apai, Dániel, Tom D. Milster, Dae Wook Kim, Alex Bixel, Glenn Schneider, Rongguang Liang, and Jonathan Arenberg. "A thousand earths: a very large aperture, ultralight space telescope array for atmospheric biosignature surveys." *The Astronomical Journal* 158, no. 2 (2019): 83.
3. Eguchi, Akira, John Brewer, and Tom D. Milster. "Optimization of random phase diversity for adaptive optics using an LCoS spatial light modulator." *Applied Optics* 58, no. 25 (2019): 6834-6840.
4. Gao, Weichuan, and Tom Milster. "Strehl ratio for optical systems with ultrafast illumination." *Optics express* 26, no. 14 (2018): 18028-18042.
5. Gao, Weichuan, Emily Finan, Geon-Hee Kim, Youngsik Kim, and Thomas D. Milster. "Optical design and system characterization of an imaging microscope at 121.6 nm." *Optical Engineering* 57, no. 3 (2018): 035101-035101.
6. Summitt, Chris, Sunglin Wang, Soha Namnabat, Lee Johnson, Tom Milster, and Yuzuru Takashima. "Fast fabrication of polymer out-of-plane optical coupler by gray-scale lithography." *Optics Express* 25, no. 15 (2017): 17960-17970.
7. Eguchi, Akira, Phat Lu, Youngsik Kim, and Tom D. Milster. "Characterization of emission from aggregated gold nanoparticles excited nonlinearly by 1560-nm femtosecond laser." *Journal of Nanophotonics* 11, no. 4 (2017): 046007-046007.
8. Pacheco, Shaun, Tom Milster, and Rongguang Liang. "Analysis of grating doublets for achromatic beam-splitting." *Optics Express* 23, no. 17 (2015): 22939-22952.
9. Pacheco, Shaun, Basel Salahieh, Tom Milster, Jeffrey J. Rodriguez, and Rongguang Liang. "Transfer function analysis in epi-illumination Fourier ptychography." *Optics letters* 40, no. 22 (2015): 5343-5346.
10. Pacheco, Shaun, Jonathan F. Brand, Melissa Zaveron, Tom Milster, and Rongguang Liang. "Sensitivity analysis and optimization method for the fabrication of one-dimensional beam-splitting phase gratings." *Optics Express* 23, no. 9 (2015): 11771-11782.
11. Ament, Craig, Lee Johnson, Andreas Schmitt-Sody, Adrian Lucero, Thomas Milster, and Pavel Polynkin. "Generation of multiterawatt vortex laser beams." *Applied Optics* 53, no. 15 (2014): 3355-3360.
12. Guyon, Olivier, Josh A. Eisner, Roger Angel, Neville J. Woolf, Eduardo A. Bendek, Thomas D. Milster, S. Mark Ammons et al. "Simultaneous exoplanet characterization and deep wide-field imaging with a diffractive pupil telescope." *The Astrophysical Journal* 767, no. 1 (2013): 11.
13. Kim, Youngsik, Phat Lu, Tom D. Milster, and Khanh Kieu. "Hyper-numerical aperture (NA= 2.8) microscope using $\lambda = 1.56 \mu\text{m}$ femtosecond source for multi-photon imaging." *Biomedical optics express* 4, no. 10 (2013): 1786-1794.
14. Park, Jong Rak, Justin Sierchio, Melissa Zaveron, Youngsik Kim, and Tom D. Milster. "Characterization of photoresist and simulation of a developed resist profile for the fabrication of gray-scale diffractive optic elements." *Optical Engineering* 51, no. 2 (2012): 023401-023401.
15. Guyon, Olivier, Eduardo A. Bendek, Josh A. Eisner, Roger Angel, Neville J. Woolf, Thomas D. Milster, S. Mark Ammons et al. "High-precision astrometry with a diffractive pupil telescope." *The Astrophysical Journal Supplement Series* 200, no. 2 (2012): 11.
16. Park, Jong Rak, Youngsik Kim, and Tom Milster. "Analysis of a laser direct writer with an acousto-optic modulator employed for dose gray-scaling." *Journal of the Korean*

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Physical Society 59, no. 5 (2011): 3289-3292.
17. T Noble, H. D., W. T. Lam, W. Dallas, R. A. Chipman, I. Matsubara, Y. Unno, S. C. McClain, P. Khulbe, D. Hansen, and T. D. Milster. "Square-wave retarder for polarization computer-generated holography." *Applied Optics* 50, no. 20 (2011): 3703-3710.
 18. George, Anoop, and Tom D. Milster. "Spot distribution measurement using a scanning nanoslit." *Applied Optics* 50, no. 24 (2011): 4746-4754.
 19. Tamkin, John M., and Tom D. Milster. "Effects of structured mid-spatial frequency surface errors on image performance." *Applied optics* 49, no. 33 (2010): 6522-6536.
 20. Tamkin, John M., William J. Dallas, and Tom D. Milster. "Theory of point-spread function artifacts due to structured mid-spatial frequency surface errors." *Applied Optics* 49, no. 25 (2010): 4814-4824.
 21. George, Anoop, and Tom D. Milster. "Characteristics of a scanning nano-slit image sensor for line-and-space patterns." *Applied optics* 49, no. 19 (2010): 3821-3830.
 22. Zhang, Jun, Seung-Hune Yang, Youngsik Kim, Tom D. Milster, and Jong Rak Park. "Microscope system for Blu-ray disc samples." *Applied optics* 49, no. 36 (2010): 6878-6887.
 23. Noble, H., E. Ford, W. Dallas, R. A. Chipman, I. Matsubara, Y. Unno, S. McClain, P. Khulbe, D. Hansen, and T. D. Milster. "Polarization synthesis by computer-generated holography using orthogonally polarized and correlated speckle patterns." *Optics letters* 35, no. 20 (2010): 3423-3425.
 24. Tamkin, John M., Tom D. Milster, and William Dallas. "Theory of modulation transfer function artifacts due to mid-spatial-frequency errors and its application to optical tolerancing." *Applied optics* 49, no. 25 (2010): 4825-4835.
 25. Yang, Seung-Hune, Tom Milster, Jong Rak Park, and Jun Zhang. "High-numerical-aperture image simulation using Babinet's principle." *JOSA A* 27, no. 5 (2010): 1012-1023.
 26. Zhang, Jun, Yongsik Kim, Seung-Hune Yang, and Tom D. Milster. "Illumination artifacts in hyper-NA vector imaging." *JOSA A* 27, no. 10 (2010): 2272-2284.
 27. Yang, Seung-Hune, Tom Milster, Jun Zhang, and Tao Chen. "Characteristics of evanescent polarization imaging." *Journal of Modern Optics* 57, no. 9 (2010): 783-797.

Peer-Reviewed Papers 2000s:

1. Zhang, Jun, Yullin Kim, Youngsik Kim, Roberto Valencia, Tom D. Milster, and Dave Dozer. "High resolution semiconductor inspection by using solid immersion lenses." *Japanese journal of applied physics* 48, no. 3S1 (2009): 03A043.
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.
3. Kim, Youngsik, Jun Zhang, and Tom D. Milster. "GaP solid immersion lens based on diffraction." *Japanese Journal of Applied Physics* 48, no. 3S1 (2009): 03A047.
4. Kang, Dongyel, and Tom D. Milster. "Simulation method for non-Gaussian speckle in a partially coherent system." *JOSA A* 26, no. 9 (2009): 1954-1960.
5. Kang, Dongyel, and Tom D. Milster. "Effect of fractal rough-surface Hurst exponent on speckle in imaging systems." *Optics letters* 34, no. 20 (2009): 3247-3249.
6. Kang, Dongyel, Eric Clarkson, and Tom D. Milster. "Effect of optical aberration on

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Gaussian laser speckle." *Optics Express* 17, no. 5 (2009): 3084-3100.
7. Aspnes, Eric, Tom D. Milster, and Koen Visscher. "Optical force model based on sequential ray tracing." *Applied optics* 48, no. 9 (2009): 1642-1650.
 8. Lang, Matthew, Eric Aspnes, and Tom D. Milster. "Geometrical analysis of third-order aberrations for a solid immersion lens." *Optics Express* 16, no. 24 (2008): 20008-20028.
 9. Chen, Tao, Tom D. Milster, Seung-Hune Yang, and Delbert Hansen. "Evanescent imaging with induced polarization by using a solid immersion lens." *Optics letters* 32, no. 2 (2007): 124-126.
 10. Lang, Matthew, Tom D. Milster, Takahisa Minamitani, and Gregg Borek. "Investigation of micro solid immersion lens mounting systems." *Japanese journal of applied physics* 46, no. 6S (2007): 3737.
 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.
 12. Fukutake, Naoki, and Tom D. Milster. "Proposal of three-dimensional phase contrast holographic microscopy." *Optics Express* 15, no. 20 (2007): 12662-12679.
 13. Lang, Matthew, and Tom D. Milster. "Investigation of Optics in the 10–200 μ m Size Regime." *Optical review* 14 (2007): 189-193.
 14. Choi, Narak, Seongbo Shim, Tom D. Milster, and Jaisoon Kim. "Optical design for the optimum solid immersion lens with high numerical aperture and large tolerance." *Japanese journal of applied physics* 46, no. 6S (2007): 3724.
 15. Chen, Tao, Tom Milster, Sang-Ki Park, Brendan McCarthy, Dror Sarid, Christian Poweleit, and Jose Menendez. "Near-field solid immersion lens microscope with advanced compact mechanical design." *Optical engineering* 45, no. 10 (2006): 103002-103002.
 16. Choi, Taeyoung, and Tom D. Milster. "Change in data marks and groove structures of compact recordable disks in response to a high power laser beam." *Optical Engineering* 45, no. 6 (2006): 064302-064302.
 17. Milster, Tom D., and Yan Zhang. "Materials for multilayer recording." *MRS bulletin* 31, no. 4 (2006): 318-323.
 18. Park, Sang-Ki, Tom D. Milster, Tim M. Miller, John Butz, and Warren Bletscher. "Master and slave beam servo technique for volumetric bit-wise optical data storage." *Japanese journal of applied physics* 44, no. 5S (2005): 3442.
 19. Beaudry, Neil A., and Tom D. Milster. "Imaging properties of a patterned rough surface: effects of roughness correlation and partial coherence." *Optical Engineering* 44, no. 7 (2005): 078001-078001.
 20. Choi, Taeyoung, Tom D. Milster, and Matthew Lang. "Wavelength-domain tracking in multiple-beam optical storage systems." *Optical Engineering* 44, no. 5 (2005): 055201-055201.
 21. Beaudry, Neil A., and Tom D. Milster. "Imaging properties of a patterned rough surface: effects of defocus." *Optical Engineering* 44, no. 6 (2005): 063201-063201.
 22. Lang, Matthew, Tom D. Milster, Takahisa Minamitani, Gregg Borek, and David Brown. "Fabrication and characterization of sub-100 μ m diameter gallium phosphide solid immersion lens arrays." *Japanese journal of applied physics* 44, no. 5S (2005): 3385.
 23. Zhang, Yan, Tom D. Milster, Jai Soon Kim, and Sang-Ki Park. "Advanced lens design for bit-wise volumetric optical data storage." *Japanese journal of applied physics* 43, no. 7S (2004): 4929.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

24. Khoh, Andrew, Ganesh S. Samudra, Yihong Wu, Tom Milster, and Byoung-Il Choi. "Image formation by use of the geometrical theory of diffraction." *JOSA A* 21, no. 6 (2004): 959-967.
25. Wu, Fung-Hsu, Han-Ping D. Shieh, Tom D. Milster, and Der-Ray Huang. "Write-once volumetric optical disk using transparent recording material with an optical switching layer." *Japanese journal of applied physics* 43, no. 7S (2004): 4937.
26. Wu, Fung-Hsu, Han-Ping D. Shieh, Der-Ray Huang, and Tom D. Milster. "Performance of a write-once multilayer optical disk that uses transparent recording material with an optical switching layer." *Applied optics* 43, no. 29 (2004): 5498-5502.
27. Zhang, Y., J. Butz, J. Curtis, N. Beaudry, W. L. Bletscher, K. J. Erwin, D. Knight, T. D. Milster, and E. Walker. "Characterization of a bit-wise volumetric storage medium for a space environment." *Optics Express* 12, no. 12 (2004): 2662-2669.
28. Milster, Tom D., and Shu Guo Tang. "Generation of compact near-field energy for optical recording: Transducer efficiency and signal detection." *Japanese journal of applied physics* 42, no. 2S (2003): 1095.
29. Tang, Shu-Guo, and Tom D. Milster. "Consideration and control of writing conditions with near-field aperture solid immersion lens probe." *Japanese journal of applied physics* 42, no. 2S (2003): 1090.
30. Milster, Tom D. "Physical optics simulation in Matlab for high-performance systems." *Optical review* 10 (2003): 246-250.
31. Tien, Chung-Hao, Hsueh-Liang Chou, Yi Chiu, Wensyang Hsu, Tom D. Milster, Yin-Chieh Lai, and Han-Ping D. Shieh. "Fiber-lens-based module for optical recording applications." *Japanese journal of applied physics* 42, no. 7R (2003): 4345.
32. Tien, Chung-Hao, Yin-Chieh Lai, Tom D. Milster, and Han-Ping D. Shieh. "Design and fabrication of fiberlenses for optical recording applications." *Japanese journal of applied physics* 41, no. 3S (2002): 1834.
33. Jo, Joshua S., Tom D. Milster, and J. Kevin Erwin. "Phase and amplitude apodization induced by focusing through an evanescent gap in a solid immersion lens microscope." *Optical Engineering* 41, no. 8 (2002): 1866-1875.
34. Beaudry, Neil A., and Tom D. Milster. "Interferometric phase reconstruction by nonuniform shifting of the reference beam." *Applied optics* 41, no. 10 (2002): 1915-1921.
35. Milster, Tom D., Farhad Akhavan Kevin Erwin, David M. Felix, Kusato Hirota Kusato Hirota, Steven Koester Steven Koester, Kei Shimura Kei Shimura, and Yan Zhang Yan Zhang. "Super-resolution by combination of a solid immersion lens and an aperture." *Japanese Journal of Applied Physics* 40, no. 3S (2001): 1778.
36. Shimura, Kei, and Tom D. Milster. "Vector diffraction analysis by discrete-dipole approximation." *JOSA A* 18, no. 11 (2001): 2895-2900.
37. Tang, Shu-Guo, Tom D. Milster, J. Kevin Erwin, and Warren L. Bletscher. "High-performance readout and recording by a combination aperture." *Optics Letters* 26, no. 24 (2001): 1987-1989.
38. Milster, Tomas D. "Near-field optical data storage: avenues for improved performance." *Optical Engineering* 40 (2001): 2255-2260.
39. Upton, Robert S., and Tom D. Milster. "Detector patterns from optical disks." *Optical Engineering* 40, no. 6 (2001): 1030-1044.
40. Shimura, Kei, and Tom D. Milster. "Analysis of three-dimensional distributions of

- scattered light by the discrete dipole approximation." In *Diffraction Optics and Micro-Optics*, p. DTuD17. Optica Publishing Group, 2000.
41. Milster, Tom D. "Near-field optics: a new tool for data storage." *Proceedings of the IEEE* 88, no. 9 (2000): 1480-1490.
 42. Hirota, Kusato, Tom D. Milster, Kei Shimura, Yan Zhang, and Joshua S. Jo. "Near-field phase change optical recording using a GaP hemispherical lens." *Japanese Journal of Applied Physics* 39, no. 2S (2000): 968.
 43. Beaudry, Neil A., and Tom D. Milster. "Effects of object roughness on partially coherent image formation." *Optics letters* 25, no. 7 (2000): 454-456.
 44. Hirota, Kusato, Tom D. Milster, Yan Zhang, and J. Kevin Erwin. "Design of a Near-Field Probe for Optical Recording Using a 3-Dimensional Finite Difference Time Domain Method." *Japanese Journal of Applied Physics* 39, no. 2S (2000): 973.
 45. Upton, Robert S., Farhad Akhavan, Tom D. Milster, Michael Schweisguth, Warren L. Bletscher, J. Kevin Erwin, and Anson M. Nichol. "Electronic crosstalk cancellation with a quadrant cell detector." *Japanese Journal of Applied Physics* 39, no. 2S (2000): 837.
 46. Shimura, Kei, Tom D. Milster, Joshua S. Jo, and Kusato Hirota. "Pupil plane filtering for optical pickup heads with effective numerical aperture of 1.1 and 2.0." *Japanese Journal of Applied Physics* 39, no. 2S (2000): 897.

Peer-Reviewed Papers 1990s:

1. Milster, Tom D., Joshua S. Jo, and Kusato Hirota. "Roles of propagating and evanescent waves in solid immersion lens systems." *Applied optics* 38, no. 23 (1999): 5046-5057.
2. Milster, Tom D., Kei Shimura, Joshua S. Jo, and Kusato Hirota. "Pupil-plane filtering for improved signal detection in an optical data-storage system incorporating a solid immersion lens." *Optics letters* 24, no. 9 (1999): 605-607.
3. Milster, Tom D., Robert S. Upton, and Hui Luo. "Objective lens design for multiple-layer optical data storage." *Optical Engineering* 38 (1999): 295-301.
4. Milster, Tom D., and Robert S. Upton. "Fundamental principles of crosstalk in optical data storage." *Japanese journal of applied physics* 38, no. 3S (1999): 1608.
5. Milster, Tom D., Joshua S. Jo, Kusato Hirota, Kei Shimura, and Yan Zhang. "The nature of the coupling field in optical data storage using solid immersion lenses." *Japanese journal of applied physics* 38, no. 3S (1999): 1793.
6. Milster, Tom D. "Chromatic correction of high-performance solid immersion lens systems." *Japanese journal of applied physics* 38, no. 3S (1999): 1777.
7. Milster, T., W. Jiang, E. Walker, D. Burak, P. Claisse, P. Kelly, and R. Binder. "A single-mode high-power vertical cavity surface emitting laser." *Applied physics letters* 72, no. 26 (1998): 3425-3427.
8. Tang, Hong, and Tomas D. Milster. "Modulation transfer function of bar code scanning." *Optical Engineering* 37, no. 9 (1998): 2574-2580.
9. Milster, Tom D. "New way to describe diffraction from optical disks." *Applied optics* 37, no. 29 (1998): 6878-6883.
10. Froehlich, Fred F., and Tom D. Milster. "Mechanical resonance behavior of near-field optical microscope probes." *Applied physics letters* 70, no. 12 (1997): 1500-1502.
11. Flagello, Donis G., and Tom D. Milster. "High-numerical-aperture effects in photoresist." *Applied Optics* 36, no. 34 (1997): 8944-8951.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

12. Kann, Joshua L., Tom D. Milster, Fred F. Froehlich, Richard W. Ziolkowski, and Justin B. Judkins. "Heating mechanisms in a near-field optical system." *Applied optics* 36, no. 24 (1997): 5951-5958.
13. Schlichting, Wolfgang, Sadeg Faris, Bunsen Fan, John Haag, Zhijian Lu, Steven Kane, Le Li, Tom Milster, and Hui Luo. "Recording and readout of a cholesteric liquid crystal based multilayer disk." *Japanese journal of applied physics* 36, no. 1S (1997): 587.
14. Russell, Timothy H., and Tom D. Milster. "Polarization switching control in vertical-cavity surface-emitting lasers." *Applied physics letters* 70, no. 19 (1997): 2520-2522.
15. Flagello, Donis G., Tom Milster, and Alan E. Rosenbluth. "Theory of high-NA imaging in homogeneous thin films." *JOSA A* 13, no. 1 (1996): 53-64.
16. Milster, Tom D., and Edwin P. Walker. "Mechanism for improving the signal-to-noise ratio in scanning optical microscopes." *Optics letters* 21, no. 16 (1996): 1304-1306.
17. Milster, T. D., Z. Chen, E. P. Walker, M. T. Tuell, and E. C. Gage. "Optical data storage readout with quadrant pupil detection." *Applied optics* 35, no. 14 (1996): 2471-2476.
18. Milster, Tomas D., and Cynthia L. Vernold. "Technique for aligning optical and mechanical axes based on a rotating linear grating." *Optical Engineering* 34, no. 10 (1995): 2840-2845.
19. Milster, Tom D., and Ronald E. Gerber. "Compensation of chromatic errors in high NA molded objective lenses." *Applied optics* 34, no. 34 (1995): 8079-8080.
20. Kann, Joshua L., Tom D. Milster, Fred Froehlich, Richard W. Ziolkowski, and Justin Judkins. "Numerical analysis of a two-dimensional near-field probe." *Ultramicroscopy* 57, no. 2-3 (1995): 251-256.
21. Froehlich, Fred F., and Tom D. Milster. "Detection of probe dither motion in near-field scanning optical microscopy." *Applied optics* 34, no. 31 (1995): 7273-7279.
22. Kann, Joshua L., Tom D. Milster, Fred F. Froehlich, Richard W. Ziolkowski, and Justin B. Judkins. "Near-field optical detection of asperities in dielectric surfaces." *JOSA A* 12, no. 3 (1995): 501-512.
23. Walker, Edwin P., and Tom D. Milster. "High-frequency enhancement of magneto-optic data storage signals by optical and electronic filtering." *Optics letters* 20, no. 17 (1995): 1815-1817.
24. Kann, Joshua L., Tom D. Milster, Fred F. Froehlich, Richard W. Ziolkowski, and Justin B. Judkins. "Linear behavior of a near-field optical scanning system." *JOSA A* 12, no. 8 (1995): 1677-1682.
25. Froehlich, Fred F., and Tom D. Milster. "Minimum detectable displacement in near-field scanning optical microscopy." *Applied physics letters* 65, no. 18 (1994): 2254-2256.
26. Schlichting, W., T. D. Milster, M. S. Wang, and C. Brucker. "Signal and noise with a magnetic circular dichroism detection system in optical data storage." *Journal of applied physics* 75, no. 5 (1994): 2322-2324.
27. Milster, Tom D., Mark S. Wang, Weiquan Li, and Ed Walker. "Optical filtering in the collection path of a data storage device." *Japanese journal of applied physics* 32, no. 11S (1993): 5397.
28. Wang, Mark S., and Tom D. Milster. "Differential wax-wane focus servo." *Applied optics* 32, no. 25 (1993): 4797-4807.
29. Schlichting, W., T. D. Milster, and C. J. Campillo. "Optical data storage based on magnetic circular dichroism." *Applied physics letters* 62, no. 22 (1993): 2751-2753.
30. Wang, Mark S. Wang Mark S., and Tom D. Milster Tom D. Milster. "Crosstalk

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

cancellation using differential wax-wane focus servo technique." Japanese journal of applied physics 32, no. 11S (1993): 5277.

31. Milster, Tom D., and Craig H. Curtis. "Analysis of superresolution in magneto-optic data storage devices." Applied optics 31, no. 29 (1992): 6272-6279.
32. Froehlich, Fred F., Mark S. Wang, and Tom D. Milster. "Technique for simultaneous alignment and collimation of a laser diode in an optical data storage head." Applied optics 30, no. 31 (1991): 4481-4483.
33. Milster, T. D., J. N. Aarsvold, H. H. Barrett, A. L. Landesman, L. S. Mar, D. D. Patton, T. J. Roney, R. K. Rowe, and R. H. Seacat. "A full-field modular gamma camera." Journal of Nuclear Medicine 31, no. 5 (1990): 632-639.

Peer-Reviewed Papers 1980s:

1. Milster, T. D., L. A. Selberg, H. H. Barrett, R. L. Easton, G. R. Rossi, J. Arendt, and R. G. Simpson. "A modular scintillation camera for use in nuclear medicine." IEEE transactions on nuclear science 31, no. 1 (1984): 578-580.
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

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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.
3. Singer, Kenneth D., Irina Shiyanovskaya, Asher Sussman, Thomas Milster, and Young Sik Kim.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

"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).
8. T. D. Milster and J. Km, "Alignment feature for near-field transducers," USP 8,737,178 (2014).
9. B. Gelernt and T. D. Milster, "Apparatus and method for deep ultraviolet optical microscopy," USP 8,472,111 (2013).
10. T. D. Milster and S. K. Park, "Optimized media structure for bit-wise multi-layer optical data storage," USP 8,003,187 (2011).
11. T. D. Milster and S. Kannan, "Application of wavelet transform filtering for processing data signals from optical data storage devices," USP 7,974,170 (2011).
12. T. D. Milster, P. K. Khulbe, and B. Gelernt, "Apparatus and method for spectroscopy," USP 7,916,291 (2011)
13. P. B. Chu, M. I. Lutwyche, T. Rausch, W. A. Challener, and T. D. Milster, "Optical system for data storage devices," USP 7,796,487 (2010).
14. W. Jiang, C. P. Wei, and T. D. Milster, "Method and apparatus for improved optical elements for vertical PCB fiber optic modules," USP 6,901,221 (2005).
15. T. D. Milster and Kei Shimura, "Method and apparatus for detecting light from a multilayerd object," USP 6,577,584 (2003).
16. W. Jiang and T. D. Milster, "Optical connector for connecting a plurality of light sources to a plurality of light sinks," USP 6,498,875 (2002).
17. T. D. Milster, W. Jiang and M. S. Lebby, "Optical pickup head including a coherent first order mode laser light source," USP 6,111,839 (2000).
18. Y. D. Milster and S. Yao, "Detector for magnetooptic recorders," USP 4,823,220 (1989).

Classes

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

2020s

1. Fan, Jonathan, Yixuan Shao, Robert Lupoiu, Zichan Wang and Tom D. Milster, “Space plates and space optics for advanced imaging systems,” (*Invited*) SPIE Optics and Photonics, Paper 13109-5, 2024.
2. Wang, Zichan, Yixuan Shao, Youngsik Kim, Robert Lupoiu, Jonathan Fan, Tom D. Milster, “Angular dependent meta surfaces for aberration correction,” in Optical Design and Testing, paper W4A-03, Optical Society of Japan, 2024.
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.
4. Wang, Zichan, Nick Brar, YiYun Wu, Edgar Durazo, and Tom D. Milster, “Correction of Fabrication Errors of Telescope Primary Lens by a Phase Plate,” in Optical Design and Testing, paper ThP-07, Optical Society of Japan, 2024.
5. Wu, YiYun, and Tom D. Milster, “Design, Fabrication, and Testing of a Grayscale Computer-Generated Hologram,” in Optical Design and Testing, paper ThP-18, Optical Society of Japan,

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

2024.

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.
7. Youngsik Kim, Zichan Wang, Nick Brar, and Tom D. Milster, "Straylight Analysis of a MODE Lens Telescope," in Optical Design and Testing, paper Th1B-03, Optical Society of Japan, 2024.
8. Milster, Tom D., Nick Brar, Youngsik Kim, Heejoo Choi, Marcos Esparza, Daewook Kim, Allen Yi, Yuxin Cai, Geon hee Kim, and Daniel Apai, "Progress on Demonstration of a MODE-Lens Telescope," in Optical Design and Testing, paper F4D-02, Optical Society of Japan, 2024.
9. Jillella, Priyanka, and Tom D. Milster, "Coherence-Based Lensless Imaging and Telescopy," in Optical Design and Testing, paper F4D-03, Optical Society of Japan, 2024.
10. Brar, Nick, Yingying Zhang, Youngsik Kim, Heejoo Choi, Marcos A. Esparza, Daewook Kim, Allen Yi et al. "Development of a MODE lens telescope." In Optical Fabrication and Testing, pp. OTu2B-4. Optica Publishing Group, 2023.
11. Esparza, Marcos, Heejoo Choi, Nicholas Brar, Zichan Wang, Youngsik Kim, Chuck Fellows, Mingab Bog et al. "Kinematically engaged yoke system for segmented lens-based space telescope integration and testing." *Journal of the European Optical Society-Rapid Publications* 19, no. 1 (2023): 2023016.
12. Milster, Thomas D., Nick Brar, Yingying Zhang, Young-Sik Kim, Heejoo Choi, Marcos Esparza, Daewook Kim et al. "Ultralightweight hybrid refractive/diffractive MODE telescopes for space applications." In Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems IV, p. PC126770G. SPIE, 2023.
13. Milster, Thomas D., Young-Sik Kim, Nick Brar, and Zichan Wang. "Theory and practice of high-harmonic diffractive surfaces." In ODS 2023: Industrial Optical Devices and Systems, p. PC1268408. SPIE, 2023.
14. Milster, Tom D., Zichan Wang, and Youngsik Kim. "Theory of color correction in high-harmonic diffractive lenses." In International Optical Design Conference, p. 120780Y. Optica Publishing Group, 2021.
15. Choi, Heejoo, Marcos A. Esparza, Ariel Lamdan, Yi-Ting Feng, Tom Milster, Daniel Apai, and Dae Wook Kim. "In-process metrology for segmented optics UV curing control." In Optical Manufacturing and Testing XIII, vol. 11487, pp. 115-121. SPIE, 2020.
16. Kim, Daewook, Tom D. Milster, and Dániel Apai. "Nautilus: The advent of large lens-based space telescopes." In EPJ Web of Conferences, vol. 266, p. 03014. EDP Sciences, 2022.
17. Wang, Zichan, Youngsik Kim, and Tom Milster. "Design of multi-order diffractive lens telescope for broadband application." In International Optical Design Conference, p. 120780X. Optica Publishing Group, 2021.
18. Kim, Youngsik, Yingying Zhang, and Tom Milster. "Molding error and its compensation in multi-order diffractive lens segmented telescope assembly." In Optical Fabrication and Testing, pp. OTu5B-3. Optica Publishing Group, 2021.
19. Choi, Heejoo, Marcos A. Esparza, Ryan Luu, Tom Milster, Daniel Apai, and Daewook Kim. "Autonomous closed-loop control for multi-segmented optic aligning and assembly." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 108-114. SPIE, 2022.
20. Zhang, Yingying, Wenchen Zhou, Oliver Spires, Young Sik Kim, Allen Yi, Rongguang Liang, and Tom D. Milster. "Precision glass molding for diffractive optics." In Frontiers in Optics, pp. FM5E-2. Optica Publishing Group, 2020.
21. Kim, Youngsik, Marcos Esparza, Zichan Wang, Nicholas Brar, Heejoo Choi, Daewook Kim,

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Daniel Apai, and Tom D. Milster. "Stray light analysis and testing of a MODE lens telescope." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 90-94. SPIE, 2022.
22. Milster, Thomas D., Youngsik Kim, and Zichan Wang. "Type 2 longitudinal chromatic aberration from a high-harmonic MODE lens and color corrector." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 72-81. SPIE, 2022.
23. Brar, Nick, Yingying Zhang, Youngsik Kim, Allen Yi, Yuxin Cai, Geon Hee Kim, and Thomas D. Milster. "Precision glass molding technology for the MODE lens telescope." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 95-107. SPIE, 2022.
24. Wang, Zichan, Youngsik Kim, Allen Yi, Hwanjin Choi, Geonhee Kim, and Tom D. Milster. "Fabrication, assembly, and testing of a MODE lens color corrector." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 82-89. SPIE, 2022.
25. Kim, Dae Wook, Christopher K. Walker, Dániel Apai, Tom D. Milster, Yuzuru Takashima, Glenn Schneider, Rongguang Liang et al. "Disruptive space telescope concepts, designs, and developments: OASIS and Nautilus-INVITED." In EPJ Web of Conferences, vol. 238, p. 06001. EDP Sciences, 2020.
26. Kim, Youngsik, Zichan Wang, and Tom Milster. "Optical design and analysis of ultralight, large aperture transmissive lenses for space telescopes." In Frontiers in Optics, pp. JTU7A-1. Optica Publishing Group, 2020.
27. Apai, Dániel, Tom D. Milster, Daewook Kim, Youngsik Kim, Glenn Schneider, Benjamin V. Rackham, Jonathan Arenberg et al. "Nautilus Space Observatory: a very large aperture space telescope constellation enabled by scalable optical manufacturing technologies." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 59-71. SPIE, 2022.
28. Milster, Tom D., Daniel Apai, Dae Wook Kim, Young Sik Kim, Geon Hee Kim, Yingying Zhang, Heejoo Choi et al. "Progress toward optical design and fabrication of ultralight, large aperture transmissive lenses for space telescopes." In Frontiers in Optics, pp. FM1A-2. Optica Publishing Group, 2020.
29. Esparza, Marcos A., Ryan Luu, Heejoo Choi, Tom D. Milster, Daniel Apai, and Daewook Kim. "Progress towards alignment of Multi-Order Diffractive Engineered (MODE) lens segments using the Kinetically-Engaged Yoke System (KEYS) for optical performance testing." In Optical Manufacturing and Testing XIV, vol. 12221, pp. 115-121. SPIE, 2022.
30. Zhang, Yingying, Rongguang Liang, and Tom D. Milster. "A simulation-based optimization approach for the heating process of precision glass molding." In Optical Fabrication and Testing, pp. OTU5B-2. Optica Publishing Group, 2021.
31. Apai, Daniel, Tom Milster, Dae Wook Kim, Glenn Schneider, Alex Bixel, Benjamin Rackham, and Jonathan Arenberg. "Very Large-diameter, Ultralight Space Telescopes to Enable Large-scale Survey of Candidate Earth-like Planets for Signatures of Life." In ASCEND 2020, p. 4022. 2020.
32. Dmitrovic, Sanja, Brian Molnar, Young Sik Kim, David Schumann, James Foley, Jacob T. Shelley, and Tom D. Milster. "Progress toward a VUV Raman spectrometer to detect pathogens." In Label-free Biomedical Imaging and Sensing (LBIS) 2021, vol. 11655, pp. 79-87. SPIE, 2021.
33. Milster, Tom D., and William P. Kuhn. "Practical measurement of cell-phone camera lens focal length." In Optical System Alignment, Tolerancing, and Verification XIII, vol. 11488, pp. 39-48. SPIE, 2020.
34. Milster, Thomas D. "Complex diversity for multiple-wavelength single-shot phase retrieval (Conference Presentation)." In Quantitative Phase Imaging VI, vol. 11249, p. 112490K. SPIE, 2020.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

35. Apai, D., T. D. Milster, D. Kim, A. Bixel, G. Schneider, B. V. Rackham, R. Liang, and J. Arenberg. "Nautilus: A Biosignature Survey in a Thousand Exo-Earths." In American Astronomical Society Meeting Abstracts# 235, vol. 235, pp. 212-06. 2020.

2010s

1. Milster, Tom D., Phat Lu, and Khanh Kieu. "Potential of multi-photon reading and writing for optical data storage systems." In Optical Data Storage 2015, vol. 9587, pp. 43-54. SPIE, 2015.
2. Kim, Youngsik, and Tom D. Milster. "Hyper Numerical Aperture Blu-ray Disc Recording." In Joint International Symposium on Optical Memory and Optical Data Storage, p. OTuD13. Optica Publishing Group, 2011.
3. Park, Jong Rak, Youngsik Kim, Melissa Zaverton, Justin Sierchio, and Tom D. Milster. "Characterization of Photoresist and Study on Developed Resist Profile for the Fabrication of Gray-Scale Diffractive Optic Elements." In Optical Fabrication and Testing, p. OTuC4. Optica Publishing Group, 2010.
4. Gao, Weichuan, Ki-Hwan Nam, Kye-Sung Lee, Gunhee Kim, Tom D. Milster, and Young-Sik Kim. "Design of High Numerical Aperture Apochromatic Objective for Biochip-Based Multiphoton Microscope." In Bio-Optics: Design and Application, pp. BT1A-7. Optica Publishing Group, 2015.
5. Eguchi, Akira, Phat Lu, Youngsik Kim, Koen Visscher, and Tom D. Milster. "Proposal of a new imaging method with trapped gold nano particles and the properties of multi-photon emission." In Laser Science, pp. JW3A-14. Optica Publishing Group, 2014.
6. Apai, Dániel, Tom D. Milster, Dae Wook Kim, Alex Bixel, Glenn Schneider, Benjamin V. Rackham, Rongguang Liang, and Jonathan Arenberg. "Nautilus observatory: a space telescope array based on very large aperture ultralight diffractive optical elements." In Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems II, vol. 11116, pp. 63-72. SPIE, 2019.
7. Murray, Ian B., Victor Densmore, Vaibhav Bora, Matthew W. Pieratt, Douglas L. Hibbard, and Tom D. Milster. "Numerical comparison of grid pattern diffraction effects through measurement and modeling with OptiScan software." In Window and Dome Technologies and Materials XII, vol. 8016, pp. 281-295. SPIE, 2011.
8. Zaverton, M., J. Sierchio, Y. S. Kim, D. Hansen, W. Bletcher, J. Tamkin, and T. D. Milster. "Maskless lithography tool for fabrication and inspection of diffractive optical elements and computer generated holograms." In Optical Fabrication and Testing, p. OTuC5. Optica Publishing Group, 2010.
9. Kim, Youngsik, Zichan Wang, and Tom Milster. "Ultralight very large aperture space telescopes using MODE lens technology." In Freeform Optics, pp. FM4B-4. Optica Publishing Group, 2019.
10. Summitt, Chris, Sunglin Wang, Lee Johnson, Melissa Zaverton, Tao Ge, Tom Milster, and Yuzuru Takashima. "Micro-optics fabrication by mask-based and mask-less mixed lithography process towards 3D optical circuits." In Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VII, vol. 8974, pp. 41-46. SPIE, 2014.
11. Summitt, Chris, Sunglin Wang, Lee Johnson, Melissa Zaverton, Tom Milster, and Yuzuru Takashima. "Flexible micro-optics fabrication by direct laser writing toward CMOS compatible 3D optical circuit." In Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VI, vol. 8613, pp. 91-96. SPIE, 2013.
12. Knight, Justin M., John Brewer, Ryan Hamilton, Karen Ward, Tom D. Milster, and Olivier

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Guyon. "Design, fabrication, and testing of stellar coronagraphs for exoplanet imaging." In *Techniques and Instrumentation for Detection of Exoplanets VIII*, vol. 10400, pp. 170-180. SPIE, 2017.
13. Keyes, Derek S., Thiago S. Jota, Weichuan Gao, Dakota Luepke, Victor Densmore, Young-Sik Kim, Gun-Hee Kim, and Thomas D. Milster. "Optomechanical design and tolerance of a microscope objective at 121.6 nm." In *Optical Manufacturing and Testing XI*, vol. 9575, pp. 24-29. SPIE, 2015.
 14. Milster, T. D., H. Noble, E. Ford, W. Dallas, R. A. Chipman, I. Matsubara, Y. Unno et al. "Polarization holograms for source-mask optimization." In *Optical Microlithography XXIV*, vol. 7973, pp. 441-448. SPIE, 2011.
 15. Tamkin, John M., and Tom D. Milster. "Analysis and tolerancing of structured mid-spatial frequency errors in imaging systems." In *International Optical Design Conference 2010*, vol. 7652, pp. 408-415. SPIE, 2010.
 16. Milster, Thomas D., and Young Sik Kim. "Adaptive optics for data recovery on optical disk fragments (Conference Presentation)." In *Optical Data Storage 2017: From New Materials to New Systems*, vol. 10384, p. 103840J. SPIE, 2017.
 17. Vorndran, Shelby D., Silvana Ayala, Yuechen Wu, Juan M. Russo, Melissa A. Zaverton, Tom Milster, and Raymond K. Kostuk. "Freeform surface relief diffractive optic for photovoltaic spectrum splitting." In *2015 IEEE 42nd Photovoltaic Specialist Conference (PVSC)*, pp. 1-5. IEEE, 2015.
 18. Kim, Jaisoon, Moonseok Kim, Sukjoon Hong, and Tom D. Milster. "Characteristics of the depth of focus in a high-NA optical system with a SIAX for data storage." In *Optical Data Storage 2010*, vol. 7730, pp. 79-85. SPIE, 2010.
 19. Jota, Thiago, Youngsik Kim, Dakota Luepke, Dolaphine Kwok, and Tom Milster. "Development of Optical Microscopy with a 121.6 nm Source." In *Laser Science*, pp. JW3A-15. Optica Publishing Group, 2014.
 20. Bendek, Eduardo A., Ruslan Belikov, Eugene Pluzhnik, Olivier Guyon, Thomas Milster, Lee Johnson, Emily Finan, Justin Knight, and Alexander Rodack. "Results of the astrometry and direct imaging testbed for exoplanet detection." In *Techniques and Instrumentation for Detection of Exoplanets VIII*, vol. 10400, pp. 393-406. SPIE, 2017.
 21. Vorndran, Shelby D., Lee Johnson, Tom Milster, and Raymond K. Kostuk. "Measurement and analysis of algorithmically-designed diffractive optic for photovoltaic spectrum splitting." In *2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC)*, pp. 3513-3517. IEEE, 2016.
 22. Walker, Edwin P., and Tom D. Milster. "Beam shaping for optical data storage." In *Laser Beam Shaping Applications*, pp. 157-181. CRC Press, 2018.
 23. Johnson, L., Apai, D., Arenberg, J., & Milster, T. (2017, July). Multiple Order Diffractive Fresnel Lens (MOD-DFL) for Atmospheric Transit Surveying of Earthlike Exoplanets. In *International Optical Design Conference* (pp. IW3A-5). Optica Publishing Group.
 24. Finan, Emily, Tom Milster, and Youngsik Kim. "Performance of an Adaptive Optics System in the Presence of Diffractive Grooves." In *Frontiers in Optics*, pp. FM3D-1. Optica Publishing Group, 2018.
 25. Wang, Sunglin, Chris Summitt, Lee Johnson, Melissa Zaverton, Tom Milster, and Yuzuru Takashima. "Optical characterization of CMOS compatible micro optics fabricated by mask-based and mask-less hybrid lithography." In *Nanoengineering: Fabrication, Properties, Optics, and Devices XI*, vol. 9170, pp. 64-69. SPIE, 2014.
 26. Bendek, Eduardo A., Olivier Guyon, Ruslan Belikov, S. Mark Ammons, Thomas Milster, Young-

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Sik Kim, and Lee Johnson. "Exoplanet detection and characterization using combined coronagraphy and sub-UAS astrometry from space." In *Techniques and Instrumentation for Detection of Exoplanets VI*, vol. 8864, pp. 26-37. SPIE, 2013.
27. Johnson, Lee, Melissa Zaverton, Tyler Hashimoto, Alex Felli, Young Sik Kim, and Tom D. Milster. "Freeform Diffractive Structure Writing through Maskless Lithography." In *Frontiers in Optics*, pp. JW3A-7. Optica Publishing Group, 2014.
28. Summitt, Chris, Sunglin Wang, Lee Johnson, Melissa Zaverton, Tao Ge, Tom Milster, and Yuzuru Takashima. "Process optimization for a 3D optical coupler and waveguide fabrication on a single substrate using buffer coat material." In *Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VIII*, vol. 9374, pp. 202-207. SPIE, 2015.
29. Apai, D., T. D. Milster, J. Arenberg, D. Kim, R. Liang, A. Bixel, C. Fellows, and J. Grunsfeld. "Nautilus deep space observatory: a giant segmented space telescope array for a galactic biosignature survey." In *Deep Space Gateway Concept Science Workshop*, vol. 2063, p. 3127. 2018.
30. Gao, Weichuan, Emily Finan, Byeongjoon Jeong, Geon-Hee Kim, Youngsik Kim, and Tom Milster. "An Imaging Microscope at 121.6 nm." In *International Optical Design Conference*, pp. JTu5A-6. Optica Publishing Group, 2017.
31. Jean, Madison, Ryan Bronson, R. Philip Scott, Michael Hart, Lee Johnson, and Tom Milster. "Multi-wavelength Characterization of Multi-Order Diffractive Lenslet Arrays." In *Optical Fabrication and Testing*, pp. OW2B-4. Optica Publishing Group, 2017.
32. Ge, Tao, Jilin Yang, Chris Summitt, Sunglin Wang, Lee Johnson, Melissa Zaverton, Tom Milster, and Yuzuru Takashima. "High contrast and metal-less alignment process for all-polymer optical interconnect devices." In *Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VIII*, vol. 9374, pp. 224-234. SPIE, 2015.
33. Eguchi, Akira, Phat Lu, Youngsik Kim, and Tom D. Milster. "Characterization of multiphoton emission from aggregated gold nano particles." In *Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XIV*, vol. 9921, pp. 46-51. SPIE, 2016.
34. Pacheco, Shaun, Tom Milster, Joe Zhou, and Rongguang Liang. "System design and evaluation of the array confocal fluorescence microscope." In *Design and Quality for Biomedical Technologies VII*, vol. 8936, pp. 142-146. SPIE, 2014.
35. Milster, Tom D. "Prospects and philosophy for high-density optical recording." In *Optical Data Storage 2014*, vol. 9201, pp. 108-115. SPIE, 2014.
36. Milster, T. D. "The Gerchberg-Saxton Phase Retrieval Algorithm and Related Variations." *Optical Holography: Materials, Theory and Applications* (2019): 61.
37. Jota, Thiago S., and Tom D. Milster. "EUVL mask inspection at Hydrogen Lyman Alpha." In *Photomask Technology 2012*, vol. 8522, pp. 537-542. SPIE, 2012.
38. Scott, R. Phillip, Madison Jean, Lee Johnson, Ridley Gatlin, Ryan Bronson, Tom Milster, and Michael Hart. "Lithographic manufacturing of adaptive optics components." In *Astronomical Optics: Design, Manufacture, and Test of Space and Ground Systems*, vol. 10401, pp. 332-340. SPIE, 2017.
39. Apai, Daniel, Alex Bixel, Benjamin V. Rackham, Glenn Schneider, Tom D. Milster, Dae Wook Kim, Rongguang Liang, Jonathan Arenberg, and John Grunsfeld. "Nautilus: A very large-aperture, ultralight space telescope for exoplanet exploration, time-domain astrophysics, and faint objects." *Bulletin of the American Astronomical Society* 51, no. 7 (2019): 141.
40. Finan, Emily, Tom Milster, and Youngsik Kim. "Adaptive optics correction using coherently illuminated diffractive objects." In *ODS 2019: Industrial Optical Devices and Systems*, vol.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

11125, pp. 15-21. SPIE, 2019.

41. Bendek, Eduardo, Dan Sirbu, Christopher Henze, Ruslan Belikov, Thomas Milster, Emily Finan, and Eugene Pluzhnik. "Sparse wavefront control: A new approach to high-contrast imaging." In *Space Telescopes and Instrumentation 2018: Optical, Infrared, and Millimeter Wave*, vol. 10698, pp. 493-501. SPIE, 2018.
42. Milster, Tom D., Youngsik Kim, and Phat Lu. "Hyper-NA (NA= 2.8) Microscope Using 1.55 μ m fs Source for Multi-Photon Imaging." In *Bio-Optics: Design and Application*, pp. BT1A-2. Optica Publishing Group, 2013.
43. Lu, Phat, Youngsik Kim, and Tom D. Milster. "Subsurface Damage Characterization with Nonlinear High Numerical Microscopy." In *Laser Science*, pp. JW3A-9. Optica Publishing Group, 2014.
44. Guyon, Olivier, Thomas Milster, Lee Johnson, Justin Knight, Alexander Rodack, Eduardo A. Bendek, Ruslan Belikov, Eugene A. Pluzhnik, and Emily Finan. "Results of the astrometry and direct imaging testbed for exoplanet detection." *SPIE-INT SOC OPTICAL ENGINEERING*, 2017.
45. Belikov, Ruslan, Eduardo A. Bendek, Dan Sirbu, Emily Finan, Thomas Milster, Chris Henze, and Eugene Pluzhnik. "Sparse wavefront control: A new approach to high-contrast imaging." *SPIE-INT SOC OPTICAL ENGINEERING*, 2018.
46. Tamkin, John M., and Tom D. Milster. "Point Spread Function Artifacts from Structured Mid-Spatial Frequency Errors." In *International Optical Design Conference*, p. ITuD4. Optica Publishing Group, 2010.
47. Zhang, Jun, Seung-Hune Yang, Tom D. Milster, Warren Bletscher, and Delbert Hansen. "Hyper-NA imaging with solid-immersion optics and induced polarization imaging." In *Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XVII*, vol. 7570, pp. 225-229. SPIE, 2010.

2000s

1. Wu, Fung Hsu, U. Rambabu, Tom D. Milster, and Han-Ping D. Shieh. "Optical Nonlinearity of Silver Oxide Super Resolution Structure as a Function of Oxygen Content." In *Optical Data Storage*, p. MB4. Optica Publishing Group, 2003.
2. Zhang, Yan, and Tom D. Milster. "Simulation of a fluorescent bit-wise volumetric optical data storage system." In *Optical Data Storage 2004*, vol. 5380, pp. 376-386. SPIE, 2004.
3. Choi, Taeyoung, Tom D. Milster, Warren Bletscher, Neil Beaudry, and Paul Hauser. "Erasure characterization of CD-Recordable disks in response to a high power laser beam." In *International Symposium on Optical Memory and Optical Data Storage*, p. WP13. Optica Publishing Group, 2005.
4. Zhang, Yan, Thomas D. Milster, John Butz, and Warren L. Bletscher. "New test stand for dynamically testing coupon samples." In *Optical Data Storage 2003*, vol. 5069, pp. 357-360. SPIE, 2003.
5. Upton, Robert S., and Tomas D. Milster. "Exit pupil patterns from optical disks." In *Optical Storage and Optical Information Processing*, vol. 4081, pp. 143-154. SPIE, 2000.
6. Miller, Timothy, John Butz, and Thomas D. Milster. "A novel method for tracking in homogeneous volumetric media." In *Optical Data Storage*, p. TuE19. Optica Publishing Group, 2003.
7. Yeo, Junyeob, Moonseok Kim, Narak Choi, Seong-Eul Choi, Tom D. Milster, and Jaisoon Kim. "Pupil Plane Characteristics and Filtering for Optical Data Storage Using Circular Polarization with a Solid Immersion Lens." *Japanese Journal of Applied Physics* 48, no. 3S1 (2009): 03A019.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

8. Zhang, Yan, John Butz, Jason B. Curtis, Neil A. Beaudry, Warren L. Bletscher, James Kevin Erwin, Dak Knight, Thomas D. Milster, and Edwin P. Walker. "Characterization of photochromic bit-wise volumetric storage media for space applications." In *Optical Data Storage 2003*, vol. 5069, pp. 286-293. SPIE, 2003.
9. Choi, Taeyoung, Tom D. Milster, David Felix, Warren Bletscher, and Delbert Hansen. "Optical data destruction system: device design and test results." In *Photon Processing in Microelectronics and Photonics VII*, vol. 6879, pp. 294-300. SPIE, 2008.
10. Won, Kitak, Narak Choi, Jiyeon Lee, Yunsup Shin, Kyungeon Lee, Tom D. Milster, Jaihyung Lee, and Jaisoon Kim. "Advanced SIL System with High NA and Large Tolerance." In *Conference on Lasers and Electro-Optics/Pacific Rim*, p. FF2_4. Optica Publishing Group, 2007.
11. Zhao, Yanming, Brendan McCarthy, Thomas D. Milster, Mark S. Anderson, and Dror Sarid. "Apertureless Scanning Raman Microscopy." In *Frontiers in Optics*, p. MT25. Optica Publishing Group, 2003.
12. Upton, R. S., and T. D. Milster. "Crosstalk cancellation for DVD-RAM type media with 0.5/ μ m track pitch." In *2000 Optical Data Storage. Conference Digest (Cat. No. 00TH8491)*, pp. 194-196. IEEE, 2000.
13. Milster, T. D. "Near-Field Nano-Optics for Industry and Research." In *Frontiers in Optics*, p. FThF2. Optica Publishing Group, 2005.
14. Milster, Tom D., Y. Zhang, T. Y. Choi, S. K. Park, J. Butz, and W. Bletscher. "Potential for Volumetric Bit-Wise Optical Data Storage in Space Applications." In *Proceedings of NASA's Earth Science Technology Conference (ESTC2004)*. 2004.
15. Walker, Edwin P., and Tomas D. Milster. "Beam shaping for optical data storage." *Laser Beam Shaping II* 4443 (2001): 73-92.
16. Milster, Tom, Tao Chen, Dongseok Nam, and Tuviah Ed Schlesinger. "Maskless lithography with the solid immersion lens nanoprobe." In *24th Annual BACUS Symposium on Photomask Technology*, vol. 5567, pp. 545-556. SPIE, 2004.
17. Kim, Jaisoon, and Tomas D. Milster. "Design aspects of waveguide hybrid advance mems (WHAM)." In *Optical Data Storage 2001*, vol. 4342, pp. 447-456. SPIE, 2002.
18. Chen, Tao, Tom Milster, Dongseok Nam, and Seung Hune Yang. "Experimental investigation of solid immersion lens lithography." In *Optical Microlithography XVIII*, vol. 5754, pp. 254-261. SPIE, 2005.
19. Nam, Dongseok, Tom D. Milster, and Tao Chen. "Potential of solid immersion lithography using I-line and KrF light source." In *Optical Microlithography XVIII*, vol. 5754, pp. 1049-1055. SPIE, 2005.
20. Zhang, Yan, T. D. Milster, J. Butz, W. Bletcher, K. J. Erwin, and E. Walker. "Signal, cross talk and signal to noise ratio in bit-wise volumetric optical data storage." In *International Symposium on Optical Memory and Optical Data Storage Topical Meeting*, pp. 246-248. IEEE, 2002.
21. Kasanavesi, Sashi K., Tom D. Milster, David Felix, and Taeyoung Choi. "Data recovery from a compact disc fragment." In *Optical Data Storage 2004*, vol. 5380, pp. 116-127. SPIE, 2004.
22. Zhang, Jun, Matt Lang, Tom D. Milster, and Tao Chen. "Fabrication and testing of a GaP SIL with NA= 2.64." In *Optical Data Storage*, p. WA6. Optica Publishing Group, 2007.
23. Milster, Tom D., Yan Zhang, J. Butz, Tim Miller, and E. P. Walker. "Volumetric Bit-Wise Memories." In *NASA earth science technology conference*. 2002.
24. Chen, Tao, Tom D. Milster, and Seung-Hune Yang. "Experimental investigation of photomask with near-field polarization imaging." In *Photomask Technology 2006*, vol. 6349, pp. 1508-1515. SPIE, 2006.
25. Dvornikov, A. S., T. D. Milster, E. Walker, and P. M. Rentzepis. "Two-photon 3D high-density optical storage media: optical properties, temperature, radiation, and fatigue studies." In *Photonics for Space Environments XI*, vol. 6308, pp. 9-22. SPIE, 2006.
26. Milster, Tomas D. "Near-field optical data storage: avenues for improved performance." In

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Optical Storage and Optical Information Processing, vol. 4081, pp. 126-134. SPIE, 2000.
27. Jo, Joshua S., Tom D. Milster, and J. Kevin Erwin. "Characteristics of gap-induced aberration in solid immersion lens systems." In 2000 Optical Data Storage. Conference Digest (Cat. No. 00TH8491), pp. 39-41. IEEE, 2000.
 28. Hashimoto, Nobuyuki, and Tomas D. Milster. "Optical equalizer of a data storage system using liquid crystal super-resolution devices." In Optical Data Storage 2001, vol. 4342, pp. 486-491. SPIE, 2002.
 29. Jo, Joshua Sseunhyeun, and Tomas D. Milster. "Tolerance issues in solid immersion lens systems." In Optical Data Storage 2001, vol. 4342, pp. 312-319. SPIE, 2002.
 30. Chen, Tao, David Felix, Sang-Ki Park, Paul Hauser, Brendan P. McCarthy, Dror Sarid, Christian D. Poweleit, Jose Menendez, and Tom D. Milster. "Near-field solid immersion lens (SIL) microscope with advanced compact mechanical design." In Optical Data Storage 2004, vol. 5380, pp. 634-641. SPIE, 2004.
 31. Milster, T. D., S. K. Park, and Y. Zhang. "Prospects and Limitations for Large Numbers of Multi-Layers in Optical Data Storage." In 2006 Optical Data Storage Topical Meeting, pp. 179-181. IEEE, 2006.
 32. Khoh, Andrew, Donis G. Flagello, Thomas D. Milster, Byoung-Il Choi, Ganesh S. Samudra, and Yihong Wu. "Extending a GTD-based image formation technique to EUV lithography." In Emerging Lithographic Technologies VII, vol. 5037, pp. 682-689. SPIE, 2003.
 33. Khoh, Andrew, Tomas D. Milster, Byoung-Il Choi, Ganesh S. Samudra, and Yihong Wu. "Influence of OPC features on the profile of 2D mask patterns." In Optical Microlithography XV, vol. 4691, pp. 1127-1138. SPIE, 2002.
 34. Choi, Taeyoung, Tom D. Milster, and Matt Lang. "Wavelength-domain tracking in multiple-beam optical storage systems." In Optical Data Storage 2004, vol. 5380, pp. 197-208. SPIE, 2004.
 35. Zhou, Lifu, James A. Bain, Tuviah E. Schlesinger, Matt Lang, and Tom D. Milster. "Prototype mode index lens for heat-assisted magnetic recording." In Optical Data Storage 2004, vol. 5380, pp. 28-33. SPIE, 2004.
 36. Milster, Tomas D., David Felix, Charles J. Burkhart, J. Butz, Yan Zhang, and Jason B. Curtis. "Semi-kinematic rails for construction of optical test stands." In Optomechanical Design and Engineering 2001, vol. 4444, pp. 358-361. SPIE, 2001.
 37. Park, Sang-Ki, Tom D. Milster, and Yan Zhang. "Prospects and limitations for large numbers of multi-layers in optical data storage." In Optical Data Storage 2006, vol. 6282, pp. 222-232. SPIE, 2006.
 38. Yang, Seung-Hune, and Tom Milster. "Sub-surface imaging system for blue ray disk." In 2009 Optical Data Storage Topical Meeting, pp. 22-24. IEEE, 2009.
 39. Walker, Edwin P., and Tomas D. Milster. "Beam shaping for a high-power vertical cavity surface emitting laser." In Laser Beam Shaping II, vol. 4443, pp. 105-114. SPIE, 2001.
 40. Dallas, William J., Tom D. Milster, Pierre-Alexander Blanche, Arnold C. Friedman, Hans Roehrig, and Elizabeth A. Krupinski. "Computer-generated holographic stereograms." In Digital Holography and Three-Dimensional Imaging, p. DWB36. Optica Publishing Group, 2009.
 41. Hong, Sukjoon, Junyeob Yeo, Tom D. Milster, and Jaisoon Kim. "Study on the scanning system for deep focused beam by Axicon." In Optical Data Storage, p. 750514. Optica Publishing Group, 2009.
 42. Olkkonen, Juuso T., Kari J. Kataja, Janne Aikio, Dennis G. Howe, and Tom D. Milster. "Analysis of sub-wavelength apertures via the extended FDTD SF technique." In Optical Data Storage 2004, vol. 5380, pp. 653-662. SPIE, 2004.
 43. Milster, T. D., F. Li, S. Kasanavesi, W. Bletscher, D. Hansen, M. Lang, and P. Hauser. "Dynamic Data Recovery from Damaged CD Media." In International Symposium on Optical Memory and Optical Data Storage, p. WC5. Optica Publishing Group, 2005.
 44. Milster, T. D., and Shu-Guo Tang. "Generation of compact near-field energy for optical

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- recording." In International Symposium on Optical Memory and Optical Data Storage Topical Meeting, pp. 281-283. IEEE, 2002.
45. Chen, Tao, and Tom D. Milster. "Near-field induced polarization imaging for optical data storage metrology." In 2006 Optical Data Storage Topical Meeting, pp. 37-39. IEEE, 2006.
 46. Choi, Taeyoung, and Tom D. Milster. "Change in data marks and groove structure of CD-recordable disks in response to a high power laser beam." In International Symposium on Optical Memory and Optical Data Storage, p. WP11. Optica Publishing Group, 2005.
 47. Milster, T. D., S. K. Park, and Y. Zhang. "Characteristics and Limitations of Multiple-Layered Optical Memories." In International Symposium on Optical Memory and Optical Data Storage, p. MC2. Optica Publishing Group, 2005.
 48. Fukutake, Naoki, and Tom D. Milster. "Proposal of three-dimensional phase contrast holographic microscopy: erratum." Optics Express 16, no. 8 (2008): 5964-5964.
 49. Milster, Tom D. "Review of Methods to Achieve Optical Recording at 1Tb/in²." In Frontiers in Optics, p. WS2. Optica Publishing Group, 2003.
 50. Chen, Tao, Tom Milster, and Seung Hune Yang. "Semiconductor pattern analysis with induced polarization." In 25th Annual BACUS Symposium on Photomask Technology, vol. 5992, pp. 511-519. SPIE, 2005.
 51. Milster, Tom, John J. Butz, Takashi Nakano, Junji Tominaga, and Warren L. Bletscher. "Signal power in the angular spectrum of AgOx SuperRENS media." Optical Nanotechnologies: The Manipulation of Surface and Local Plasmons (2003): 119-140.
 52. Jo, Joshua Sseunhyeun, Tomas D. Milster, and James Kevin Erwin. "Amplitude and phase apodization caused by focusing light through an evanescent gap in SIL recorders." In Optical Storage and Optical Information Processing, vol. 4081, pp. 135-142. SPIE, 2000.
 53. Zhang, Yan, Tom D. Milster, John Butz, Dak Knight, Warren Bletcher, and Ed Walker. "Characterization of a three dimensional bit wise volumetric storage media in a space environment." In Optical Data Storage, p. TuE38. Optica Publishing Group, 2003.

1990s

1. Froehlich, Fred F., and Tom D. Milster. "A near-field scanning optical microscope for analysis of magneto-optic media." In Conference Digest Joint International Symposium on Optical Memory and Optical Data Storage 1993, pp. 83-84. IEEE, 1993.
2. Shimura, Kei, Tomas D. Milster, Kusato Hirota, and Joshua Sseunhyeun Jo. "Pupil plane filtering for improved signal detection in an optical data storage system incorporating a solid immersion lens." In Joint International Symposium on Optical Memory and Optical Data Storage 1999, vol. 3864, pp. 354-356. SPIE, 1999.
3. Upton, Robert S., Farhad Akhavan, Tomas D. Milster, Warren L. Bletscher, James Kevin Erwin, Anson M. Nicol, and Steban Flores. "Cross talk cancellation with a quadrant cell detector." In Joint International Symposium on Optical Memory and Optical Data Storage 1999, vol. 3864, pp. 23-25. SPIE, 1999.
4. Vernold, Cynthia L., and Tomas D. Milster. "Alignment of an optical axis to a rotating mechanical axis using grating phase modulation." In Second Iberoamerican Meeting on Optics, vol. 2730, pp. 639-642. SPIE, 1996.
5. Beaudry, Neil A., and Tomas D. Milster. "Effects of mask roughness and condenser scattering in EUVL systems." In Emerging Lithographic Technologies III, vol. 3676, pp. 653-662. SPIE, 1999.
6. Flagello, Donis G., and Tomas D. Milster. "Three-dimensional modeling of high-numerical-aperture imaging in thin films." In Design, modeling, and control of laser beam optics, vol. 1625, pp. 246-261. SPIE, 1992.
7. Burge, James H., David S. Anderson, Tomas D. Milster, and Cynthia L. Vernold. "Measurement of a convex secondary mirror using a holographic test plate." In Advanced Technology Optical

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- Telescopes V, vol. 2199, pp. 193-198. SPIE, 1994.
8. Milster, Tomas D., and Neil A. Beaudry. "Scattering and Coherence in EUVL." In *Emerging Lithographic Technologies II*, vol. 3331, pp. 537-543. SPIE, 1998.
 9. Vernold, Cynthia L., and Tomas D. Milster. "Nonphotolithographic fabrication of large computer-generated diffractive optical elements." In *Current Developments in Optical Design and Optical Engineering IV*, vol. 2263, pp. 125-133. SPIE, 1994.
 10. Milster, T. D. "A user-friendly diffraction modeling program." In *1997 Optical Data Storage Topical Meeting ODS Conference Digest*, pp. 60-61. IEEE, 1997.
 11. Hirota, Kusato, Joshua S. Jo, and Tom D. Milster. "High density phase change optical recording using a solid immersion lens." In *Optical Data Storage*, pp. MD-2. Optica Publishing Group, 1998.
 12. Treptau, Jeffrey P., Tomas D. Milster, and Donis G. Flagello. "Laser beam modeling in optical storage systems." In *Modeling and Simulation of Laser Systems II*, vol. 1415, pp. 317-321. SPIE, 1991.
 13. Milster, Tomas D., and Jen Nan Wong. "Modeling and measurement of a micro-optic beam deflector." In *Design, Modeling, and Control of Laser Beam Optics*, vol. 1625, pp. 78-83. SPIE, 1992.
 14. Rowe, R. K., J. N. Aarsvold, H. H. Barrett, J. Chen, J. N. Hall, A. L. Landesman, L. S. Mar et al. "The design and implementation of modular SPECT imaging systems." In *Medical Images: Formation, Handling and Evaluation*, pp. 543-550. Springer Berlin Heidelberg, 1992.
 15. Flagello, Donis G., and Tomas D. Milster. "Experimental verification of high-numerical-aperture effects in photoresist." In *Optical/Laser Microlithography VII*, vol. 2197, pp. 466-477. SPIE, 1994.
 16. Froehlich, Fred Franklin, Tomas D. Milster, and R. Uber. "High-resolution optical lithography with a near-field scanning subwavelength aperture." In *Miniature and Micro-Optics: Fabrication and System Applications II*, vol. 1751, pp. 312-320. SPIE, 1993.
 17. Upton, Robert S., and Tomas D. Milster. "Complex-plane description of differential plane detection in optical data storage." In *Optical Data Storage'98*, vol. 3401, pp. 263-271. SPIE, 1998.
 18. Milster, Tom D. "Characteristics Of Phase-Compensation Techniques In Magneto-optical Read-Back Systems." In *Polarization Considerations for Optical Systems II*, vol. 1166, pp. 355-367. SPIE, 1990.
 19. Milster, Tom D., Fred F. Froehlich, Mark S. Wang, Jeff P. Treptau, and J. Kevin Erwin. "Differential spot-size focus servo." In *Optical Data Storage*, p. WB3. Optica Publishing Group, 1991.
 20. Hirota, Kusato, Tomas D. Milster, Kei Shimura, Yan Zhang, and Joshua Sseunhyeun Jo. "Near-field phase-change optical recording using a GaP hemispherical lens." In *Joint International Symposium on Optical Memory and Optical Data Storage 1999*, vol. 3864, pp. 339-341. SPIE, 1999.
 21. Milster, Tomas D., and Edwin P. Walker. "Figures of merit for laser beam quality." In *Laser Energy Distribution Profiles: Measurement and Applications*, vol. 1834, pp. 79-85. SPIE, 1993.
 22. Milster, Tomas D., Robert S. Upton, and Hui Luo. "Objective lens design for multiple-layer optical data storage." In *Optical Data Storage 1997 Topical Meeting*, vol. 3109, pp. 142-149. SPIE, 1997.
 23. Milster, Tom D., Robert M. Trusty, Mark S. Wang, Fred F. Froehlich, and J. Kevin Erwin. "Micro-optic lens for data storage." In *Optical Data Storage*, p. TuD3. Optica Publishing Group, 1991.
 24. Milster, Tomas D., Melvin K. Benedict, and Ronald P. Stahl. "Laser diode requirements for magneto-optical storage devices." In *Optical Data Storage*, vol. 1316, pp. 143-149. SPIE, 1990.
 25. Milster, Tomas D. "Combination of ray-trace and diffraction modeling to describe coupling laser

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

- diodes to fibers and waveguides." In *Laser Diode Chip and Packaging Technology*, vol. 2610, pp. 194-202. SPIE, 1996.
26. Akhavan, Farhad, and Tomas D. Milster. "CD-R and CD-RW optical disk characterization in response to intense light sources." In *Recent Advances in Metrology, Characterization, and Standards for Optical Digital Data Disks*, vol. 3806, pp. 84-92. SPIE, 1999.
 27. Milster, Tomas D., and Jeffrey P. Treptau. "Measurement of laser spot quality." In *Laser Beam Diagnostics*, vol. 1414, pp. 91-96. SPIE, 1991.
 28. Hirota, Kusato, Tomas D. Milster, and Yan Zhang. "Design of a near-field probe for optical recording using a three-dimensional finite-difference time-domain method." In *Joint International Symposium on Optical Memory and Optical Data Storage 1999*, vol. 3864, pp. 243-245. SPIE, 1999.
 29. Schlichting, Wolfgang, Sadeg Faris, Bunsen Fan, John Haag, Zhijian Lu, Le Li, Tom Milster, and Hui Luo. "Recording and read-out of a cholesteric liquid crystal based multilayer disk." In *Symposium on Optical Memory*, pp. OWB-3. Optica Publishing Group, 1996.
 30. Milster, Tomas D. "A new way to describe diffraction from optical disks." In *Optical Data Storage 1997 Topical Meeting*, vol. 3109, pp. 229-234. SPIE, 1997.
 31. Kann, Joshua L., Tomas D. Milster, Fred Franklin Froehlich, Richard W. Ziolkowski, and Justin B. Judkins. "Rigorous numerical modeling of novel optical data storage systems." In *Optical Data Storage 1997 Topical Meeting*, vol. 3109, pp. 222-228. SPIE, 1997.
 32. Milster, Tom D., and Robert S. Upton. "Complex plane description of differential phase detection in optical data storage." In *Optical Data Storage*, pp. PDP-9. Optica Publishing Group, 1998.
 33. Milster, Tomas D. "Design issues in optical data storage." In *Proc. SPIE*, vol. 2383, pp. 382-389. 1995.
 34. Milster, Tomas D., and Craig H. Curtis. "Transfer function characteristics of superresolving systems." In *Optical Data Storage*, vol. 1663, pp. 123-126. SPIE, 1992.
 35. Milster, Tom D., and Jeffrey P. Treptau. "Combining ray-trace and diffraction analysis: a design example." *Research Studies on Advanced Optical Module (Head Designs for Optical Data Storage (1992))*.
 36. Milster, T. D., W. L. Bletscher, E. P. Walker, and E. C. Gage. "Quadrant Pupil Detection for Optical Data Storage." In *Symposium on Optical Memory*, pp. OFA-5. Optica Publishing Group, 1996.
 37. Milster, T. D., W. L. Bletscher, E. P. Walker, S. B. Hamilton, and M. L. Caldwell. "A Magneto-Optic Testbed for 532nm Sensitive Media." In *Symposium on Optical Memory*, pp. OTuB-12. Optica Publishing Group, 1996.
 38. Milster, T., K. Erwin, F. Froehlich, J. Kann, W. Li, W. Schlichting, R. Shetty, E. Walker, and M. Wang. "Dynamic testbed laboratory and micro-optics." *Research Studies on Advanced Optical Module (Head Designs for Optical Disk Recording Devices (1993))*.
 39. Wang, Mark S., and Tom D. Milster. "A complete study of differential wax-wane focus servo technique." In *Conference Digest Joint International Symposium on Optical Memory and Optical Data Storage 1993*, pp. 157-158. IEEE, 1993.
 40. Walker, Edwin P., and Tomas D. Milster. "Superresolution by optical and electronic filtering." In *Optical Data Storage'95*, vol. 2514, pp. 112-117. SPIE, 1995.
 41. Milster, Tom D., and Zhiyong Chen. "Signal and Noise Patterns in the Collection Aperture of Optical Data Storage Devices." In *Optical Data Storage*, p. WD3. Optica Publishing Group, 1994.
 42. Milster, Tomas D., D. P. Gregg, and K. C. Wilson. "Crescent geometry for an optical ribbon recorder." In *Joint International Symposium on Optical Memory and Optical Data Storage 1999*, vol. 3864, pp. 95-97. SPIE, 1999.
 43. Wang, Mark S., and Tom D. Milster. "Effects of higher order aberrations on beam shape in an optical recording system." *Research Studies on Advanced Optical Module (Head Designs for Optical Data Storage (1992))*.

Declaration of Dr. Tom D. Milster
U.S. Patent No. 7,618,162

44. Milster, Tom D. "Optimization of DVD media parameters." In 1997 Optical Data Storage Topical Meeting ODS Conference Digest, pp. 34-35. IEEE, 1997.

1980s

1. Milster, T. D., L. A. Selberg, H. H. Barrett, A. L. Landesman, and R. H. Seacat. "Digital position estimation for the modular scintillation camera." IEEE Transactions on Nuclear Science 32, no. 1 (1985): 748-752.
2. Barrett, H. H., W. E. Smith, K. J. Myers, T. D. Milster, and R. D. Fiete. "Quantifying the performance of imaging systems." In Application of Optical Instrumentation in Medicine XIII, vol. 535, pp. 65-69. SPIE, 1985.
3. Myers, K. J., H. H. Barrett, M. C. Borgstrom, E. B. Cargill, A. V. Clough, R. D. Fiete, T. D. Milster et al. "A systematic approach to the design of diagnostic systems for nuclear medicine." In Information Processing in Medical Imaging: Proceedings of the 9th conference, Washington DC, 10-14 June 1985, pp. 431-444. Springer Netherlands, 1986.
4. Aarsvold, J. N., H. H. Barrett, J. Chen, A. L. Landesman, T. D. Milster, D. D. Patton, T. J. Roney, R. K. Rowe, R. H. Seacat III, and L. M. Strimbu. "Modular scintillation cameras: a progress report." In Medical Imaging II, vol. 914, pp. 319-325. SPIE, 1988.
5. Milster, T. D., and T. S. Gardner. "Modeling of a magneto-optic read path." In Optical Storage Technology and Applications, vol. 899, pp. 61-68. SPIE, 1988.