

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG DISPLAY CO., LTD.,
Petitioner,

v.

PICTIVA DISPLAYS INTERNATIONAL LTD.,
Patent Owner.

Case No. IPR2024-00855
Patent No. 8,314,547

**DECLARATION OF J. GARY EDEN, PH.D. IN SUPPORT OF PETITION
FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 8,314,547**

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1. I, J. Gary Eden, have been retained by counsel for Petitioner Samsung Display Co, Ltd. to provide my expert opinions concerning the validity of certain claims of U.S. Patent No. 8,314,547 (“the ’547 patent”). For the reasons discussed below, it is my opinion that claims 1–5 and 8–14 of the ’547 patent would have been obvious to a person of ordinary skill in the art.

I. BACKGROUND AND QUALIFICATIONS

2. In this section, I summarize my qualifications for forming the opinions set forth in this declaration. Additional information is provided in my *curriculum vitae*, which is attached as Appendix A. My curriculum vitae also includes a list of my publications and the patent cases in which I have testified at a deposition, hearing, or trial during the past ten years (pp. 57–59).

3. I received the B.S. degree in Electrical Engineering from the University of Maryland (College Park) in 1972, the M.S. degree in Electrical Engineering in 1973 from the University of Illinois (Urbana) in 1973, and the Ph.D. degree in Electrical Engineering from the University of Illinois in 1976. During my graduate research at the University of Illinois, I conducted experiments with some of the earliest semiconductor lasers (GaAs) that had been fabricated at IBM by Dr. John Marinace. Professor Nick Holonyak, Jr., the inventor of the first LEDs, was a member of my Ph.D. Committee. I have been working in the fields of lasers, optoelectronics, and photonics for more than 50 years.

4. In 1975, I was appointed a National Research Council (NRC) Postdoctoral Research Associate at the U.S. Naval Research Laboratory (NRL) in Washington, D.C. where I conducted research on ultraviolet and visible lasers. From 1976 through August of 1979, I served as a Laser Physicist on the staff of NRL's Optical Sciences Division. In that capacity, I discovered and developed a variety of ultraviolet and visible (primarily violet, blue, and green) lasers, and received the NRL Research Publication Award in 1978 for the discovery of a particular laser.

5. In 1979, I joined the faculty of the University of Illinois (Urbana-Champaign) and have now served in the Department of Electrical and Computer Engineering (ECE) for almost 45 years. I have served as Assistant Dean in the College of Engineering, Associate Dean of the Graduate College, and Associate Vice-Chancellor for Research. I have served (and continue to serve) as Director of the Laboratory for Optical Physics and Engineering, as well as Research Professor in the Coordinated Science Laboratory, and Professor in the Holonyak Micro and Nanotechnology Laboratory (HMNTL). I have received affiliate faculty appointments in the Departments of Bioengineering, Materials Science and Engineering, and Nuclear, Plasma and Radiological Engineering for a number of years.

6. During my tenure at the University of Illinois, I have conducted research devoted to the discovery and development of numerous types of light

sources in the visible, ultraviolet (UV), and vacuum ultraviolet (VUV) regions of the electromagnetic spectrum, including LEDs, lasers, and plasma lamps. My research has involved studying the atomic and molecular physics, material properties (including optical properties), and laser spectroscopy of both solid state (semiconductor and non-semiconductor) and plasma (gas discharge)-based optical sources.

7. To date, 65 individuals have received the Ph.D. degree in ECE, Physics, Materials Science and Engineering, Chemistry, Bioengineering, Nuclear, Plasma, and Radiological Engineering, or Environmental Engineering under my direction. I am the author or co-author of more than 340 peer-reviewed scientific publications and am a co-inventor of 105 U.S. and international patents. The claims for several other patent applications have recently been allowed.

8. I am a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), the Optical Society of America, the American Physical Society, the American Association for the Advancement of Science (AAAS), and the Society of Photo-Optical Instrumentation Engineers (SPIE). I have served in several official positions of the IEEE Photonics Society and, in 1998, I served as President of the Society. I am a co-founder of five companies, three of which are currently manufacturing products in Champaign, IL. Two of these (Eden Park Illumination and Cygnus Photonics) are devoted to visible/ultraviolet optical sources and their

applications in industry and medicine. Eden Park manufactures a wide range of flat and efficient UV and VUV lamps, for example, for applications such as materials identification, curing of polymers, medical phototherapeutics, and surface disinfection. Indeed, Eden Park lamps emitting at 222 nm are presently being applied worldwide to disinfecting air and surfaces in public spaces. These lamps were quite effective during the COVID-19 pandemic (and since) and are being installed in offices, schools and school buses, restaurants, restrooms, commercial buildings, and military installations because 222 nm UV “light” is not harmful to human tissue (as are UV “germicidal” lamps) but is lethal for viral and bacterial pathogens. Cygnus Photonics manufactures ultraviolet photolithography systems, as well as systems for the photoassisted growth of semiconductor thin films and electronic and optical devices.

9. My background includes considerable experience in the design and manufacture of white light sources. During its first seven years of operation, Eden Park Illumination (EPI) manufactured flat and thin, white-emitting lamps for the videography and cinematography markets. These lamps typically had emitting areas of 1 ft² and were based on the conversion of ultraviolet (UV) light into white light by means of several phosphors. Our mixture of phosphors was proprietary and designed to yield the maximum value for the Color Rendering Index (CRI), while

generating white light having one of several specific values Correlated Color Temperature (CCT). Achieving a CRI above 90 required at least four phosphors.

10. During my formal education, I acquired a background in electrical engineering and physics, particularly in the sub-fields of optics, optical engineering, semiconductor physics, microelectronics, and optoelectronics. This background facilitated my academic, governmental, and industrial research and development activities. Over the past 52 years, my work has centered on research in, and the development of, light-emitting devices including LEDs, lasers, and lamps. My research and industry experience has included the development of white-light lamps energized by the UV excitation of a combination of several phosphors. These lamps were designed for, and marketed to, the cinematography and videography markets. In short, my academic, governmental laboratory, and industry experience in creating, developing, and manufacturing optoelectronic devices and products has explored most of the visible and UV emitters in existence (in the solid or gas phase), and their applications in markets including lighting and displays.

11. My work on optoelectronic devices began at the outset of my career when I studied under Professor Nick Holonyak, Jr., who is credited with the invention of the first LED. I was a student in his graduate course entitled “Compound Semiconductor Devices,” where his pioneering work in the semiconductor LED and laser field was discussed in detail. Later, Prof. Holonyak

served as a member of my Ph.D. Committee, and I became familiar with his work in developing red (AlGaAs), orange, yellow, and green (GaP:N) LEDs. He and his students provided advice for experiments I was conducting, and several of his most prominent Ph.D. graduates have been life-long friends and colleagues. It was during my graduate research that I used GaAs semiconductor lasers in atomic physics experiments. These lasers, some of the earliest III-V semiconductor lasers (and LEDs) were fabricated and supplied by Dr. Marinace of IBM. It was at this time I also began researching and utilizing many different optical materials in optoelectronic applications. For example, my research included the use of diamond (specifically Type IIA) and other crystalline materials as heat-sinks for semiconductor applications. I also became familiar with, and often used, optically-transmissive materials such as sapphire, fused silica, quartz, and zinc selenide because of their value as optical or infrared windows in semiconductor device and other light emitter applications. Sapphire was of particular value to my graduate research because it is resistant to chemical attack by alkali metals (such as sodium, potassium, and cesium) which were part of my research. Sapphire was also of considerable importance because of its transparency throughout the visible and deep into the ultraviolet. Major areas of my research while at the University of Illinois have included optoelectronic devices such as LEDs and lasers, optical physics, nanophysics, plasma science, laser spectroscopy, and photophysics. It should also

be mentioned that through the IEEE Photonics Society, I have become familiar with other aspects of the history, physics, and commercialization of III-V semiconductor emitters and power devices.

12. I have received a number of research honors, including, among others, the SPIE Harold E. Edgerton Award (2010), the C.E.K. Mees Medal from the Optical Society of America (2007), the Aron Kressel Award from the IEEE Lasers and Electro-Optics Society (2005) (now known as the IEEE Photonics Society), the Third Millennium Medal from the IEEE (2000), and the Distinguished Service Award from the IEEE Lasers and Electro-Optics Society (1996). In 2014, I was elected into the National Academy of Engineering (NAE) and the National Academy of Inventors (NAI). In 2020, I was elected into the Innovation Hall of Fame of the A. James Clark School of Engineering at the University of Maryland. Recently, I received the IEEE Plasma Science and Applications (PSAC) Award, and was appointed a Hagler Fellow in the Institute for Advanced Study at Texas A&M University.

13. Much of my experience in research and product development has centered on light sources and the materials required for photonic applications. Accordingly, please indulge my providing a few examples of my experience that are germane to the issues central to this matter. However, these examples should not be

regarded as being exhaustive in describing my more than 50 years of research in the field.

14. In the 1980s and 1990s, I developed with my students photochemical methods for growing both elemental and compound semiconductor materials. Specifically, we were able to grow thin crystalline and polycrystalline films of both silicon- and gallium arsenide (GaAs)-based materials – the foundation of many photonic and electronic devices – by employing a laser to break the chemical bonds of one or more “precursor” molecules. For example, in partnership with Prof. James J. Coleman (the inventor of strained-layer semiconductor lasers), we demonstrated the ability of ultraviolet lasers to grow LED films and semiconductor laser films on various substrates by a photoassisted growth process based on metal organic chemical vapor deposition (MOCVD) techniques. I also conducted research on molecular beam epitaxy (MBE) semiconductor growth.

15. In the late 1990s, my research group collaborated with another ECE research group at the University of Illinois to grow GaN LED and laser materials. This work demonstrated efficient laser and LED operation at room temperature (300 K) which was significant because most previous work required the LED or laser materials to be cooled to temperatures well below room temperature.

16. My research group also demonstrated the growth of Gallium Nitride (GaN) and Aluminum Nitride (AlN) films for various optoelectronic applications.

These materials are the basis of many LEDs and lasers manufactured at present, and our experiments were among the first to grow them, and by a photoassisted process, in particular. Today, my laboratory continues to work on these materials and their applications to LEDs. At present, we are investigating the growth of GaN, AlN, aluminum oxide (Al_2O_3), and gallium oxide (Ga_2O_3) by a process developed in our laboratory. Gallium-oxide is of particular interest as a “next generation” light-emitting semiconductor material, and we have succeeded in growing polycrystalline material at room temperature for photodetector applications. Single crystal material has not yet been grown but our plasma-assisted atomic layer deposition (ALD) process appears to have the potential to grow both crystalline gallium-nitride (GaN) and gallium-oxide films, and their alloys with indium, in the future. For this work, we also develop techniques that often employ materials such as sapphire, silicon, fused silica (or quartz) and other substrate materials as heat-sinks and/or as substrates for the purpose of growing epitaxial (crystalline) or polycrystalline films.

17. In addition to the study and development of the light emitters themselves, my work has focused extensively on the optical properties of materials used in lighting applications. For example, I commonly use sapphire, quartz, fused silica, and other transparent materials in my research for purposes of increasing light extraction and/or dissipating heat. Fused silica, for example, often serves as either an optical window, optical fiber, or an optical waveguide with other than cylindrical

geometry for transporting light. Sapphire is an important material for optical windows because of its mechanical strength and its high transmission throughout the visible and ultraviolet, and well into the vacuum ultraviolet region. It is also of considerable importance as the substrate material for the growth of GaN, InGaN, and other III-V crystalline thin films. I also have experience in the application of ceramic and polymer materials for optical packaging applications, including polycrystalline aluminum oxide. I have studied these materials extensively and have developed techniques for measuring and quantifying their optical properties.

18. This summary of my research and experience is meant only to provide general background, and additional experience is set forth in my CV which is provided in Appendix A.

II. MATERIALS CONSIDERED

19. In forming my opinions, I have reviewed the documents in the following table. I have also relied on my education, knowledge, and experience gained by working in the field for more than 50 years.

Exhibit No.	Description
1001	U.S. Patent No. 8,314,547
1002	Certified File History for U.S. Patent No. 8,314,547
1004	U.S. Patent Application Publication No. 2007/0023734 (Igarashi)
1005	Certified Translation of Japanese Published Application No. H10-170918 (Shiotani)
1006	U.S. Patent No. 6,949,389 (Pilcher)
1007	U.S. Patent No. 6,624,828 (Dresevic)

Exhibit No.	Description
1008	U.S. Patent No. 2005/0189857 (Kobori)
1009	Warren J. Smith, <i>Modern Optical Engineering</i> (3d ed. 2000)
1010	Hongxia Li et al., <i>Zinc Oxide Films Prepared by Sol-Gel Method</i> , 275(1) J. Crystal Growth e943–e946 (2005)
1011	Japanese Published Application No. H10-170918 (Shiotani)
1012	Ho-Chi Huang et al., <i>Processes, Characterizations, and System Applications of Color-filter Liquid-crystal-on-silicon Microdisplays</i> , 14(5) J. SID 499–508 (2006)
1013	U.S. Patent Application Publication No. 2006/0152150 (Boerner)
1014	Eugene Hecht, <i>Optics</i> (4th ed. 2002)
1015	Safer Mourad, <i>Color Predicting Model For Electrophotographic Prints On Common Office Paper</i> , Thesis No.2708 (2003)
1016	U.S. Patent No. 6,897,876 (Murdoch)
1017	McGraw-Hill Dictionary of Scientific and Technical Terms (5th ed. 1994) (McGraw-Hill)
1018	Zhuohao Xiao et al., <i>Materials Development and Potential Applications of Transparent Ceramics: A Review</i> , Material Sci. & Eng'g R. 139 (2020)
1019	U.S. Patent Application Publication No. 2007/0159061 (Krummacher)
1020	A.P. Ghosh, <i>Full-Color OLED on Silicon Microdisplay</i> , 4464(1) Proc. SPIE 1–10 (2002)
1021	Celine Chartier et al., <i>Photoluminescence of Eu²⁺ in SrGa₂S₄</i> , 111(3) J. Luminescence 147–58 (2005)
1022	Pochi Yeh & Claire Gu, <i>Optics of Liquid Crystal Displays</i> (2009)
1023	U.S. Patent No. 7,193,364 (Klausmann)
1024	U.S. Patent No. 7,402,951 (Cok)
1025	Wolfgang Kowalsky et al., <i>OLED Matrix Displays: Technology and Fundamentals</i> , 442(1) Thin Solid Films 20–28 (2001)
1026	U.S. Patent No. 7,489,073
1027	Reflection and Refraction, Encyclopedia Britannica, https://www.britannica.com/science/light/Reflection-and-refraction (last visited Apr. 28, 2024)

Exhibit No.	Description
1028	Sapphire, ESCO Optics, https://escooptics.com/pages/sapphire (last visited March 4, 2024)
1029	Docket Control Order, <i>Pictiva Displays International Ltd. v. Samsung Electronics Co., Ltd., et al.</i> , Case No. 2:23-cv-00495, Dkt. #40 (E.D. Tex. Apr. 17, 2024)

III. RELEVANT LEGAL STANDARDS

20. I am not an attorney. I have been informed by counsel about aspects of the law that are relevant to forming my opinions.

21. I have been informed that a patent claim is “anticipated” if each element is present explicitly or inherently in a single prior art reference, with the elements arranged in the same manner as in the claim. I have been informed that an element is inherently present if it necessarily flows from the disclosures of the prior art reference.

22. I have been informed that a patent claim would have been obvious to a person of ordinary skill in the art if the differences between the subject matter in the prior art and the subject matter in the claim would have been obvious to a person of ordinary skill in the art at the time the application was filed. I have been informed whether a claim would have been obvious involves consideration of (1) the level of ordinary skill in the art at the time the application was filed, (2) the scope and content of the prior art, (3) what differences, if any, existed between the claimed invention and the prior art, and (4) any secondary considerations of nonobviousness.

23. I have been informed that a patent claim may be rendered obvious by a single reference if the differences between the claim and that reference would have been obvious to a person of ordinary skill in the art. I have been informed that a claim may also be rendered obvious by a combination of two or more references if the combination would have been obvious to a person of ordinary skill in the art. I am informed that in determining whether a claim is obvious based on the teachings of a single reference or based on the teachings of a combination of references, it is appropriate to consider the following:

- whether the teachings of the prior art references disclose known concepts combined in familiar ways, and when combined, would yield predictable results;
- whether a person of ordinary skill in the art could implement a predictable variation, and would see the benefit of doing so;
- whether the claimed elements represent one of a limited number of known design choices, and would have a reasonable expectation of success by those skilled in the art;
- whether a person of ordinary skill would have recognized a reason to combine known elements in the manner described in the claim;
- whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent;

- whether the innovation would have been obvious to try, i.e., involving a choice from a finite number of identified, predictable solutions, with a reasonable expectation of success; and
- whether the innovation applies a known technique that had been used to improve a similar device or method in a similar way.

24. I am informed that a person of ordinary skill in the art is considered to have ordinary creativity and not be an automaton. I am further informed, however, that in considering whether a patent claim is obvious it is important not to use hindsight derived from the patent at issue.

25. I am informed that secondary considerations of nonobviousness can include a long-felt but unmet need for the claimed invention, failure of others, copying, unexpected results, commercial success, skepticism, or industry praise. I understand that it is generally the patent owner's burden to present evidence of secondary considerations if the patent owner contends that any apply. I am not aware of any evidence of secondary considerations of nonobviousness that would apply to the claims at issue. If any such alleged evidence is later identified, I reserve the right to respond at an appropriate time.

IV. TECHNOLOGY BACKGROUND

26. In this section, I will explain several concepts regarding visible light and the transmission of light through a material, which are important to understanding the '547 patent.

A. Brief Description of Light

27. Visible light is a form of electromagnetic radiation, and as such is a portion of the electromagnetic spectrum. The wavelengths of the visible light portion of the spectrum span from approximately 400 nm (violet) to 700 nm (deep red), where “nm” represents the nanometer (*i.e.*, one billionth of a meter in length). The blue, green, yellow, orange, and red regions of the spectrum lie roughly in the 450–470 nm, 500–540 nm, 570–590 nm, 595–605 nm, and 630–700 nm wavelength intervals. It must be noted, however, that the colors of the visible spectrum (the “rainbow”) transition smoothly and gradually from one to the next and, therefore, much of the spectrum can be viewed as arising from mixtures of colors. For example, light emitted in the 480-510 nm interval in wavelength is blue-green in color, whereas light emitted in the 605-630 nm region is orange-red in color and often referred to as “neon red” because the neon atom emits light strongly in this spectral range.

28. Visible light, like all forms of electromagnetic radiation, exhibits properties of both waves and particles. For example, light propagates through space

and materials as a wave but it is known to consist of photons in the same way that all material is composed of atoms. A photon of visible light has a specific amount of energy, which depends on its wavelength. For example, the energy of a red photon having a wavelength of 630 nm is approximately 2.0 eV (electron-Volts) while each blue photon having a wavelength of 450 nm has an energy of approximately 2.75 eV.

B. Synthesis of “White Light” From Individual Colors

29. The generation of white light from a blue or ultraviolet (UV) optical source, such as an OLED or LED, entails the “down conversion” of high-energy photons (e.g. blue or UV light) into lower-energy photons (e.g., green, yellow, orange, or red light), using materials known as phosphors. After blue or UV light is absorbed by a phosphor, green, yellow, orange, and/or red light is emitted by the phosphor, with the emission color depending on the chemical composition of the phosphor. The fluorescent lamps introduced by General Electric (GE) at the 1938 International Exposition in Chicago were the first commercial lighting products to be based on the conversion of UV or blue light into white light.

30. Because phosphors are designed to emit a particular color of visible light and no one phosphor is capable of emitting white light, LEDs and OLEDs that produce white light of high quality do so by relying on several phosphors of different colors. In other words, producing white light that most closely resembles the light

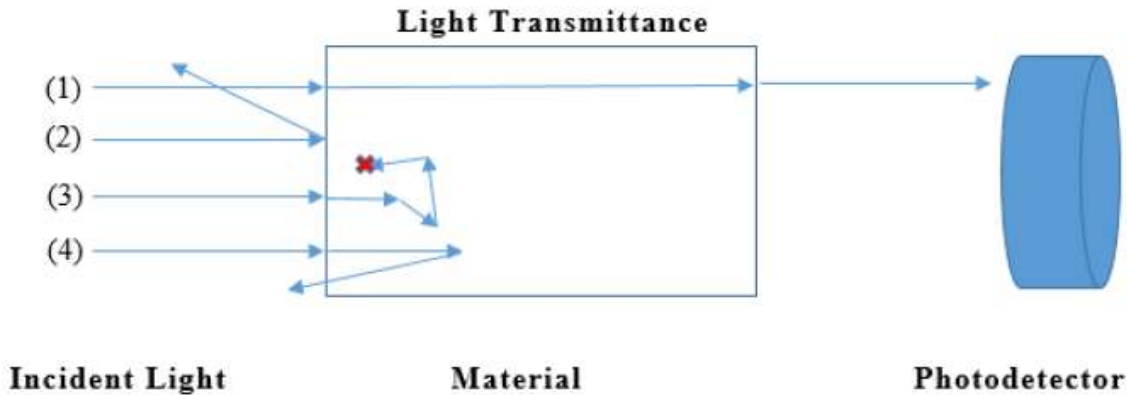
produced by the Sun requires that the visible spectrum be approximated or “pieced together” from, for example, a blue source light and red, orange, and yellow phosphors.

31. Additionally, light sources based solely on combining blue light (e.g., from an OLED or LED) with yellow light (e.g., typically from a phosphor) can emit “whitish” light as discussed in the ’547 patent. However, the “white light” emitted by such sources is of lesser quality. That is, the color rendering index (CRI) is relatively low. Accordingly, such sources are used only in lighting applications in which the accurate reproduction of color for an observer is not a priority.

C. Transmission, Reflection, and Scattering of Light in Materials

1. Visible Light Transmittance

32. When light propagates through a material, a fraction of the light (*i.e.*, a fraction of the photons) is lost due to scattering or absorption. The optical transmittance (or transmission) of a material is the ratio of light that passes through the material, relative to the amount of light that was incident on the material. *See* McGraw-Hill (Ex. 1017) at 2059 (defining “transmittance” as “[t]he radiant power transmitted by a body divided by the total radiant power incident upon the body”). The figure below is an illustration of a beam of light, indicated by light “rays,” impinging on a material from the left.



33. Light rays are a simplification of how photons interact with a solid material, but they can be a useful simplification because they are helpful in visualizing the passage of light through an optical system such as a telescope or a camera lens. Light rays may enter a material and then pass freely through the material (as shown by ray #1) in the figure, where the bulk (*i.e.*, interior of the material) does not change the direction of a ray propagating (passing) through the material. Rays that pass undisturbed through the material can be observed on the back (“downstream”) side of the material. Other rays, such as ray #2, are reflected at the surface of the material. In the case of ray #3 and ray #4, however, the light enters the material but is then scattered (*i.e.*, deflected or deviated from its original path) by defects, pores, impurities, or other imperfections in the solid material. Scattered rays (as well as non-scattered rays) may be absorbed (at the red “x”) by the material as shown by ray #3 (at red “x”). Alternatively, ray #4 demonstrates that scattering may also result in the ray being sent back through the incident surface, or a side surface of the material. In summary, only a fraction of the light impinging on

a material may actually reach the detector shown at the right in the figure (in this case only ray #1). The physical phenomena of absorption, reflection, and scattering are explained in more detail below.

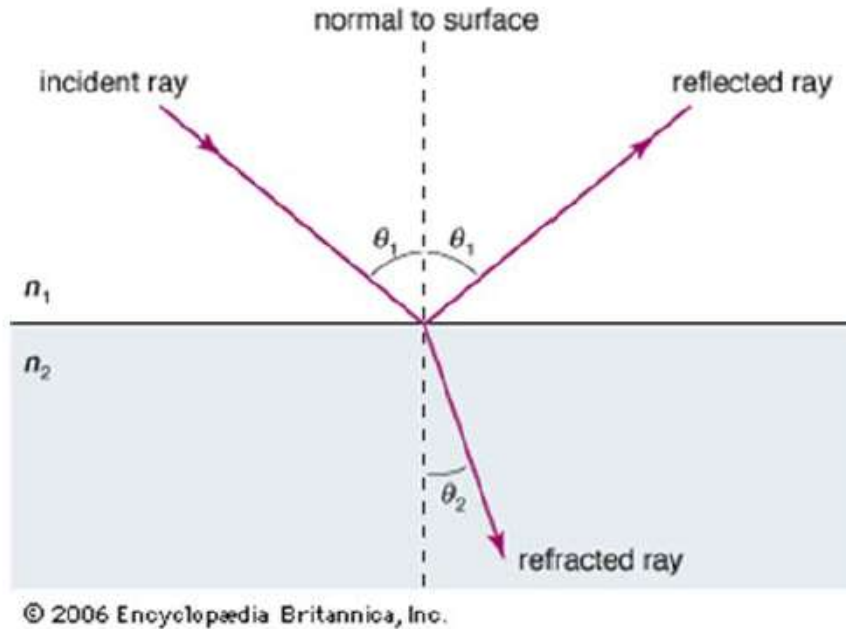
2. Absorption

34. Absorption is the physical process in which light is converted into another form of energy as it passes through a material. *See McGraw-Hill (Ex. 1017) at 8.* Photons that are absorbed are not transmitted through the material but rather are absorbed by an atom, molecule, or defect in the material and converted to heat. The absorption of light in a material can arise from one or more of a variety of factors, including the electronic states of the material, impurities (which can be introduced either intentionally or unintentionally), and/or defects. One example of the latter is the occasional absence of an oxygen atom in the lattice of an oxide material such as ceramic alumina. During the processing of sintering silica (SiO_2) or alumina (Al_2O_3), a small number of oxygen atoms may escape the material. Such “oxygen vacancies” are actually capable of absorbing or emitting a photon in response to an incoming beam of light.

35. In addition, openings or holes within a material, known as “pores,” can lead to repeated scattering within the material, increasing the likelihood of absorption.

3. Reflection and Refraction

36. Reflection is the optical process in which the direction of a light beam is abruptly altered upon reaching an interface between two dissimilar materials. When reflection occurs, the difference in the index of refraction between the two media at the interface causes a portion of the incident light to be reflected back into the original medium while the remaining portion of the beam passes through the interface and into the second medium. *See* McGraw-Hill (Ex. 1017) at 1674 (defining “reflection”). We observe this phenomenon daily. For example, we observe reflection when we see ourselves in bathroom mirrors, which comprise a glass plate having a metallic or other reflective coating on its rear surface. We also observe a reflection from the windows in our homes. The reflection occurring at interfaces including air/glass and glass/water is the result of the difference in the refractive indices of the two materials at the interface. An example of a reflected light ray is shown below where n_1 and n_2 represent the refractive indices of the two media at the interface. Ex. 1027.



Id.

37. The figure above illustrates the refraction of light, which is the term given to the portion of the incident light beam that enters the second medium. When light reaches an interface between two media with two different refractive indices, as shown in the figure, a portion of light that reaches the interface will generally be reflected and another portion of the light will generally be *refracted* such that it enters the second medium but propagates through the material with an angle (with respect to the surface normal) that differs from that of the incident light beam. Refraction occurs because the speed of light is different in materials with different refractive indices. This change in the direction of light, as light passes from one medium to another, is known as refraction. See McGraw-Hill (Ex. 1017) at 1676

(defining “refraction”). The angle at which the light is refracted is dictated by Snell’s Law.

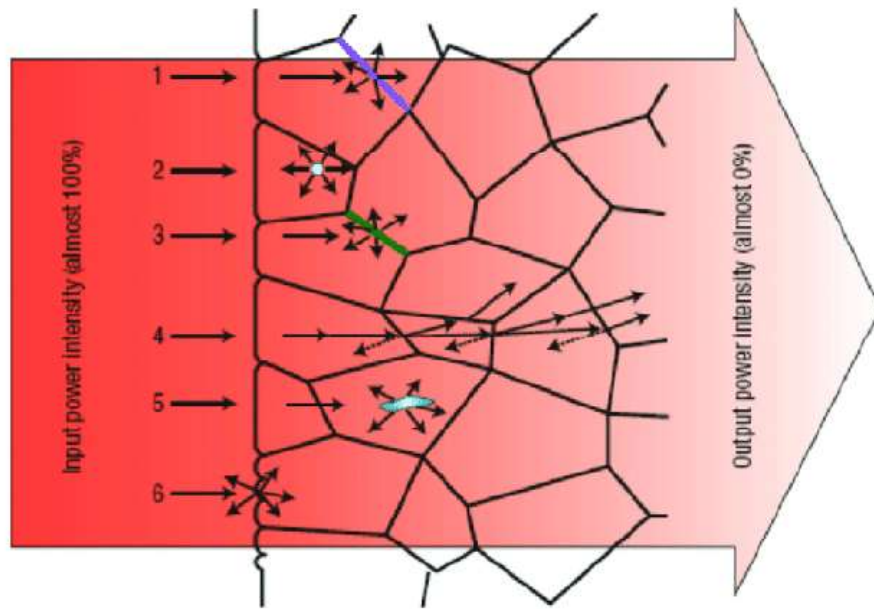
4. Scattering

38. The process often responsible for light not being transmitted through a material is optical scattering. *See* McGraw-Hill (Ex. 1017) at 1760 (defining “scattering”). Optical scattering refers to the deflection of photons from their original paths as a result of interactions with imperfections at the surface or within the bulk material as the photons propagate through the material. Scattering can occur at the surface of a material, for example, due to surface topography that exists intentionally or unintentionally. Most scattering typically occurs within the material and is the result of photons encountering defects, impurities, polycrystalline grains, pores, and other imperfections in the material. Small particles may also be introduced intentionally into a material so as to randomize the direction with which light “rays” leave an optical material, as discussed in the ’547 patent. Internal or bulk scattering is generally responsible for a material not being transparent (*i.e.*, opaque or translucent).

39. For example, in polycrystalline materials such alumina, the material contains many individual “grains” or microcrystals (also known as crystallites), and the boundaries between these grains are known as grain boundaries. Such materials also often have pores or voids between the grains, depending on the process by which

the material was manufactured. Alumina, for example, is generally made by sintering, which is performed by heating a powder under pressure to a temperature insufficient to fully liquify (melt) the material, but sufficient to fuse the powder together to form a solid having pores that are typically several microns in size. When light reaches these grain boundaries and pores, it is scattered one or more times and can be trapped by the pore. That is, a photon can enter a pore and be absorbed. Impurities or additives within a material can cause also additional scattering. Any internal interface (between a crystallite and amorphous material, for example), impurity, defect, or other inhomogeneity contributes to the scattering of light within that material.

40. Imperfections in internal structure, particulates, and other defects in a solid can all cause scattering. Examples of such imperfections include: particles embedded in the material, grain boundaries in polycrystalline materials, and lattice vacancies or pores. These imperfections within the material can prevent light incident on the material from reaching the exit (“downstream”) side of the material. For many polycrystalline materials, optical scattering from the material may dominate optical losses such that few photons will reach the rear surface of the material (*i.e.*, the transmittance is low) and the material will be opaque. The figure below illustrates light scattering within a polycrystalline material.



Xiao (Ex. 1018) at 2.

41. As is illustrated in the figure, light ray #1 is scattered when it reaches a grain boundary (shown by the blue line) within the polycrystalline material. Light ray #2 is scattered when it encounters a pore in the polycrystalline material. Light ray #3 is scattered when it encounters an impurity in the polycrystalline material. Light ray #4 represents one or more photons that are scattered multiple times through repeated interactions with crystallite boundaries or the microcrystals themselves, resulting in back scattering and path deviations and deflections that often result in light leaving the polycrystalline material through the sides or front face of the material, or being absorbed before reaching the perimeter of the material. In either case, these photons are not transmitted by the material. Light ray #5 is scattered as it encounters a secondary phase within a crystallite—*i.e.*, a microcrystallite within a

larger crystallite. Light ray #6 is scattered at the surface of the polycrystalline material owing to surface topography inherent to the manner in which the material was made. As a result of all of these scattering events, it can be the case that little of the incident light is transmitted through the polycrystalline material. In such a case, the polycrystalline material would be considered opaque. It should also be mentioned that the degree of optical scattering from the surface, or within the bulk, of a material is nearly independent of wavelength. In other words, red light is scattered to the same degree as that for blue light or green light.

V. OVERVIEW OF U.S. PATENT NO. 8,314,547

A. Summary

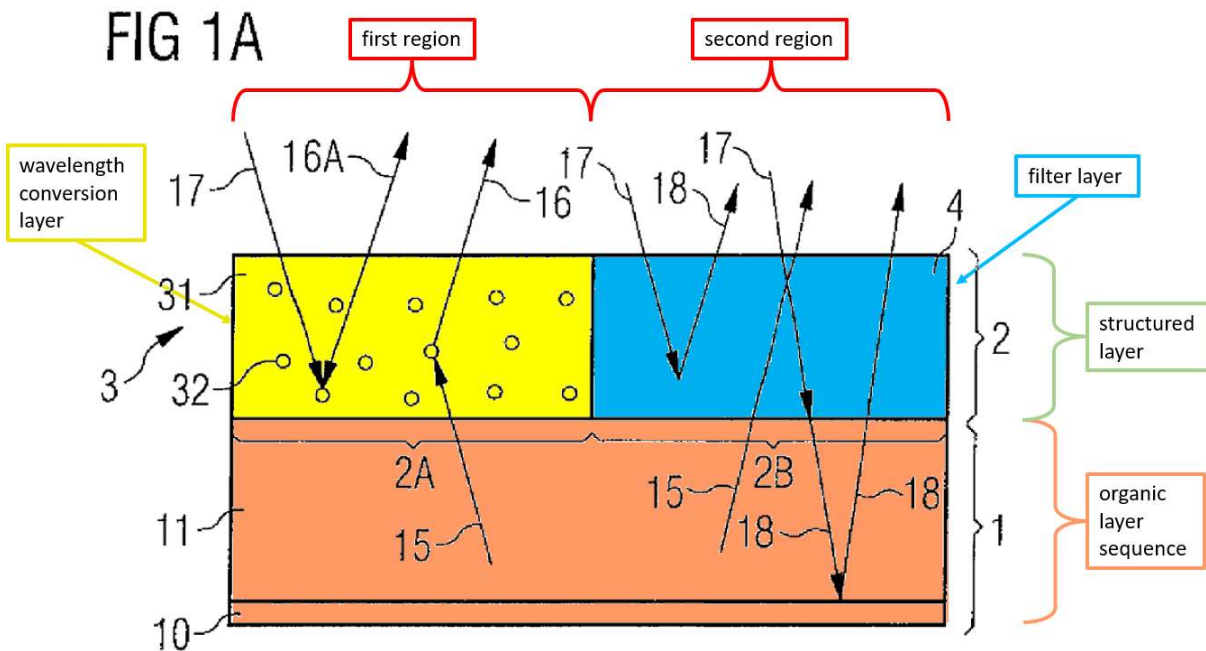
42. The '547 patent is directed to an optoelectronic device that “can be suitable” for “illumination devices” or “a component of a flashlight.” '547 patent, 14:31–36. More specifically, the patent states that its “invention relates to an optoelectronic device which [1] can emit electromagnetic radiation during operation and [2] has a desired color impression in the switched-off state.” *Id.*, 1:13–15.

43. In discussing light-emitting devices that include “blue OLEDs and a phosphor conversion substance,” the '547 patent states that:

It can be the case here that the phosphor conversion substance is visible externally through a transparent cover or a lens when such a light-emitting device is not in operation, which can lead to a color impression that is undesired for esthetic reasons, for example.

'547 patent, 4:3–13. That is, the device can have a “yellowish color impression.” *See id.*, 9:1–2. Accordingly, a stated object of the patent is “to provide an optoelectronic device comprising a wavelength conversion layer, which device can reduce or avoid an undesired color impression in a switched-off state.” *Id.*, 1:19–22.

44. As shown in Figure 1A, for example, “the optoelectronic device has an organic layer sequence 1 . . . embodied as an OLED, for example,” with an “active region 11 . . . [which] is suitable for emitting electromagnetic radiation 15 having a first wavelength spectrum.” '547 patent, 10:5–12. It further includes a “structured layer comprising a first region 2A and a second region 2B.” *Id.*, 10:13–14. The first region has a “wavelength conversion layer 3,” *id.*, 10:16, which can emit a wavelength spectrum that “comprises a yellow wavelength range,” *id.*, 11:40–41. The second region has a “filter layer 4,” *id.*, 1:20, 1:34, which can be “transmissive to blue light . . . while it is opaque to electromagnetic radiation having a yellow wavelength range and a red and green wavelength range,” *id.*, 11:43–47. For clarity, annotated version of Figure 1A is provided below:



'547 patent, Fig. 1A (annotated).

45. During operation of the device, i.e. when it is “on,” the '547 patent states that the device emits “whitish” radiation. '547 patent, 11:14–15. To accomplish this, the organic layer sequence emits “electromagnetic radiation 15 having a first wavelength spectrum” (*i.e.*, blue light). In the first region, this radiation 15 is converted by the wavelength conversion layer “at least partially . . . into electromagnetic radiation 16 having a second wavelength spectrum” (e.g., yellow light). *Id.*, 10:22–25. In the second region, the radiation 15 “can pass through the filter layer 4 in an unimpeded manner and substantially without any alteration of its spectral components.” *Id.*, 10:38–40. “Advantageously, this results in an electromagnetic radiation from a yellow wavelength range combined with an

electromagnetic radiation from a blue wavelength range, which results in a desired, for example whitish, emission characteristic.” *Id.*, 11:13–16.

46. The ’547 patent further states that the device provides a “whitish” color impression when it is in the switched-off state :

In the wavelength conversion layer, [incident] electromagnetic radiation 17 is converted into electromagnetic radiation 16A, and in the filter layer 4 the incident electromagnetic radiation 17 is filtered, resulting in the filtered electromagnetic radiation 18. Consequently, once again through combination of a yellowish portion of the electromagnetic radiation 16A and a bluish portion of the electromagnetic radiation 18, a non-yellowish, preferably whitish, color impression arises for an observer of the optoelectronic device in the switched-off state thereof.

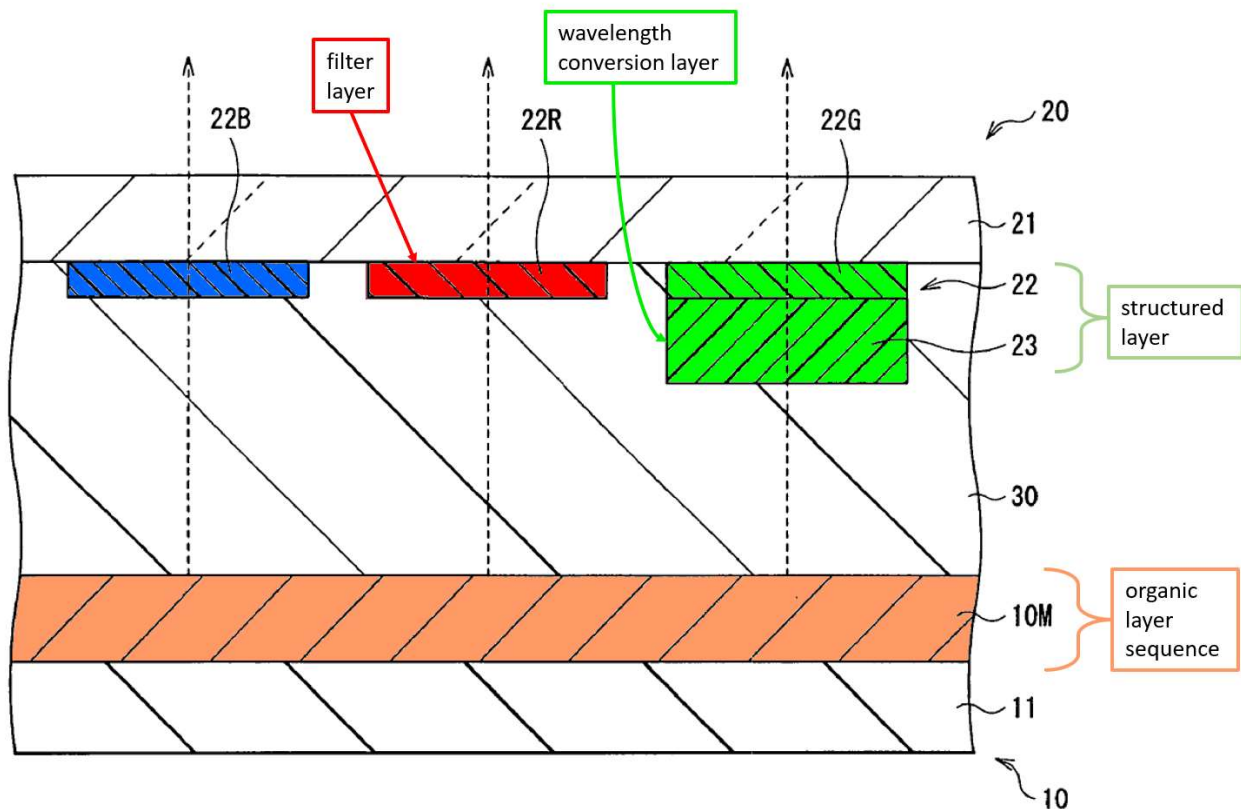
’547 patent, 11:20–29.

B. Prosecution History

47. During prosecution of the ’547 patent, prosecution claims 1 and 3–15 were rejected as being anticipated by and/or obvious in view of Kobori (Ex. 1008) and/or Krummacher (Ex. 1019).

48. While embodiments in the ’547 patent’s specification relate to a “whitish emission” device for a flashlight or other illumination devices, Kobori is directed to a color display having red, green, and blue pixels. Nonetheless, the Examiner determined that Kobori’s display satisfied all elements of prosecution

These elements are depicted in Kobori's Figure 1, as annotated below:



49. However, the Examiner stated that prosecution claim 2 contained allowable subject matter. Ex. 1002 (File History) at 513. Prosecution claim 2 was a dependent claim that added the element “wherein the filter layer is *transparent to*

the electromagnetic radiation having the first wavelength spectrum.” Ex. 1002 (File History) at 576 (emphasis added); *see also* ’547 patent, 10:37–40 (“[E]lectromagnetic radiation 15 having the first wavelength spectrum can pass through the filter layer 4 in an unimpeded manner and substantially without any alteration of its spectral components.”). It appears that the reason the Examiner did not find this element present in Kobori is that Kobori’s red color filter 22R (the “filter layer” identified by the Examiner) is not transparent to the emission of its organic light-emitting device 10M (the “first wavelength spectrum”).

50. Kobori’s display uses an “organic light emitting device 10M of *multicolor* light emission for emitting *blue, red, and green* light, or of white light emission.” Kobori, ¶ [0033] (emphasis added). Its red color filter 22R would not be transparent to the blue or green components of such multicolor (or white) light. As a result, Kobori’s “filter layer” (red color filter 22R) was not “transparent to the electromagnetic radiation having the first wavelength spectrum” emitted by Kobori’s organic light-emitting device 10M.

51. The applicants did not dispute the Examiner’s findings on Kobori (or Krummacher). Instead, the applicants submitted an amendment to the claims. Specifically, the applicants cancelled prosecution claim 2 and amended prosecution claim 1 “to incorporate the subject matter of dependent claim 2 (now cancelled).” Ex. 1002 at 565 (further including “amendments to claims 5-13 [that] correct minor

claim wording, and are cosmetic in nature”). Following this amendment, the claims were allowed.

C. Challenged Claims

52. I have been asked to consider the patentability of claims 1–5 and 8–14 of the ’547 patent (“challenged claims”).

VI. LEVEL OF ORDINARY SKILL IN THE ART

53. I have been informed by counsel that there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including the educational level of active workers in the field at the time of the alleged invention, the sophistication of the technology, the type of problems encountered in the art, and the prior art solutions to those problems. Considering these factors, it is my opinion a person of ordinary skill in the art (POSITA) at the time of the alleged inventions would have had a B.S. degree in electrical engineering, physics, or a comparable field of study, and would have had at least three years of research or industrial experience with semiconductor (organic or inorganic) optoelectronic devices and/or lighting or displays. An individual with additional education could have less research or industrial experience and vice versa.

VII. CLAIM CONSTRUCTION

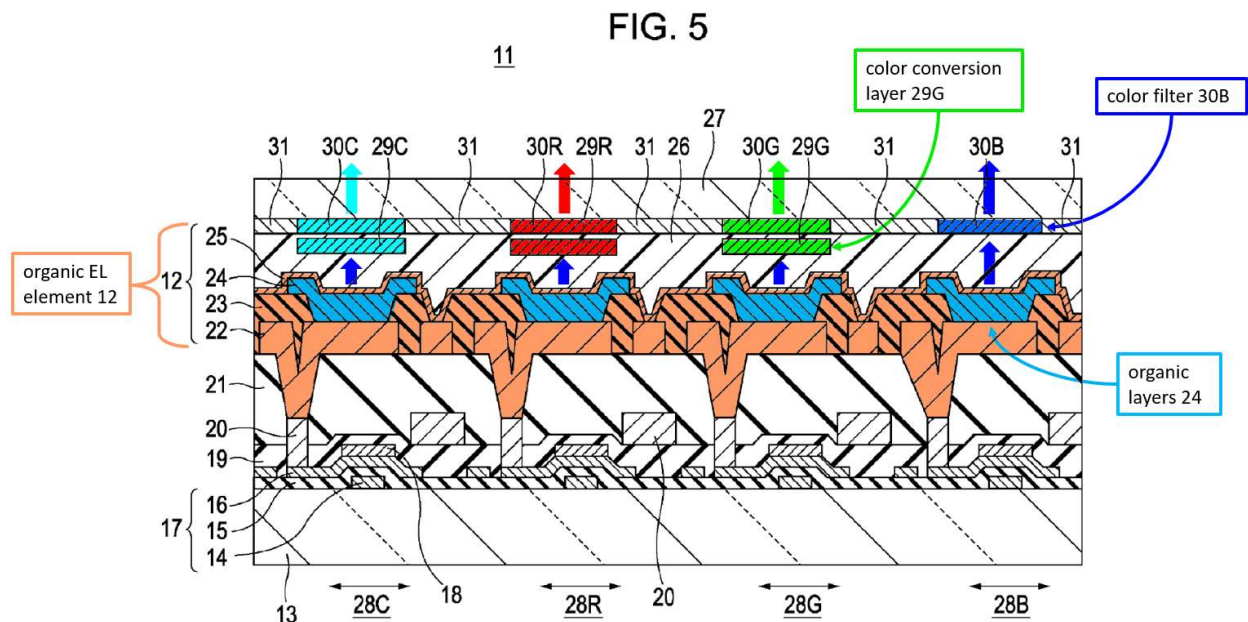
54. I have been informed that, in an IPR, the claims of the patent are construed in accordance with the ordinary and customary meaning as understood by

a POSITA at the time of the invention. I understand that no specialized constructions have been identified for any of the terms appearing in the claims of the '547 patent. I have, therefore, applied the ordinary and customary meaning of the terms in the challenged claims.

VIII. OVERVIEW OF THE PRIOR ART REFERENCES

A. Igarashi (Ex. 1004)

55. Igarashi “relates to a phosphor, an optical device including the phosphor, and a display device including the phosphor.” Igarashi, ¶ [0002]. Figure 5 of Igarashi illustrates an embodiment of such a display device comprising organic light emitting diodes (“OLEDs”).



Igarashi, Fig. 5 (annotated). The display includes a plurality of cyan, red, green, and blue pixels (labelled 28C, 28R, 28G, and 28B, respectively).

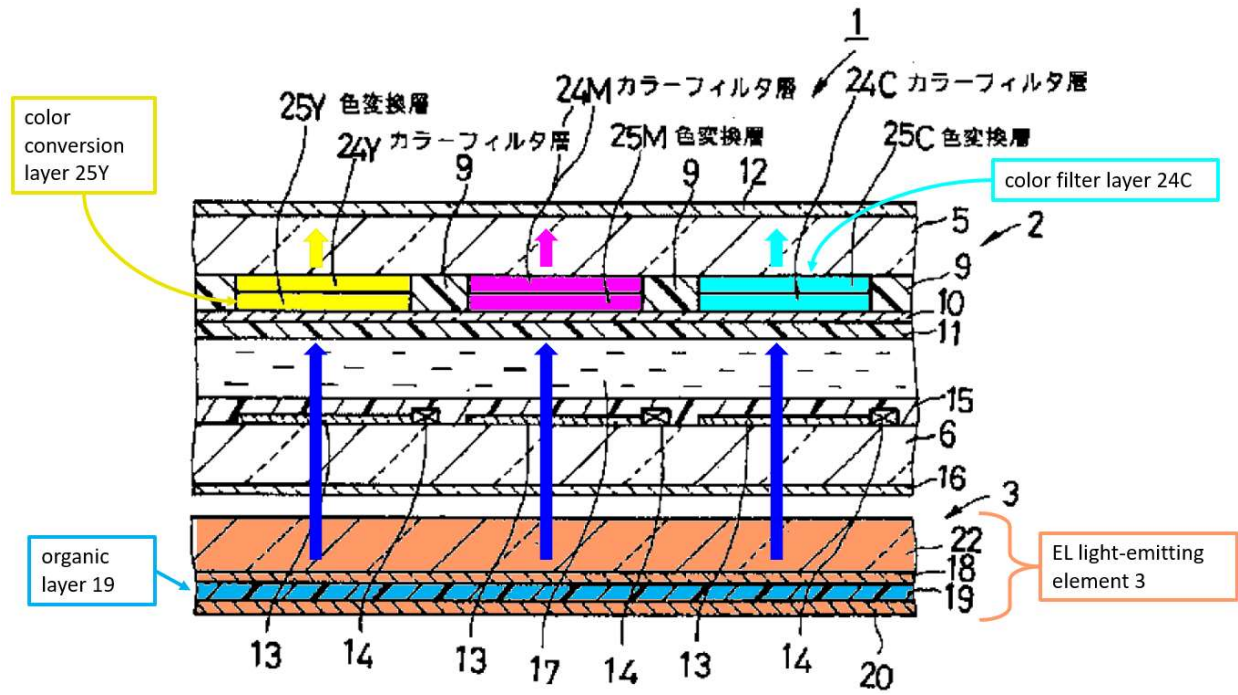
56. Each pixel “includes an organic electroluminescent (EL) element 12” having at least an anode (22), organic layer (24), and cathode (25). Igarashi, ¶¶ [0087–88]. Each electroluminescent element emits “light in the blue region having a wavelength of 450 to 470 nm.” *Id.*, ¶ [0088]. The cyan, red, and green pixels also include “[c]olor conversion layers corresponding to a target color for each pixel. *Id.*, ¶ [0089]. “[T]he color conversion layers can be formed using an inorganic phosphor having a high durability.” *Id.*, ¶ [0090]. The phosphor absorbs the blue light emitted by electroluminescent element 12 and emits light of the desired color. “[N]o color conversion layer is provided” for the blue pixels, *id.*, ¶ [0089], because blue light is generated by the OLED itself and is one of the primary colors.

57. Each pixel may also include a “color filter,” identified as 30R, 30G, 30B, and 30C in Figure 5. Igarashi, ¶ [0089]. Furthermore, a “black matrix” lies between the color filters for the purpose of improving the contrast of the display: “A black matrix 31 that at least optically separates the color filters is provided between the color filters.” *Id.*

B. Shiotani (Ex. 1005)

58. Shiotani “relates to a display device, and in further detail, relates to a liquid crystal display device provided with a color conversion layer capable of color display, which can be used for both reflective and transmissive applications.”

Shiotani, ¶ (0001). Figure 7 of Shiotani (produced below) illustrates an embodiment of such a display device.



Shiotanti, Fig. 7 (annotated).

59. When used as a transmissive device,¹ the light is generated by “EL light-emitting element 3.” Shiotani, ¶ (0021). The element is an OLED “formed by sequentially laminating a front electrode 18 made of transparent ITO, an organic EL light-emitting layer 19, and a light-reflective rear electrode 20 across the entire

¹ Shiotani discloses that the same device can also be used in reflective applications. Shiotani, ¶¶ (0001), (0042). In such applications, the light emitting element 3 is turned off and colors are generated by reflecting ambient light. For purposes of this declaration, however, I have focused on the transmissive applications of the display.

display region on the rear surface of an EL substrate 22 made of transparent glass.”

Id., ¶ (0022). The organic EL material “generates blue light when a predetermined voltage is applied between the front and rear electrodes 18 and 20.” *Id.* “The rear electrode 20 is preferably covered with a protective film to prevent oxidation.” *Id.*, ¶ (0023).

60. The light from EL light-emitting element 3 is transmitted through “liquid crystal cell 2.” Shiotani, ¶ (0018). “The liquid crystal cell 2 has a front transparent substrate 5 and a rear transparent substrate 6 that face each other, and a plurality of pixel regions are set within the display area.” *Id.* In the embodiment of Figure 7, the pixels are configured to emit yellow, magenta, and cyan light. *Id.*, ¶ (0040). Each pixel includes a “color conversion layer” that absorbs the blue light emitted by the OLED and emits light of the desired color. *Id.* “Three types of color conversion layers are arranged: a color conversion layer 25Y that converts the B (blue) component light into Y component light; a color conversion layer 25M that converts the B component light into M component light; and a color conversion layer 25C that converts the B component light into C component light.’ *Id.*

61. Shiotani explains how each color conversion layer works:

[T]he color conversion layer 25Y is a mixture of a color conversion layer that converts the B component light into R component light and a color conversion layer that converts the B component light into G component light to obtain Y, a color mixture of the R and G component

light. The color conversion layer 25M is essentially a color conversion layer that converts the B component light into R component light, but is set to convert only about half of the incident B component intensity into R component light Furthermore, the color conversion layer 25C is essentially a color conversion layer that converts the B component light into G component light, but is set to convert only about half of the incident B component intensity into G component light.

Shiotani, ¶ (0041).

62. Each pixel further comprises a “color filter layer.” Shiotani, ¶ (0040). As shown in Figure 7 (shown earlier), the color filter layers, which are arranged “downstream” from the color conversion layer, filter the light emitted by the color conversion layers. Each yellow pixel has “a color filter layer 24Y that transmits only the Y component.” *Id.* Similarly, each magenta pixel has “a color filter layer 24M that transmits only the M component” and each cyan pixel has “a color filter layer 24C that transmits only the C component.” *Id.*

63. Shiotani’s display is capable of reproducing a wide range of different colors by combining light from the different pixels. “On the front side of the rear transparent substrate 6, a plurality of pixel electrodes 13 made of ITO are formed,” with one electrode per pixel. Shiotani, ¶ (0019). “ITO” is an acronym for “indium tin oxide” which is a well-known material widely applied to displays because, in the form of a thin film, it is both transparent and electrically conducting. “Also, a thin-film transistor 14 as a switching element is formed to connect to each of the pixel

electrodes 13.” *Id.* The voltage applied to pixel electrode 13 controls the amount of light from EL light-emitting element 3 that is transmitted through liquid crystal cell 2. *Id.*, ¶ (0027). “[T]he colors of each pixel can be mixed and displayed by modulating the electric field of the liquid crystal cell 2. In particular, a wide chromaticity range can be achieved by controlling the gradation of each color.” *Id.*, ¶ (0031).

C. Pilcher (Ex. 1006)

64. Pilcher relates to encapsulation of OLED devices. As explained in Pilcher, “[e]ncapsulation is a way to protect the OLED device from the damaging environmental effects—primarily from oxygen and moisture.” Pilcher, 1:8–10. Pilcher describes multiple encapsulation methods, which are required for OLED displays because OLEDs degrade quickly with exposure to water vapor or air. It was “well known in the art to encapsulate an OLED display by physically mating a top glass (or other suitable material) over, but usually not touching, the OLED device with an epoxy border.” *Id.*, 1:10–13. Pilcher further explains that it was also known in the art that there was “a cheaper and better manner of encapsulation, called ‘direct thin-film’ encapsulation.” *Id.*, 1:18–19. In thin-film encapsulation, also called “polymer multi-layer” or “PML” encapsulation, “alternating and repeating layers of an organic . . . and a barrier layer” are deposited over the OLED structures. *Id.*, 1:20–23.

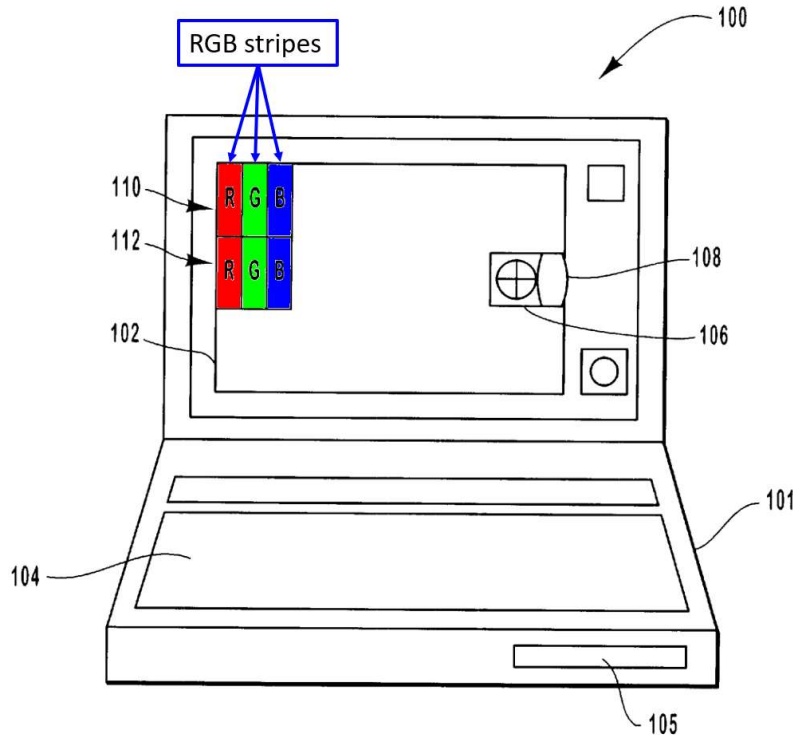
65. Pilcher identifies several “advantages of direct thin-film encapsulation,” including “cost reduction and improved reliability.” Pilcher, 1:48–49. “Using direct thin-film encapsulation, the package may also be thinner and/or lighter and/or mechanically more flexible. Several structures and steps of the prior art may be excluded with this process. For example, there is no need for a separate glass plate, no need for an epoxy seal, [and] no need for a getter.” *Id.*, 1:52–55.

D. Dresevic (Ex. 1007)

66. Another relevant publication is Dresevic, which discloses a common pixel arrangement often incorporated into flat panel displays. Dresevic discloses that each pixel typically comprises three or more colored elements that are arranged in vertical “stripes.” According to Dresevic,

In displays commonly used for computer applications, each pixel on a color LCD display usually comprises three non-square elements, i.e., red, green and blue (RGB) pixel sub-components. . . . LCD displays of this type comprise a series of RGB pixel sub-components which are commonly arranged to form stripes along the display. The RGB stripes normally run the entire length of the display in one direction. The resulting RGB stripes are sometimes referred to as “RGB striping”.

Dresevic, 2:3–13. Figure 1 of Dresevic (reproduced below) illustrates this stripe arrangement:



Dresevic, Fig. 1 (annotated).

IX. SPECIFIC GROUNDS OF CHALLENGES

A. Ground I: Claims 1–5, 8–11, and 13 Are Obvious Based on Igarashi

1. Independent Claim 1

a. Preamble: An optoelectronic device, comprising:

67. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express an opinion as to whether or not the preamble to claim 1 is limiting. However, if the preamble is limiting, it is my opinion that Igarashi discloses the limitation.

68. Igarashi is entitled “Phosphor, optical device, and display device” and states that “[t]he present invention generally relates to a phosphor, an optical device

including the phosphor, and a display device including the phosphor.” Igarashi ¶ [0002]. In my opinion, a POSITA would readily understand that Igarashi’s display device is “[a]n optoelectronic device,” as required by claim 1 of the ’547 patent.

69. According to Igarashi, “FIG. 5 is a schematic cross-sectional view of a display device according to an embodiment of the present invention.” Igarashi ¶ [0086]. This figure is a cross-sectional diagram of a display device comprising pixels of four different colors: red, green, blue, and light blue (often referred to as “cyan”). *Id.* ¶¶ [0089], [0113]. Igarashi states that in alternative embodiments, the pixels may also be designed to emit magenta or yellow light. *Id.* ¶ [0113] (“Alternatively, the display device according to an embodiment of the present invention may include a pixel corresponding to violet (magenta: M) light emission or yellow (Y) light emission.”).

70. Igarashi’s display device is an electronic device. Each pixel includes a “thin film transistor (TFT) element.” Igarashi ¶ [0087]. In addition, “[a] wiring 20 is provided on the TFT element 17,” “[a] first electrode 22 is provided as a positive electrode.” *Id.* Igarashi further states that “[t]he first electrode 22 is electrically connected to the TFT element 17 via a corresponding wiring 20, thereby forming an active matrix structure driven by the TFT element 17.” *Id.*

71. Since Igarashi’s display device is an electronic device that emits light, it is, in my opinion, an optoelectronic device.

b. Element 1[a]: an organic layer sequence which emits an electromagnetic radiation having a first wavelength spectrum during operation; and

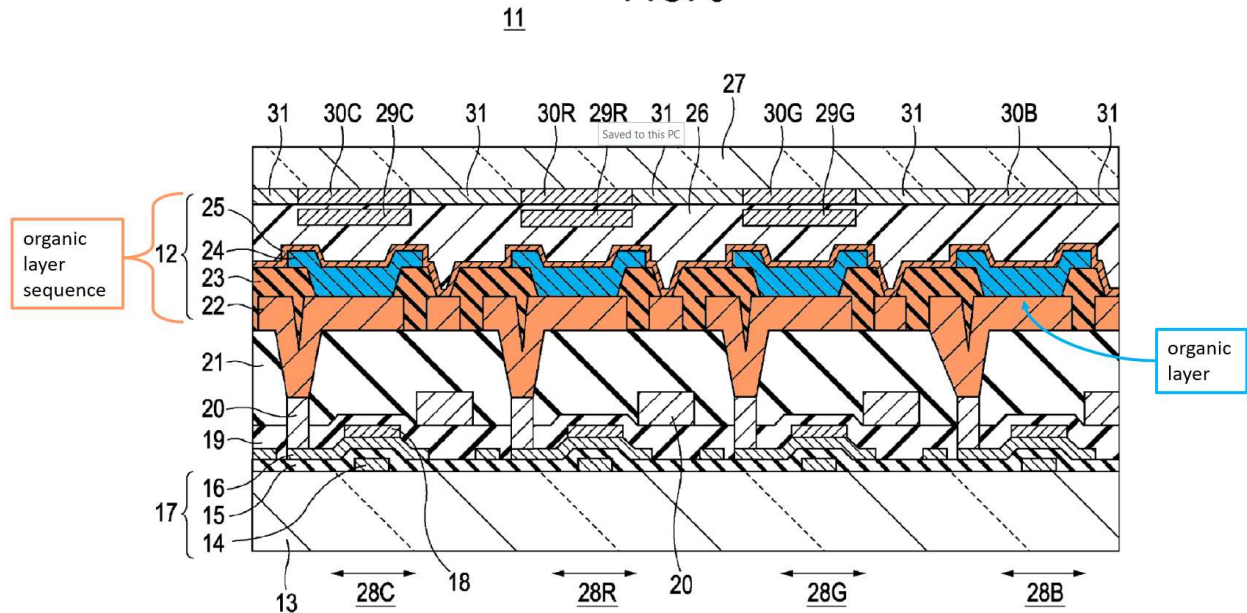
72. In my opinion, Igarashi discloses this element. Igarashi's "organic electroluminescent (EL) element 12" comprises an "organic layer sequence" as that term is used in the '547 patent. The '547 patent states that "the organic layer sequence can be embodied in particular as an organic light-emitting diode (OLED)," '547 patent, 4:33–34. The patent also states:

In this case, an OLED can have an organic layer or a layer sequence comprising at least one organic layer, having an active region that can emit electromagnetic radiation during operation. Furthermore, an OLED can have a first electrode and a second electrode, wherein the organic layer or the layer sequence comprising at least one organic layer having the active region can be arranged between the first and second electrodes.

'547 patent, 4:34–42.

73. Igarashi's "organic electroluminescent (EL) element 12" is such an OLED. Igarashi ¶ [0087]. As shown in Figure 5, reproduced below, Igarashi's EL element 12 comprises a "first electrode 22," an "interlayer insulating film 23," an "organic layer 24 comprised of an organic luminescent material," and a "second electrode 25." *Id.* ¶ [0088].

FIG. 5



Igarashi, Fig. 5 (annotated).

74. The '547 patent further states:

The organic layer or the layer sequence comprising one or more functional layers composed of organic materials can be applied over the first electrode. The functional layers, which can comprise the active region, can in this case have electron transport layers, electroluminescent layers, and/or hole transport layers, for example.

'547 patent, 4:47–52.

75. The “organic layer 24” in Igarashi’s EL element 12 is similarly formed over Igarashi’s first electrode (“first electrode 12”) and comprises multiple functional layers including electron transport layers, electroluminescent layers, and/or hole transport layers. Igarashi ¶ [0107]. As described in Igarashi, “organic layer 24” comprises a “hole-injecting layer,” a “hole transport layer,” a “blue light

emitting layer (EML),” an “electron transport layer,” and an “electron-injecting layer” which are “sequentially formed on the surface of the first electrode 22.” *Id.* Igarashi describes each of the layers, and the process for forming the layers, as follows:

An organic layer 24 is formed on the first electrode 22 by vapor deposition. Specifically, organic substances (each 0.2 g) are placed in boats for resistance heating, and the boats are attached to predetermined electrodes of a vacuum evaporation system. The pressure of a vacuum tank is reduced to 1.0×10^{-4} Pa, a voltage is then applied to each boat, and the boats are sequentially heated to perform vapor deposition. Thus, the following films are sequentially formed on the surface of the first electrode 22. For example, a 4,4',4''-tris (3-methylphenylphenylamino) triphenylamine (m-MTDATA) film with a thickness of 20 nm is formed as a hole-injecting layer, a bis[(N-naphthyl)-N-phenyl]benzidine (α -NPD) film with a thickness of 30 nm is formed as a hole transport layer, a blue light emitting layer (EML) with a thickness of 55 nm that serves as a host and that is composed of 4,4-bis(2,2-diphenylvinyl) biphenyl (DPVBi) that contains 5% of 4,4-bis(3-carbazolylvinyl)biphenyl (BCzVBi) as blue emission species serving as a dopant is formed, an 8-hydroxyquinoline aluminum (Alq3) film with a thickness of 10 nm is formed as an electron transport layer, a LiF layer with a thickness of 0.3 nm is formed as an electron-injecting layer, and a MgAg film with a thickness of 1 nm is then formed, thereby forming the organic layer 24.

Igarashi ¶ [0107]. All of the layers mentioned by Igarashi, including the hole-injection, hole-transport, electron-injection, and electron-transport layers, have compositions that were well-known in the field of OLED devices and displays.

76. Igarashi's organic layer 24 "emits an electromagnetic radiation having a first wavelength spectrum during operation," as required by this claim element. As shown above, organic layer 24 includes a "blue light emitting layer (EML)" which consists of the host (biphenyl DPVBi) and the biphenyl emitter, BCzVBi. Igarashi ¶ [0107]. A POSITA would be familiar with BCzVBi as a blue emitter commonly incorporated into OLED devices and displays. According to Igarashi, "in this embodiment, light in the blue region having a wavelength range of 450 to 470 nm is emitted." Igarashi ¶ [0088]. This spectrum of light (or "electromagnetic radiation") emitted by organic layer 24 is, therefore, the required "first wavelength spectrum."

77. It is my opinion, therefore, that Igarashi's "organic electroluminescent (EL) element 12" comprises an "organic layer sequence" satisfying the requirements of claim element 1[a].

78. I note that Figures 1 and 4 of the '547 patent suggest that "organic layer sequence 1" comprises both "active region 11" and "electrode 10," '547 patent, 10:5–12, and that the '547 patent states that an OLED (which can "embody" the organic layer sequence) "can have a first electrode and a second electrode, wherein the organic layer or the layer sequence comprising at least one organic layer ... can

be arranged between the first and second electrodes.” ’547 patent, 4:38–42. To the extent that the “organic layer sequence” limitation requires the electrodes, Igarashi’s organic electroluminescent element 12 includes “first electrode 22” and “second electrode 25,” with “organic layer 24” disposed between them. Igarashi, ¶¶ [0087]–[0088]. Therefore, regardless of whether or not the electrodes are required by the limitation, Igarashi’s organic electroluminescent element 12 comprises an “organic layer sequence.”

c. Element 1[b]: a structured layer disposed downstream of the organic layer sequence in a beam path of the electromagnetic radiation emitted by the organic layer sequence and including first and second regions;

79. In my opinion, Igarashi discloses this element. Igarashi’s display includes a “resin layer 26,” into which are integrated “color conversion layers” which serve to convert the blue light emitted by the OLED into red, green, and cyan light. Igarashi ¶ [0089]. Also, color filters and a black mask are located on the resin layer, as described by Igarashi:

A resin layer 26 is provided on the second electrode 25 that is common to a plurality of pixels, for example, so as to cover the entire surface. Color conversion layers corresponding to a target color for each pixel are provided in the resin layer 26 according to need. Specifically, for example, in a pixel 28B corresponding to blue (B), no color conversion layer is provided. In pixels 28R, 28G, and 28C corresponding to red (R), green (G), and light blue (cyan: C), color conversion layers 29R, 29G, and 29C are provided, respectively. In the pixels 28R, 28G, 28B,

and 28C corresponding to the colors, color filters 30R, 30G, 30B, and 30C for corresponding pixels may be provided on the resin layer 26 including the color conversion layers. A black matrix 31 that at least optically separates the color filters is provided between the color filters.

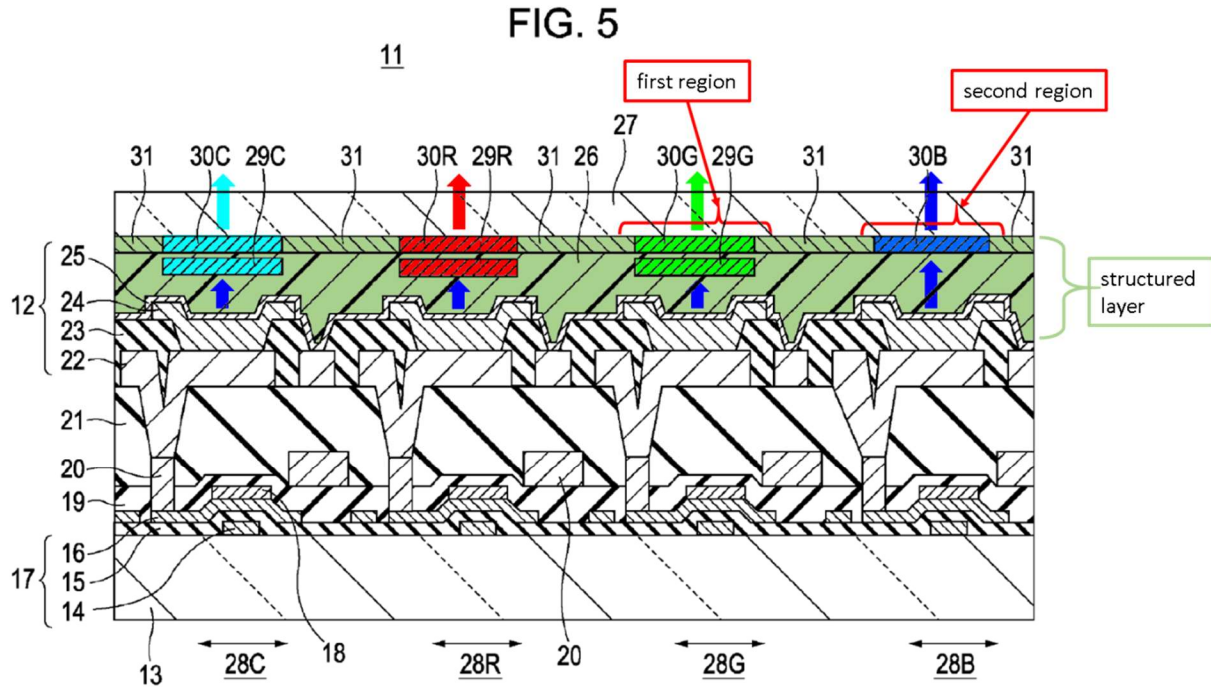
Igarashi ¶ [0089].

80. Igarashi's resin layer 26, together with the color conversion layers, color filters, and black matrix, constitutes a "structured layer" as required by this claim element. The '547 patent describes an embodiment of a "structured layer" as follows:

A structured layer comprising a first region 2A and a second region 2B is arranged in the beam path of the electromagnetic radiation 15 having the first wavelength spectrum. The first region 2A has a wavelength conversion layer 3 comprising a wavelength conversion substance 32. As shown in the exemplary embodiment, the wavelength conversion substance 32 can be embedded into a matrix material 31, for example. The second region 2B has a fourth layer 4.

'547 patent, 10:13–20. Igarashi discloses the same "structured layer," with wavelength (i.e., color) conversion layers "embedded into a matrix material," the latter of which in the case of Igarashi is resin layer 26.

81. In the figure below, Igarashi's Figure 5 is annotated to highlight the "structured layer."



Igarashi, Fig. 5 (annotated).

82. In Igarashi, the “structured layer” has “first regions,” corresponding to green pixels 28G. The “structured layer” also has “second regions,” corresponding to blue pixels 28B. The first and second regions are shown in the annotated figure above.

83. Igarashi’s display device has a “plurality of pixels.” Igarashi ¶¶ [0026], [0088], [0089], [0112]. Igarashi states that its display device “is driven by an active matrix.” Igarashi ¶ [0112]. A POSITA would understand that an active matrix display typically has thousands, if not millions, of pixels of each color, arranged in columns and rows (*i.e.*, as a “matrix”). Igarashi’s display device requires a plurality of pixels of each color in order to function as a display. Each green pixel has a

corresponding “first region.” Each blue pixel has a corresponding “second region.” Therefore, to the extent that the claim requires multiple “first regions” and/or multiple “second regions,” Igarashi’s display satisfies this requirement.

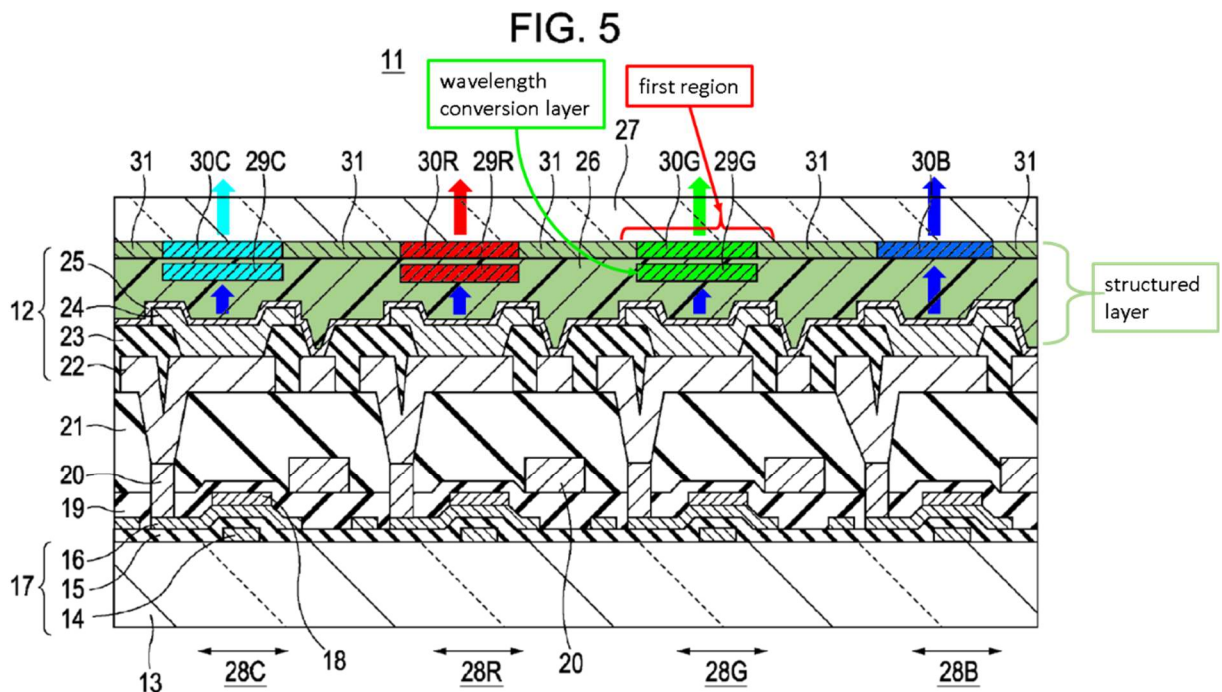
84. Igarashi’s “structured layer” is “disposed downstream of the organic layer sequence in a beam path of the electromagnetic radiation emitted by the organic layer sequence” as required by the claim element. As discussed above with respect to claim element 1[a], Igarashi’s organic electroluminescent element 12 comprises an “organic layer sequence.” Igarashi states that, in the embodiment shown in Figure 5, the “organic EL element has a top emission structure.” That is, the OLED emits electromagnetic radiation in an upward direction through the structured layer’s color conversion layers and color filters. In the annotated figure above, the colored arrows indicate the direction of the beam path of the electromagnetic radiation. As shown, the “structured layer” is downstream of the “organic layer sequence.”

85. Therefore, it is my opinion that Igarashi’s display device includes a “structured layer” satisfying all of the requirements of claim element 1[b].

- d. **Element 1[c]: wherein the first regions each include a wavelength conversion layer configured to convert at least partially electromagnetic radiation having a first wavelength spectrum into an electromagnetic radiation having a second wavelength spectrum;**

86. In my opinion, Igarashi also discloses this element. Each green pixel includes a “color conversion layer” 29G, which is the claimed wavelength conversion layer.

87. As discussed above with respect to claim element 1[b], Igarashi’s “structured layer” includes “color conversion layers 29R, 29G, and 29C.” Igarashi ¶ [0089]. The “first region” is the portion of the structured layer corresponding to green pixel 28G. As shown in the annotated figure below, color conversion layer 29G is included in the first region.



Igarashi, Fig. 5 (annotated).

88. Color conversion layer 29G is a “wavelength conversion layer.” The ’547 patent describes a “wavelength conversion layer” as being “designed to convert at least partially electromagnetic radiation having the first wavelength spectrum into an electromagnetic radiation having a second wavelength spectrum.” ’547 patent, 1:30–34. The ’547 patent further specifies that a phosphor can be used as a “conversion substance” in the “wavelength conversion layer” to convert the electromagnetic radiation. *Id.*, 4:7–8.

89. In Igarashi, color conversion layer 29G generates “green output light in the pixel 28G,” Igarashi ¶ [0091], and “can be formed using an inorganic phosphor,” *id.* ¶ [0090]. Igarashi discloses a family of phosphors that can be used in the color conversion layer. *Id.* (“In the display device of this embodiment, the color conversion layer 29G corresponding to green includes the phosphor according to an embodiment of the present invention.”). The phosphor absorbs the blue light emitted by organic layer 24 and emits green light. Igarashi ¶ [0091]–[0095]. Color conversion layer 29G is, therefore, “configured to convert at least partially electromagnetic radiation having a first wavelength spectrum”—that is, the spectrum of blue light emitted by organic layer 24—“into an electromagnetic radiation having a second wavelength spectrum”—the spectrum of the green light emitted by the phosphor.

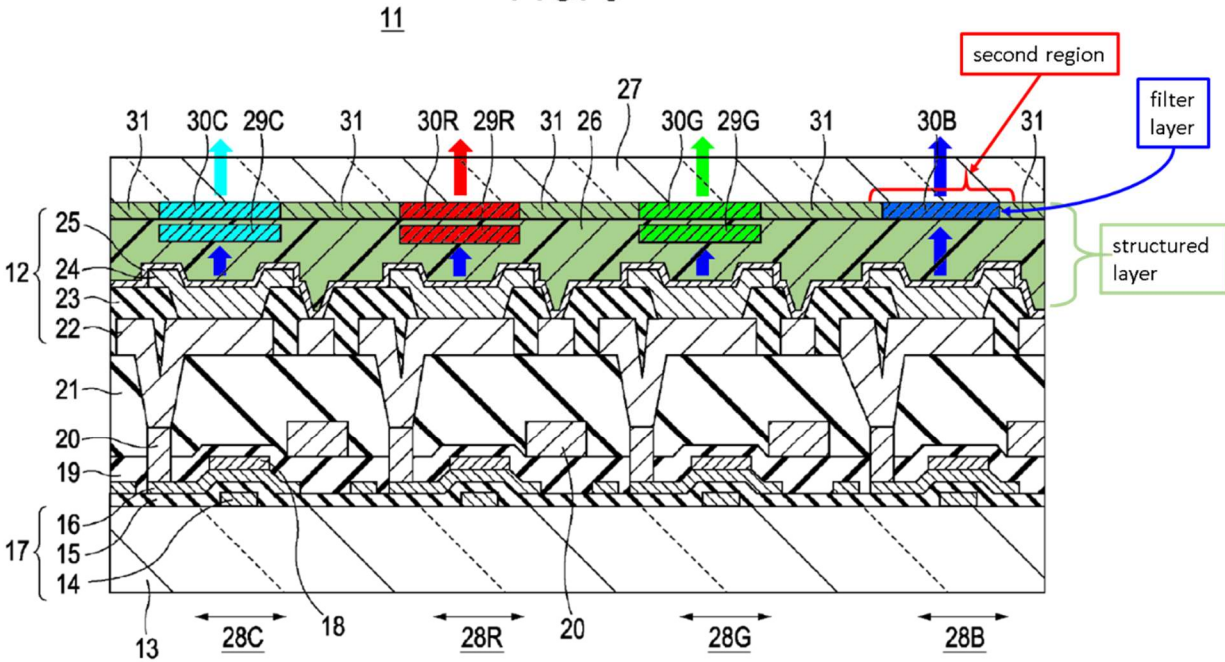
90. Therefore, it is my opinion that Igarashi's display device satisfies all of the requirements of claim element 1[c].

- e. **Element 1[d]: wherein the second regions each include a filter layer which is at least partially opaque to an electromagnetic radiation having a third wavelength spectrum which corresponds to at least one part of the second wavelength spectrum;**

91. In my opinion, Igarashi discloses this element. Each blue pixel includes a blue "color filter 30B," which is the claimed "filter layer."

92. As discussed above with respect to claim element 1[b], Igarashi's "structured layer" includes "color filters 30R, 30G, 30B, and 30C." Igarashi ¶ [0089]. The "second region" is the portion of the structured layer corresponding to blue pixel 28B. Therefore, as shown in the annotated figure below, blue color filter layer 30B is included in the second region.

FIG. 5



Igarashi, Fig. 5 (annotated).

93. A POSITA would understand that color filter 30B “is at least partially opaque to an electromagnetic radiation having a third wavelength spectrum,” as this is the purpose of color filters—namely, filtering out light having wavelengths lying outside the desired range or interval. Optical filters are a basic component of optical systems and optical engineering. The most common class of optical filters is known as “bandpass” filters, which are designed to “pass” (transmit) optical wavelengths in a desired “band” (or range of wavelengths, known as a “passband”) while rejecting those wavelengths lying outside that range. For example, Smith explains that “[a]bsorption filters are composed of materials which transmit light selectively; that is, they transmit certain wavelengths more than others.” Ex. 1009 at 192. Shiotani

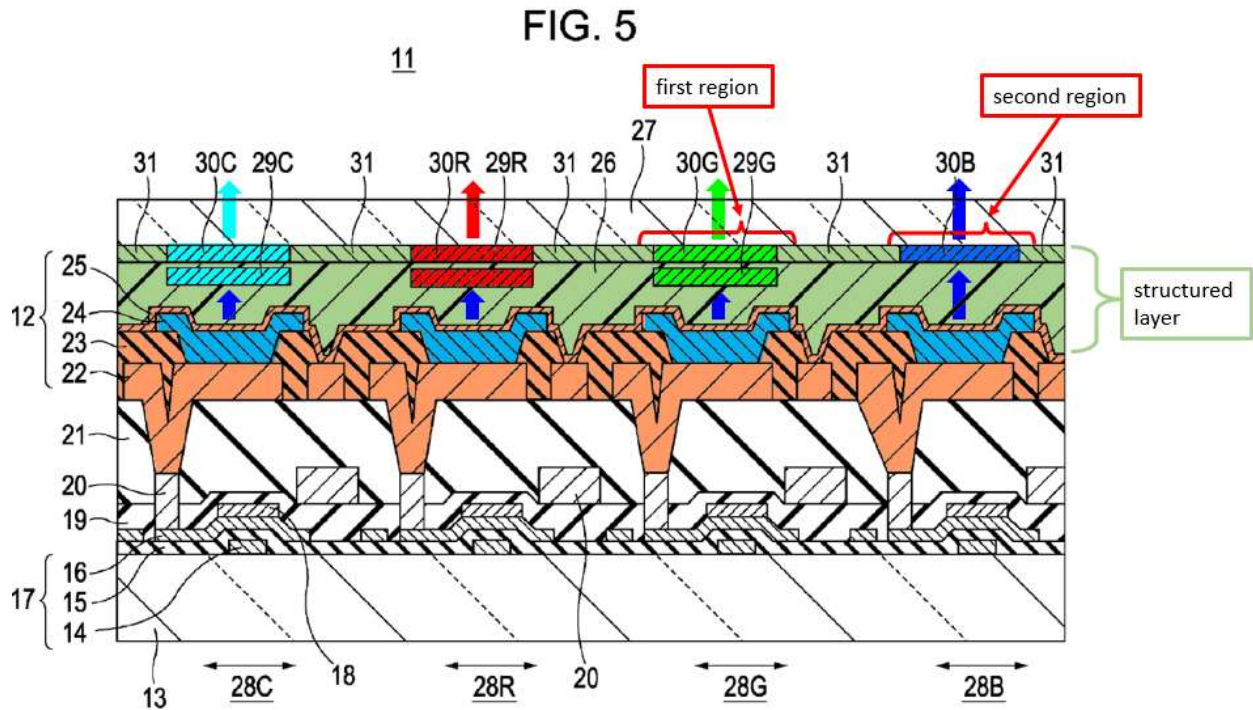
likewise explains that a “color filter layer 7B for blue” serves to “transmit[] light in the blue wavelength region and absorb[] light in other wavelength regions when light containing light in the blue wavelength region is incident.” Shiotani, Abstract, ¶ [0018].

94. As discussed above with respect to claim element 1[c], the “second wavelength spectrum” is the spectrum of light emitted by color conversion layer 29G. Blue color filter 30B rejects (*i.e.* does not transmit) a significant portion of the green light emitted by the phosphor in color conversion layer 29G because the blue filter is intended to pass only the blue light emitted by the OLED. The green light rejected by color filter 30B is the “third wavelength spectrum” and “corresponds to at least one part of the second wavelength spectrum,” as required by this claim element.

95. Therefore, it is my opinion that Igarashi’s display device satisfies all of the requirements of claim element 1[d].

f. Element 1[e]: wherein the first and second regions of the structured layer are arranged laterally in a beam path of the optoelectronic device; and

96. It is also my opinion that Igarashi discloses this element. In the figure below, Igarashi’s Figure 5 is annotated to highlight the “first and second regions of the structured layer” and to indicate a “beam path of the optoelectronic device” with colored arrows.



Igarashi, Fig. 5 (annotated).

97. Igarashi states that the “organic EL element [12] has a top emission structure.” Igarashi ¶ [0112]. That is, the OLED emits electromagnetic radiation in an upward direction through the structured layer’s color conversion layers and color filters. Therefore, as shown in the figure, the first and second regions are arranged such that they lie in a beam path of the optoelectronic device. Figure 5 also illustrates that “the first and second regions of the structured layer are arranged laterally” in the beam path, as the first and second regions are arranged from left to right.

98. Therefore, it is my opinion that Igarashi’s display device satisfies all of the requirements of claim element 1[e].

- g. Element 1[f]: wherein the filter layer is transparent to the electromagnetic radiation having the first wavelength spectrum.**

99. It is also my opinion that Igarashi discloses this element. As discussed above with respect to claim element 1[a], Igarashi's "first wavelength spectrum" is the spectrum of light (or "electromagnetic radiation") emitted by organic layer 24. Igarashi states that "light in the blue region having a wavelength range of 450 to 470 nm is emitted." Igarashi ¶ [0088]. As I discussed above for claim element 1[d], the "filter layer" in Igarashi is blue color filter 30B.

100. A POSITA would understand that the color filter 30B is "transparent to the electromagnetic radiation having the first wavelength spectrum"—*i.e.*, is transparent to light in the blue region having a wavelength of 450 to 470 nm. A POSITA would understand that Igarashi's color filter 30B would likely be a color glass filter or similar filter. Such filters serve the function of transmitting light having wavelengths within a desired range while rejecting light having wavelengths outside that range. Because color filter 30B is the color filter "in the pixel 28B corresponding to the blue light emission," a POSITA would understand that it is a *blue* color filter—*i.e.*, a filter that transmits (and is transparent to) blue light. Igarashi ¶ [0089]

101. "Transparent" generally means that objects on the far side of an optical material are seen clearly through the material. *See, e.g.* McGraw-Hill (Ex. 1017) at 2060 (defining "transparent medium" as "[a] medium which has the property of

transmitting rays of light in such a way that the human eye may see through the medium distinctly”). The field of optical engineering characterizes the properties of optical materials by their transmittance—the fraction of light (of a given wavelength) that passes through the material. Measurements of the transmission of light over a specific range of wavelengths are typically measured by a spectrophotometer. A transparent material is one with high optical transmittance.

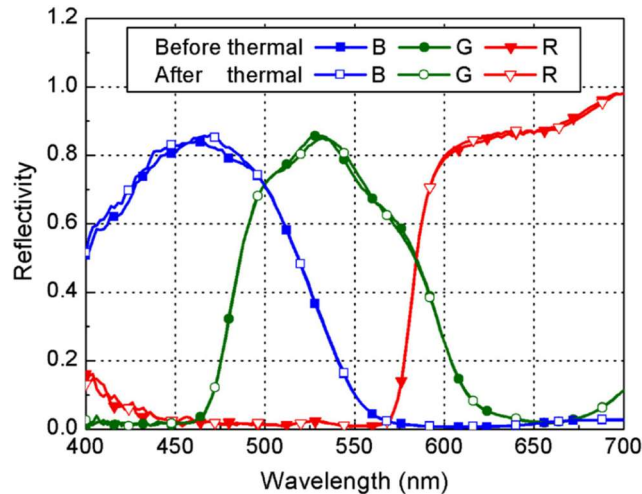
102. A POSITA would understand that Igarashi’s color filters are designed so as to have high optical transmittance (i.e., transparency) over the wavelength region of interest for that filter. A POSITA would recognize that the needless loss of light as photons exit the display or lamp is undesirable and would, therefore, use color filters having high transmittance over the desired wavelength range. Indeed, because: 1) generating photons by an OLED or LED source is often the most (or one of the most) expensive portion of the cost of manufacturing displays or light sources, and 2) maximum light intensity output is generally a design priority, the materials for any optical element that lies in the optical path between the optical source and the observer (the customer) will be carefully chosen. The transmittance of the optical elements in the optical path directly impacts the efficiency of the optoelectronic system which, in turn, drives power consumption. In particular, the overall transmission of an optical “train” consisting of, for example, filters and lenses is the product of the transmissions of each optical element in the train. These

considerations underscore why, when Shiotani states, for example, that a “color filter layer 7B for blue” serves to “*transmit[] light in the blue wavelength region and absorb[] light in other wavelength regions when light containing light in the blue wavelength region is incident,*” a POSITA would understand that the intent is to maximize the transmission of the filter in the desired wavelength range (blue, in this instance), thereby allowing as many blue photons as possible to exit the system. Shiotani at Abstract, ¶ [0018] (emphasis added).

103. Optical filters have been widely available for more than a century and color filters available commercially at the time of the '547 patent routinely offered transmission values above 80% or even 90% in the wavelength region of interest (the desired passband). *See, e.g.*, Ex. 1009 at 192–95. Whether the filter comprises a stack of ultrathin (one-quarter wavelength) layers or is simply colored-glass or plastic, filters that are transparent throughout the desired passband were widely available and employed routinely by optoelectronic device and systems manufacturers.

104. As an example, Huang confirms that transparent blue filters were well-known in the art. Ex. 1012. Huang presents a type of “microdisplay that integrates color filters on silicon.” *Id.*, Abstract. In characterizing the optical properties of the filters, Huang states: “The Cauchy coefficients of . . . the blue color filter *in its transparent region of 400 to 500 nm* were also obtained and are listed in Table 1.”

Id. at 502 (emphasis added). The transparency of the blue filter is further confirmed by the following “reflectivity” curve:



Id., Fig. 6. This curve measures the percentage of ambient light (*i.e.* light from outside the display) that passes through the color filters, reflects off the silicon substrate, and then passes through the color filters a second time. *See id.* at 499 (“[T]he thickness of color filters should be reduced from 1.5 to 0.75 μm , because the light transverses through the color filters twice in reflective LCOS microdisplays.”). As shown in the above figure, more than 80% of the light having a wavelength between 450 and 470 nm passes twice through the blue filter. Even accounting for the light that would be reflected off the top surface of the filter, these data indicate that the transmittance of the blue filter in this wavelength range is greater than 85%. That is, since the overall transmission of 80% is the result of a double pass through the filter, then the single pass transmission must be larger than the square root of 0.8 (80%), which is almost 90%. The transmittance of Huang’s filter in the blue

wavelength region is, therefore, comparable to that of sapphire or glass. Ex. 1028. Although Huang describes a “liquid-crystal-on-silicon (LCOS) microdisplay,” Ex. 1012 at 499, a POSITA would understand that the same types of filters were used in both liquid crystal (LCD) and OLED displays. *See, e.g.*, Ex. 1020 at 2 (describing an OLED display using “a white OLED emitter” in which “the individual red, green and blue primary colors are generated by LCD type color filters”).

105. As a further example, Boerner describes an OLED display with a blue filter than “shows a high transparency in the blue region of the visible spectra” and which transmits blue light “almost without losses.” Ex. 1013, ¶ [0036]; *see also id.*, Fig. 4 (showing the transmission curve for the blue filter).

106. Therefore, in my opinion, a POSITA would understand that the color filter 30B used in Igarashi would be “transparent to the electromagnetic radiation having the first wavelength spectrum,” as required by claim element 1[f].

107. In the alternative, if there was any question as to whether Igarashi’s color filter 30B is “transparent to the electromagnetic radiation having the first wavelength spectrum,” it would have been obvious to use such a transparent filter. By August 4, 2008 (the earliest possible priority date for the ’547 patent), color filters that were transparent to the blue light emitted by OLEDs were well known in the art, as illustrated by the examples of Huang (Ex. 1012), Smith (Ex. 1009), and Shiotani (Ex. 1005).

108. A POSITA would have been motivated to use transparent filters in order to produce a display that is as bright and energy efficient as possible. A filter that is “transparent to the electromagnetic radiation having the first wavelength spectrum” would allow more light to reach the viewer than a filter that is not transparent. If the filter were not transparent, it would have been necessary to increase the current through organic electroluminescent element 12 to generate more light in order to compensate for the light that was not transmitted by the filter. This would increase the power consumed by the display, making it less energy efficient and reducing the lifetime of the OLED emitters because increasing current heats OLEDs and LEDs. A POSITA would understand that the use of a filter that is “transparent to the electromagnetic radiation having the first wavelength spectrum” would extend the life of the display and increase its value to the customer because of its increased brightness.

109. A POSITA would have a reasonable expectation of success using a transparent filter in Igarashi’s display. Color filters having the required optical properties were commercially available and it would have been a routine matter to replace one color filter with another. In addition, Igarashi teaches that the color filters are formed on a glass plate, separate from the substrate on which the OLEDs are formed. Igarashi ¶ [0109]. The glass plate and the substrate are only bonded at the end of the manufacturing process. *Id.* Replacing one type of filter with another would

be a simple matter that would not require any significant changes to the manufacturing process, and would employ conventional optical materials according to their accepted use.

2. Dependent Claim 2: The optoelectronic device as claimed in claim 1, wherein the first wavelength spectrum comprises a blue wavelength range and the second wavelength spectrum comprises a yellow wavelength range.

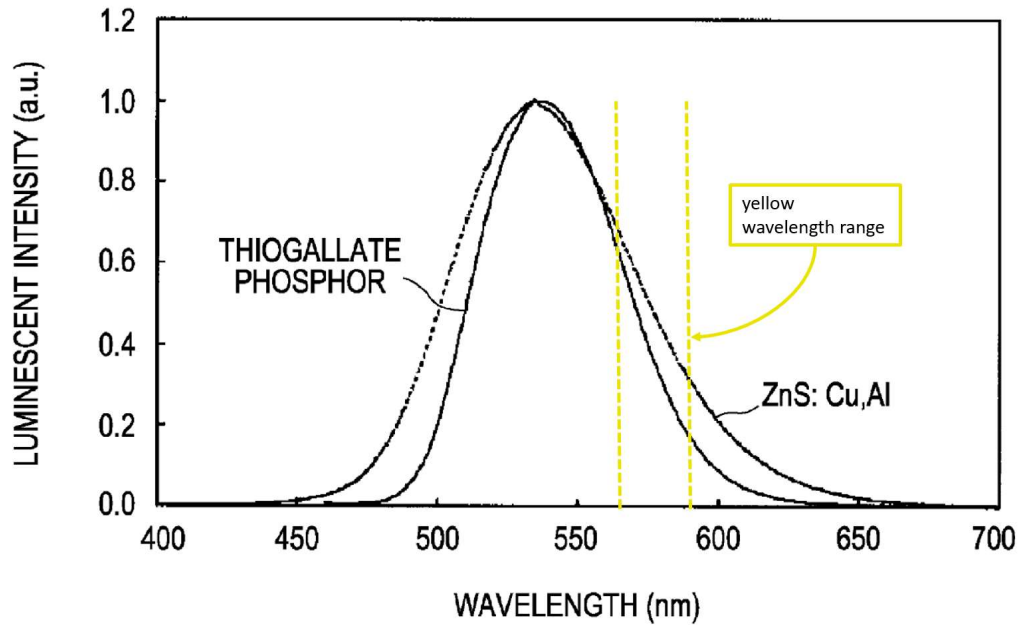
110. In my opinion, Igarashi discloses an optoelectronic device satisfying the limitations of claim 2.

111. As discussed above with respect to claim element 1[a], Igarashi's "first wavelength spectrum" is the spectrum of light (or "electromagnetic radiation") emitted by organic layer 24. Igarashi states that the electroluminescent element emits "light in the blue region having a wavelength range of 450 to 470 nm." Igarashi ¶ [0088]. Therefore, "the first wavelength spectrum comprises a blue wavelength range" as required by this claim element.

112. As discussed above with respect to claim element 1[c], Igarashi's "second wavelength spectrum" is the spectrum of light emitted by color conversion layer 29G. In Igarashi's display device, "the color conversion layer 29G corresponding to green includes the [thiogallate] phosphor according to an embodiment of the present invention." Igarashi at ¶ [0090]. The thiogallate phosphor absorbs the blue light emitted by organic layer 24 and emits "green output light in the pixel 28G." *Id.* at ¶ [0091].

113. It should be mentioned here that the spectra emitted by most commercially available phosphors extend into the spectral regions occupied by adjacent colors. That is, a phosphor designed to emit green light also emits “green-yellow” and “green-blue” light because the yellow and blue portions of the visible spectrum border the green region. The breadth of the light spectrum emitted by phosphors commonly used in commercial products extends well beyond the center of the “green” spectral region. In other words, the wavelength range emitted by most green phosphors (for example) is broader than the region that is perceived by the human eye to be “pure green.” The same applies to other regions of the visible spectrum, such as yellow, orange, and red.

114. Figure 10 of Igarashi, reproduced below, shows the emission spectrum of two common green phosphors, zinc sulfide (ZnS) and the strontium thiogallate phosphor $\text{SrGa}_2\text{S}_4\text{:Eu}$. Igarashi ¶ [0006] (citing Chartier, Photoluminescence of Eu^{2+} in SrGa_2S_4 , *Journal of Luminescence*, Vol. 111, at 147–58 (2005)) (Ex. 1021), at Fig. 6.



Igarashi, Fig. 10 (annotated). As seen in the figure, the emission spectrum for both phosphors peaks at approximately 535 nm and extends into the yellow (570–590 nm) and yellow-green (540–570 nm) regions. For the relatively-narrow-band thiogallate phosphor, computer calculations show that approximately 10% of the integrated intensity emitted by the phosphor lies in the yellow (570-590 nm) wavelength interval, and this percentage rises to 47% if the 540–570 nm yellow-green region is included. These calculations were performed with MATLAB software (used routinely at the University of Illinois and throughout the world) to graphically integrate the area under the thiogallate curve in Igarashi’s Fig. 10 in the wavelength ranges listed above. Any of a variety of other scientific/engineering software packages are capable of graphical integration, and may also be used to obtain the same result.

115. Igarashi's color conversion layer 29G contains the strontium thiogallate phosphor $\text{SrGa}_a\text{S}_4\text{:Eu}$, where "Eu" indicates that the thiogallate host is doped with Europium (Eu). Igarashi ¶ [0091]–[0094]. Igarashi varied "the stoichiometric ratio (Ga/Sr) of Ga to Sr in the preparation of the formulation" (denoted by "a" in the chemical formula) to study the effect on the luminescent intensity ratio. *Id.* ¶ [0095], Table 7. Igarashi also created displays in which the phosphor "had a known composition $\text{SrGa}_2\text{S}_4\text{:Eu}$." *Id.* A POSITA would understand that each of these phosphors emit light in the yellow wavelength range, which is determined primarily by the rare-earth dopant europium (Eu) although the "host" for the rare-earth atom in the phosphor also influences the color of the emitted light. Other rare-earth elements are routinely incorporated into phosphors to emit light in other portions of the visible spectrum. Terbium (Tb) incorporated (*i.e.*, "doped") into zinc sulfide (ZnS), for example, also yields green light. In summary, the spectrum of the "known composition $\text{SrGa}_2\text{S}_4\text{:Eu}$ " is shown in Figure 10 to emit yellow light. *Id.* Adjusting the stoichiometric ratio of gallium to strontium would have at most a minor effect on the amount of yellow light emitted; it would not eliminate the yellow light. Varying the ratio of the strontium (Sr) to gallium (Ga) ratio has been found to slightly shift the wavelength at which peak emission (*i.e.*, maximum light intensity) occurs, but has little impact on the amount of "green" light emitted (that is, the efficiency of converting blue light to green).

116. A POSITA would understand that thiogallate-based Eu phosphors have an emission spectrum, similar to those shown in Figure 10, extending throughout the yellow (570–590 nm) region and beyond. Indeed, commercially available green phosphors invariably produce light on either side of the green region because the pure “green” region is narrow (approximately 510–540 nm in breadth) and developing phosphors that do *not* emit outside this region is usually unnecessary and economically not feasible. Light having wavelengths in the 540–570 nm “gap” region is generally regarded as yellow-green light, and green phosphors also generate light in this region.

117. In summary, it is my opinion that Igarashi discloses a display device in which the first wavelength spectrum comprises a blue wavelength range and the second wavelength spectrum comprises a yellow wavelength range.

118. If there was any question as to whether or not the second wavelength spectrum emitted by color conversion layer 29G “comprises a yellow wavelength range,” it would have been obvious for a POSITA to use a green phosphor in Igarashi’s display that emits light in a yellow wavelength range including, for example, either zinc sulfide or the thiogallate phosphor having the “known composition $\text{SrGa}_2\text{S}_4\text{:Eu}$.” A POSITA would have been motivated to use such phosphors because they were commercially available with well-known properties.

Using a commercially available and well-known phosphor would avoid the expense and extra manufacturing steps required to manufacture a custom phosphor.

119. A POSITA would have a reasonable expectation of success in using such a commercially-available phosphor. Replacing one phosphor with another would have been a routine matter and Igarashi had already demonstrated that the “known composition” could be successfully used in his display. Indeed, it was well known in the art that a wide variety of phosphors could be used in OLED displays. Boerner, for example, identifies several “suitable color converting materials” for use in OLED displays, including strontium thiogallate. Ex. 1013, ¶ [0032], Table 1.

3. Dependent Claim 3: The optoelectronic device as claimed in claim 1, wherein the optoelectronic device has a non-yellow color impression.

120. In my opinion, Igarashi discloses an optoelectronic device satisfying the limitations of claim 3.

121. A POSITA would understand that the claimed “non-yellow color impression” refers to the color impression when the device is turned off. The specification of the ’547 patent repeatedly refers to the “color impression in the switched-off state.” For example, the “Field of the Invention” states that “[t]he present invention relates to an optoelectronic device which can emit electromagnetic radiation during operation and has a desired color impression in the switched-off state.” ’547 patent, 1:13–15. The “Summary of the Invention” states that “[o]ne

object of specific embodiments of the present invention is to provide an optoelectronic device comprising a wavelength conversion layer, which device can reduce or avoid an undesired color impression in a switched-off state.” *Id.*, 1:19–22.

The Summary of the Invention also states that “it can be possible that the wavelength conversion layer, *in the case of a switched-off state of the optoelectronic device*, in accordance with its absorption spectrum and its emission spectrum, as a result of radiation which is incident on the optoelectronic device from outside and which can be reflected or emitted by an absorption and re-emission process described, can give an observer a color impression which can be intrinsically undesired.” *Id.*, 3:14–21.

The ’547 patent states that one of the features of the device is that “even in the switched-off state, a superimposition of electromagnetic radiation having a wavelength range of the first wavelength spectrum and an electromagnetic radiation having the wavelength range of the second wavelength spectrum occurs, with the result that a desired, preferably non-yellowish, color impression is established.” *Id.*, 3:40–45; *see also id.*, 11:24–29 (“Consequently, once again through combination of a yellowish portion of the electromagnetic radiation 16A and a bluish portion of the electromagnetic radiation 18, a non-yellowish, preferably whitish, color impression arises for an observer of the optoelectronic device in the switched-off state thereof.”).

122. A POSITA would understand that Igarashi's display has a non-yellow color impression when in the switched-off state. Igarashi's display includes red, green, blue, and cyan filters, each the size of a single pixel, and these combine to produce a white or grey color impression. As in the '547 patent, when Igarashi's display is in the switched-off state, the light reflecting off the red, green, blue, and cyan color filters form a "superimposition of electromagnetic radiation." '547 patent, 3:40–45. The combination (or superimposition) of these colors would produce a gray-white impression.

123. Furthermore, the color filters of the red, green, blue, and cyan pixels occupy only a portion of the display surface. In addition to the pixels, "[a] black matrix 31 that at least optically separates the color filters is provided between the color filters." Igarashi at ¶ [0089]; *see also id.* ¶ [0109] ("On the glass plate, color filters 29R, 29G, 29B, and 29C are formed at the positions of the corresponding pixels and a black matrix 31 is formed there between."). As shown in Figure 5 of Igarashi, the black matrix occupies approximately as much area on the display as all of the colored pixels combined. If black matrix resin is also placed between the rows of pixels (*i.e.*, perpendicular to the plane of Figure 5), most of the surface of the display would be covered by this black mask. Such a "mask" or "matrix" is routinely incorporated by manufacturers into displays for the purpose of increasing contrast. It is well-known to anyone who owns an OLED or LED television that the inclusion

of the black matrix results in a screen that appears black or dark grey when the television is off. In any event, Igarashi's display "has a non-yellow color impression," as required by the claim.

124. At a minimum, it would have been obvious to a POSITA for Igarashi's display to have a non-yellow color impression when in the "switched-off state." Such displays invariably appear black (or dark grey) when the pixels are off in order to maximize the contrast of the display. It would have been obvious to implement Igarashi's display in the standard way for OLED displays, such that it appears black (or dark grey) when it is off. Indeed, the function of the black matrix is to create a black screen so as to increase contrast. An OLED display produces black image content by turning off the associated pixels. On the other hand, an OLED display that had a yellow color impression when turned off would be unable to display black. Such a display would have a low-contrast appearance and would produce a yellow tint to any image shown on the display. A black screen also has the beneficial effect of reducing the amount of energy required to drive the OLED display and increasing the visibility of the display in ambient lighting.

125. My opinions are consistent with those of the Examiner during prosecution of the '547 patent. The examiner initially rejected (what was then) claim 4 as being obvious over the flat-panel OLED display of Kobori. According to the examiner:

Regarding claim 4, Kobori is silent as to the color of the device when it is turned off, but *one of ordinary skill in the art would have reasonably contemplated having the display appear black to an observer as is expected for flat panel displays*. Therefore, it would have been obvious to one of ordinary skill in the art to have the display appear black to an observer in order to meet flat panel display appearance expectations.

Ex. 1002 (File History) at 513 (emphasis added). I agree with the Examiner. I also note that the applicants did not dispute the Examiner's analysis. The Examiner's analysis is equally applicable to the flat-panel OLED display of Igarashi.

126. Even if the claim was interpreted to require that “the optoelectronic device has a non-yellow color impression” when in the switched-on state, it is my opinion that Igarashi discloses a display that satisfies this requirement. At a minimum, this limitation would have been obvious. Igarashi discloses a display comprising red, green, blue, and cyan pixels, three of which represent the primary colors *See* Igarashi at ¶ [0089], Fig. 5. A POSITA would understand that, when in operation, such a display is intended to reproduce a wide range of colors (*i.e.*, visible light). The large number of colors of which the display is capable of generating is known as the “palette” or “gamut”. As explained by Murdoch, for example:

In a common OLED color display device a pixel includes red, green, and blue colored OLEDs. These light emitting color primaries define a color gamut, and by additively combining the illumination from each

of these three OLEDs, i.e. with the integrative capabilities of the human visual system, a wide variety of colors can be achieved.

Murdoch at 1:17–23.

127. A POSITA would understand that Igarashi's display, which additionally includes cyan pixels, functions to produce a gamut of colors, by combining light from its red, green, blue, and cyan pixels. *See* Igarashi at ¶ [0113] ("The pixel structure can be selected according to a desired color reproducing range."). Therefore, it would have been at least obvious to use Igarashi's display to reproduce a range of colors, which includes non-yellow colors. As a result, it would have been obvious for Igarashi's display (optoelectronic device) to have a non-yellow color impression.

4. Dependent Claim 4: The optoelectronic device as claimed in claim 1, wherein the filter layer is configured to convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range.

128. In my opinion, claim 4 would have been obvious based on Igarashi. As discussed above for claim element 1[d], Igarashi's color filter 30B is the required filter layer and the filter "is at least partially opaque to an electromagnetic radiation having a third wavelength spectrum."

129. As further explained above, a POSITA would understand that Igarashi's blue color filter 30B is a "bandpass" filter that transmits optical

wavelengths in the desired range while at least partially absorbing wavelengths outside that range. For example, Smith explains that “[a]bsorption filters are composed of materials which transmit light selectively; that is, they transmit certain wavelengths more than others.” Ex. 1009 at 192; *see also* Shiotani at Abstract, ¶ [0018] (explaining that a “color filter layer 7B for blue” serves to “transmit[] light in the blue wavelength region and absorb[] light in other wavelength regions when light containing light in the blue wavelength region is incident.”); Yeh (Ex. 1022) at 271 (When using red, green, and blue color filters, “each color filter can transmit only one-third of the total optical energy. In other words two-thirds of the energy is absorbed by the color filters, if the filters are based on absorption.”).

130. The '547 patent states that the filter layer may “convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range” by absorbing the electromagnetic radiation, which will convert the radiation into heat (which is infrared radiation). '547 patent, 3:46–65. According to the patent, a filter layer that “absorb[s] the radiation having a third wavelength spectrum” means that “the filter layer is designed to convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range” or, “[t]o put it another way, the filter layer is designed to convert

electromagnetic radiation having the third wavelength spectrum into heat or thermal radiation.” *Id.*

131. A POSITA would have understood that Igarashi’s color filter 30B “convert[s] the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range” in precisely this manner. As discussed above, Igarashi’s color filter absorbs electromagnetic radiation having the third wavelength spectrum and converts the absorbed energy into infrared radiation which is invisible to the human eye.

132. A POSITA would also have understood that the absorption of the electromagnetic radiation converts the radiation “into an electromagnetic radiation from a non-visible wavelength range” in the form of heat, which is infrared radiation. For example, as Hecht explains,

if the photon’s energy matches that of one of the excited states, the atom will absorb the light, making a quantum jump to that higher energy level. In the dense atomic landscape of ordinary gases (at pressures of about 10^2 Pa and up), solids, and liquids, it’s very likely that this excitation energy will rapidly be transferred, via collisions, to random atomic motion, thermal energy, before a photon can be emitted. This commonplace process (the taking up of a photon and its conversion into thermal energy) was at one time widely known as “absorption,” but nowadays that word is more often used to refer just to the “taking up” aspect, regardless of what then happens to the energy. Consequently, it’s now better referred to as dissipative absorption. All material media

partake in dissipative absorption to some extent, at one frequency or another.

Ex. 1014 at 67.

133. At a minimum, it would have been obvious to use an absorptive filter in Igarashi's display, as such absorptive filters, including color glass filters, were the most common type of filter used in such displays. A POSITA would have a reasonable expectation of success in using a well-established type of filter for its customary purpose.

134. Therefore, in my opinion it would have been obvious, based on Igarashi, to employ a filter layer (for Igarashi's color filter 30B) that is configured to convert the radiation having a third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range (*e.g.*, infrared radiation).

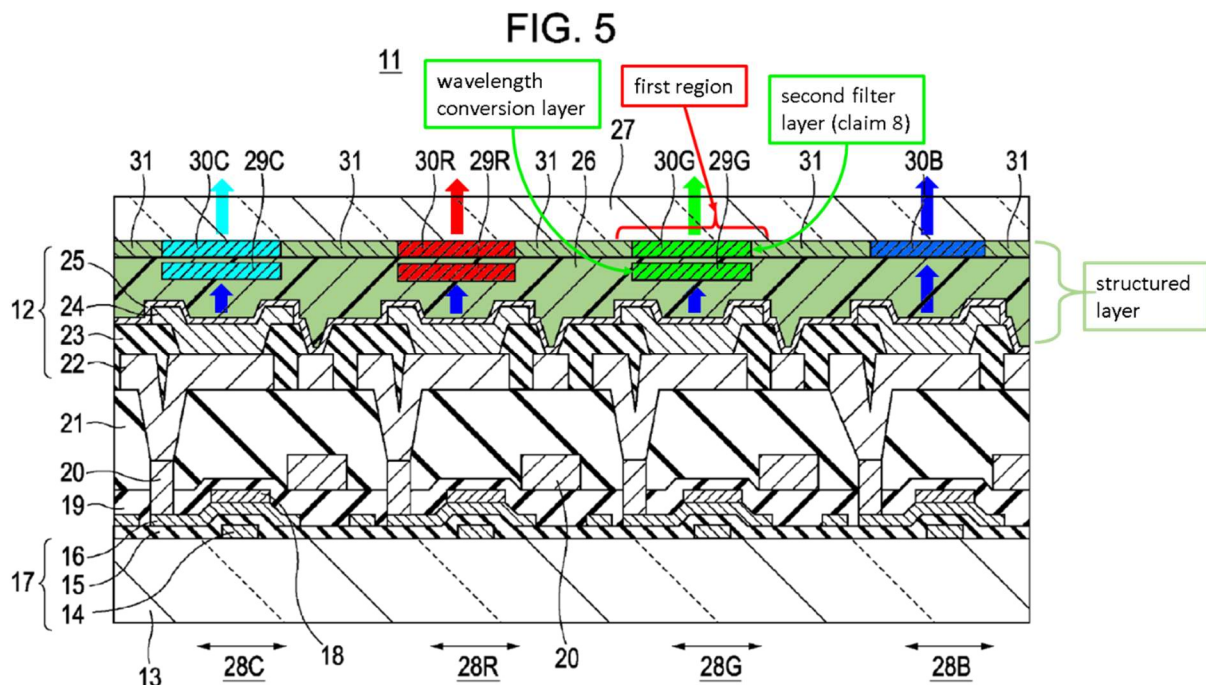
5. Dependent Claim 5: The optoelectronic device as claimed in claim 4, wherein the filter layer is further configured to absorb the electromagnetic radiation having the third wavelength spectrum.

135. In my opinion, claim 5 would have been obvious based on Igarashi. As I discussed above for claim 4, Igarashi's color filter 30B is the required filter layer and it would have been obvious to use a filter that absorbs the electromagnetic radiation having the third wavelength spectrum. Indeed, such filters were the most common color filters used in displays, and served to convert the absorbed radiation into an electromagnetic radiation from a non-visible wavelength range.

6. Dependent Claim 8

- a. The optoelectronic device as claimed in claim 1, wherein the first regions each have a second filter layer disposed downstream of the wavelength conversion layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence and

136. In my opinion, Igarashi discloses this element. Igarashi's green color filter 30G is the required "second filter layer." See Igarashi ¶ [0089]. As discussed above with respect to claim element 1[d], Igarashi's "structured layer" includes "color filters 30R, 30G, 30B, and 30C." *Id.* The "first region" is the portion of the structured layer corresponding to blue pixel 28G. As shown in the annotated figure below, color filter layer 30G is included in the first region.



Igarashi, Fig. 5 (annotated).

137. The figure further shows that color filter 30G is “disposed downstream of the wavelength conversion layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence,” as required by the claim element. Igarashi states that, in the embodiment shown in Figure 5, the “organic EL element has a top emission structure.” That is, organic layer 24 emits electromagnetic radiation in an upward direction through the structured layer’s color conversion layers and color filters. In the annotated figure above, the colored arrows indicate the direction of the beam path of the electromagnetic radiation. As shown, the “second filter layer” (i.e., color filter 30G) is downstream of the “wavelength conversion layer” (i.e., color conversion layer 29G).

138. To the extent that this claim element requires more than one “first regions” and more than one “second filter layer,” Igarashi discloses a display having a “plurality of pixels.” Igarashi ¶¶ [0026], [0088], [0089], [0112]. Igarashi also states that its display device “is driven by an active matrix.” Igarashi ¶ [0112]. A POSITA would understand that such a display would typically have thousands, if not millions, of pixels of each color, arranged in columns and rows (*i.e.*, as a “matrix”). Each of the green pixels has a “first region” including a “second filter layer.” Indeed, Igarashi’s display device would need to have a plurality of pixels, including a plurality of green pixels, in order to function as a display.

139. Therefore, it is my opinion that Igarashi's display device satisfies this claim element.

- b. which is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum which corresponds to at least one part of the first wavelength spectrum.**

140. In my opinion, Igarashi also discloses this element of claim 8. As discussed above with respect to the previous limitation, Igarashi's color filter 30G is the required "second filter layer."

141. As discussed above with respect to Igarashi's color filter 30B, a POSITA would understand that Igarashi's color filters are "at least partially opaque to an electromagnetic radiation," because blocking the passage of specified wavelengths of light is precisely the function of color filters. Such filters are known in the art as "bandpass" filters which are designed to "pass" (transmit) optical wavelengths in a desired range while rejecting (blocking) those wavelengths lying outside that range. For example, Smith explains that "[a]bsorption filters are composed of materials which transmit light selectively; that is, they transmit certain wavelengths more than others." Ex. 1009 at 192. Shiotani likewise explains that a "color filter layer 7B for blue" serves to "transmit[] light in the blue wavelength region and absorb[] light in other wavelength regions when light containing light in the blue wavelength region is incident." Shiotani, Abstract, ¶ [0018]. The same is true for Igarashi's color filter 30G. Although color filter 30G transmits green light

instead of the blue light transmitted by color filter 30B, both filters (and all color filters) operate on similar principles. The blue light absorbed by green color filter 30G is the required “fourth wavelength spectrum.”

142. A POSITA would understand that the “fourth wavelength spectrum . . . corresponds to at least one part of the first wavelength spectrum.” As discussed above for claim element 1[a], in Igarashi, the spectrum of light emitted by organic layer 24 is the required “first wavelength spectrum.” According to Igarashi, organic layer 24 emits “light in the blue region having a wavelength range of 450 to 470 nm.” Igarashi ¶ [0088]. Since pixel 28G produces a “green (G) light emission,” *id.* ¶ [0113], a POSITA would understand that green color filter 30G would reject or block (and thus be “at least partially opaque to”) the blue light emitted by organic layer 24.

143. Therefore, it is my opinion that Igarashi’s display device satisfies this claim element.

7. Dependent Claim 9: The optoelectronic device as claimed in claim 8, wherein the second filter layer is configured at least partially to absorb the electromagnetic radiation having the fourth wavelength spectrum.

144. In my opinion, claim 9 would have been obvious based on Igarashi. As discussed above with respect to claim 8, Igarashi’s green color filter 30G is the required “second filter layer” and the filter “is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum.”

145. As I explained above, a POSITA would understand that Igarashi's color filters are "bandpass" filters that transmit optical wavelengths in a desired range while at least partially absorbing wavelengths lying outside that range. Although discussed above with respect to blue color filter 30B, a POSITA would understand that color filter 30G operates on similar principles. For example, Smith explains that "[a]bsorption filters are composed of materials which transmit light selectively; that is, they transmit certain wavelengths more than others." Ex. 1009 at 192; *see also* Shiotani at Abstract, ¶ [0018] (explaining that a "color filter layer 7B for blue" serves to "transmit[] light in the blue wavelength region and absorb[] light in other wavelength regions when light containing light in the blue wavelength region is incident."); Yeh (Ex. 1022) at 271 (When using red, green, and blue color filters, "each color filter can transmit only one-third of the total optical energy. In other words two-thirds of the energy is absorbed by the color filters, if the filters are based on absorption.").

146. Therefore, a POSITA would understand that Igarashi's green color filter 30G at least partially absorbs blue light that is not transmitted by the filter, which is "the electromagnetic radiation having the fourth wavelength spectrum." At a minimum, it would have been obvious to use such an absorptive filter in Igarashi's display, because, as discussed above for limitation 1[f], such absorptive filters, including color glass filters, are commonly employed in such displays.

8. Dependent Claim 10: The optoelectronic device as claimed in claim 8, wherein the second filter layer is configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum.

147. In my opinion, claim 10 would have been obvious based on Igarashi. As discussed above with respect to claim 8, Igarashi's color filter 30G is the required "second filter layer" and the filter "is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum."

148. Igarashi's color conversion layer 29G is fabricated from materials different from those for color filter 30G. *See* Igarashi ¶ [0094] ("The color conversion layer 29G was prepared by dispersing a phosphor having a composition represented by chemical formula 13 in an amount of 30 weight percent into an epoxy resin serving as a resin for dispersion, and forming the resin so as to have a thickness of 50 μm ."). Thus, when radiation passes from Igarashi's color conversion layer 29G to color filter 30G, a portion of the radiation will be reflected back toward the organic electroluminescent element 12 (rather than passing into the color filter) because the refractive index changes at the phosphor/color filter interface. *See* Mourad (Ex. 1015) at 15 ("At the interface of an optical filter, part of the incident radiant power is lost due to *surface reflection* resulting from the discontinuity of the *refractive index*."). A POSITA would have understood that when a beam of radiation strikes an interface between two different transparent media, some of the light will be reflected. For example, Hecht explains that, "at an interface between two different

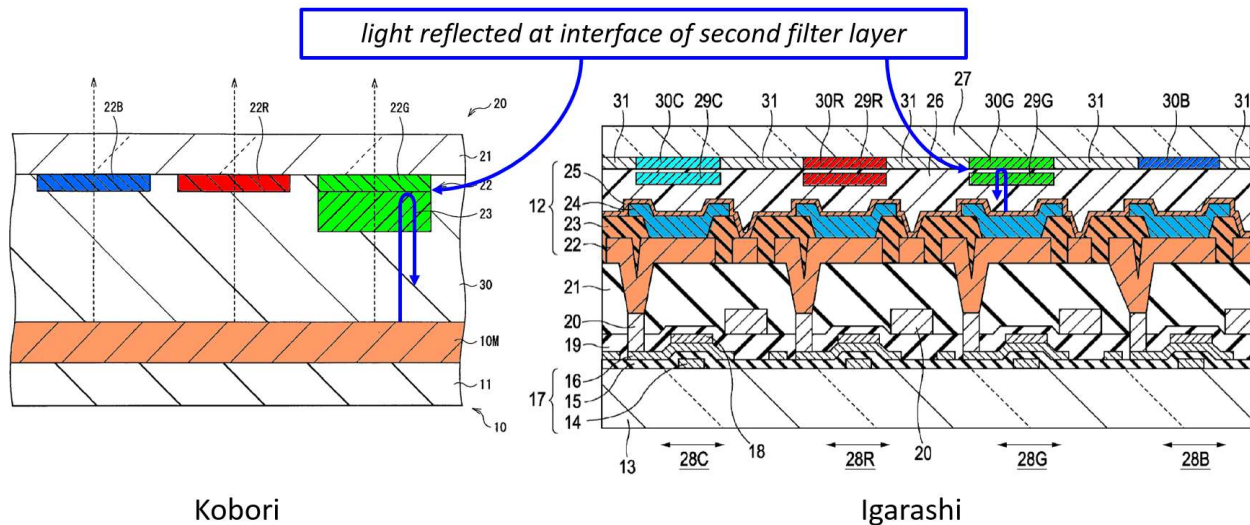
transparent media (such as air and glass) . . . some light is always scattered backward, and we call this phenomenon reflection.” Ex. 1014 at 95. The reflected radiation will comprise blue light emitted by Igarashi’s organic electroluminescent element, given that the color conversion layer 29G will not convert fully 100% of the blue light to green. Thus, a POSITA would understand that Igarashi’s color filter 30G (second filter layer) is configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum.

149. At a minimum, it would have been obvious to a POSITA that color filter 30G would be “configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum.” Indeed, as I have discussed, some reflection is characteristic of color filters and most other optical components.

150. My opinions are consistent with those of the Examiner during prosecution of the ’547 patent. The examiner initially rejected (what was then) claim 11 as being obvious over the flat-panel OLED display of Kobori. According to the examiner:

Regarding claim 11, Kobori further discloses wherein the second filter layer is designed at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum (22G; the Examiner notes that *the interface between layers 23 and 22G will characteristically reflect some of the electromagnetic radiation emitted by the organic layer sequence*).

Ex. 1002 (File History) at 509 (emphasis added). I agree with the Examiner. The Examiner's analysis (which the applicants did not dispute) is equally applicable to Igarashi. In my opinion, some radiation from the organic layer sequence similarly is reflected at the interface between the "wavelength conversion layer" (Igarashi's color conversion layer 29G) and "second filter layer" (Igarashi's color filter 30G). In the figure below, I have annotated the figures from both Kobori and Igarashi to show the similar path of the light reflected by the "second filter layer."



Kobori at Fig. 1 and Igarashi at Fig. 5 (annotated). It should also be mentioned that a fraction of the light emitted upwards by the blue OLED will also be reflected when the blue light impinges on the surface of the "wavelength conversion layer."

Therefore, it is my opinion that it would have been obvious to a POSITA that Igarashi's display device satisfies this claim element.

9. Dependent Claim 11: The optoelectronic device as claimed in claim 1, further comprising an encapsulation one of disposed upstream and disposed downstream of the structured layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence.

151. In my opinion, Igarashi discloses an optoelectronic device satisfying the limitations of claim 11.

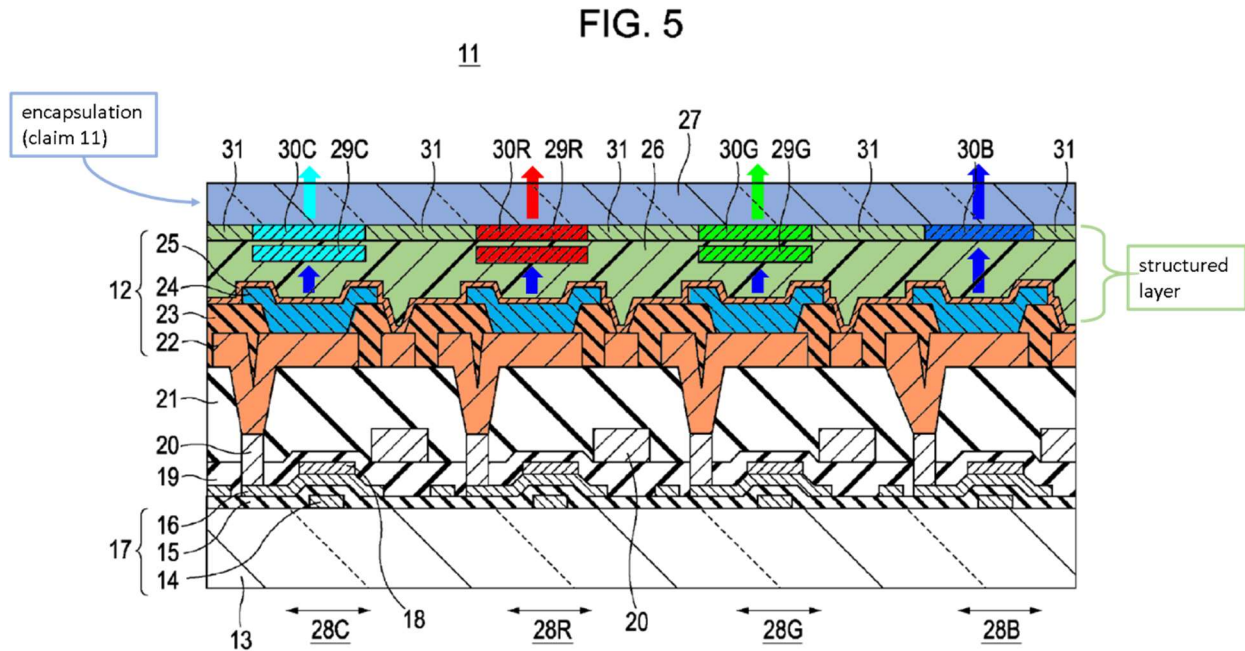
152. It was well known in the art before the '547 patent that the organic materials in OLED devices are degraded quickly by exposure to oxygen and atmospheric moisture and, as a result, such devices must be sealed or “encapsulated” to prevent the organic materials from deteriorating. Klausmann, for example, explains in the “Background of the Invention” that

Various types of devices may require hermetic sealing to protect the active components from atmospheric elements, such as moisture and/or gases. For example, devices which include organic active elements such as OLEDs require protection from moisture or gases.

Ex. 1023, 1:27–31; *see also id.*, 1:51–53 (“Active components, such as the cathode and organic layers in organic devices are adversely impacted by potentially deleterious components such as water, oxygen and other gaseous components.”). As another example, Cok observes that “[m]ost OLED devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere.” Ex. 1024, 8:63–67.

153. Igarashi's display device includes an encapsulation—sealing substrate 27. Igarashi states that “[a] sealing substrate 27 composed of, for example, glass is provided on the entire surface to form the display device 11.” Igarashi ¶ [0089]. Igarashi explains that the display device is manufactured in two pieces. The organic electroluminescent (EL) elements (i.e. OLEDs) are “formed on a substrate 13 composed of, for example, glass.” *Id.* ¶ [0105]. Separately, the color filters and color conversion layers are formed on the sealing substrate. *Id.* ¶ [0109]. The substrate 13 and sealing substrate 27 are “then bonded with each other,” *id.*, encapsulating the OLEDs.

154. Igarashi discloses that sealing substrate 27 is “disposed downstream of the structured layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence,” as required by the claim. In the figure below, I have annotated Igarashi's Figure 5 to highlight the encapsulation, the structured layer, and the beam path of the electromagnetic radiation.



Igarashi, Fig. 5 (annotated). As shown in the figure, the beam path of the OLED-produced blue light travels upwards from organic layer 24, through the structured layer, and then through the encapsulation (*i.e.*, sealing substrate 27). Therefore, sealing substrate 27 is “in the beam path of the electromagnetic radiation emitted by the organic layer sequence” and is “disposed downstream of the structured layer.”

155. Therefore, in my opinion, Igarashi’s display device comprises an encapsulation satisfying all of the requirements of claim 11.

- 10. Dependent Claim 13: The optoelectronic device as claimed in claim 1, wherein the electromagnetic radiation which is emitted by the optoelectronic device corresponds to a superimposition of the electromagnetic radiation having the first wavelength spectrum and the electromagnetic radiation having the second wavelength spectrum.**

156. In my opinion, this claim would have been obvious to a POSITA based on Igarashi. Igarashi discloses a display comprising red, green, blue, and cyan pixels. *See* Igarashi ¶ [0089], Fig. 5. A POSITA would understand that such a display is configured to reproduce a range of visible colors by combining light from different colored pixels. As explained by Murdoch, for example:

In a common OLED color display device a pixel includes red, green, and blue colored OLEDs. These light emitting color primaries define a color gamut, and by additively combining the illumination from each of these three OLEDs, i.e. with the integrative capabilities of the human visual system, a wide variety of colors can be achieved.

Murdoch (Ex. 1016), 1:17–23.

157. A POSITA would understand that Igarashi's display functions to produce a gamut of colors by combining light from its red, green, blue, and cyan pixels. *See* Igarashi ¶ [0113] ("The pixel structure can be selected according to a desired color reproducing range."). This is the principle by which all displays generate an extensive range of colors. For example, white light is produced by turning on all of the different colored pixel. This combination of colors constitutes a

“superimposition” (generally referred to as a “superposition”) of light from the individual pixels.

158. It would have been at least obvious to use Igarashi’s display such that the electromagnetic radiation emitted by the display (optoelectronic device) corresponds to a superimposition of the electromagnetic radiation having the first wavelength spectrum (blue light from the blue pixels) and the electromagnetic radiation having the second wavelength spectrum (green light from the green pixels). The function of a color display display such as that disclosed in Igarashi is to display full color images. A POSITA would be motivated to use the display device for its intended purpose and would have a reasonable expectation of success in using Igarashi’s display device to display full color images forming a superimposition of electromagnetic radiation.

B. Ground II: Claim 12 Is Obvious Based on Igarashi and Pilcher

1. Dependent Claim 12: The optoelectronic device as claimed in claim 11, wherein the encapsulation comprises a thin-film encapsulation.

159. In my opinion, this claim would have been obvious to a POSITA based on Igarashi in view of Pilcher. As discussed above with respect to claim 11, Igarashi discloses a device that meets the requirements of claim 1, and Igarashi’s sealing substrate 27 is an encapsulation. Igarashi states that the sealing substrate may be “composed of[] for example glass.” Igarashi ¶ [0089]. Although Igarashi does not

explicitly state that the encapsulation could be a thin-film encapsulation, it would have been obvious to a POSITA to use thin-film encapsulation in Igarashi's display.

Prior to the '547 patent, thin-film encapsulation was a well-known alternative to glass encapsulation of organic light-emitting displays. For example, Pilcher states:

It is well known in the art to encapsulate an OLED device by physically mating a top glass (or other suitable material) layer over, but usually not touching, the OLED device with an epoxy border. . . .

Of late, there has been some discussion in the art to provide a cheaper and better manner of encapsulation, called "direct thin-film" encapsulation. In this manner, thin film encapsulation is typically described as a "polymer multi-layer" (PML) comprising alternating and repeating layers of an organic (usually acrylate or the like) and a barrier layer.

Pilcher, 1:10–22 (emphasis added). Additionally, it was known that thin film encapsulation provided a number of advantages over glass. For example:

The advantages of direct thin-film encapsulation over the prior art are primarily cost reduction and improved reliability. Using direct thin-film encapsulation, *the package may also be thinner and/or lighter and/or mechanically more flexible.* Several structures and steps of the prior art may be excluded with this process. For example, there is no need for a separate glass plate, no need for an epoxy seal, no need for a getter (which is typical in the prior art).

Pilcher, 1:48–55 (emphasis added).

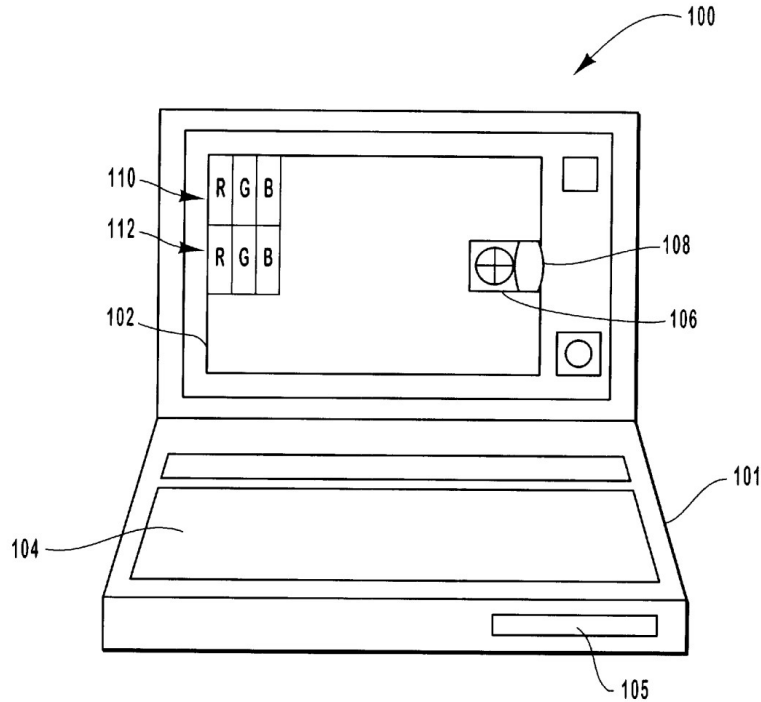
160. In view of the above, it would have been obvious to a POSITA to use employ thin-film encapsulation in the display of Igarashi. A POSITA would have been motivated to use thin-film encapsulation in order to achieve the advantages discussed in Pilcher and the reduction in weight. Another advantage of adopting thin film encapsulation is that much of the structure of the OLED display described in Igarashi is manufactured today (and was manufactured before the '547 patent) using thin film deposition techniques. Since thin film encapsulation was known to be effective (not requiring a relatively thick glass plate encapsulation), employing thin film deposition processes and tools to produce the encapsulation would be very attractive to a POSITA. Additionally, a POSITA would have had a reasonable expectation of success in adopting thin-film encapsulation. The replacement of the glass encapsulation approach explicitly discussed in Igarashi with Pilcher's thin-film encapsulation replaces one well-known method with another that is clearly superior for commercial products such as the manufacture of flat-panel displays. Implementing such a known, predictable variation of the encapsulation already disclosed in Igarashi would have been well within the ability of a POSITA.

C. Ground III: Claim 14 Is Obvious Based on Igarashi and Dresevic

- 1. Dependent Claim 14: The optoelectronic device as claimed in claim 1, wherein the structured layer has at least one of striped, crossed-striped, circular, triangular, and rectangular regions.**

161. In my opinion, this claim would have been obvious to a POSITA based on Igarashi in view of Dresevic. In Igarashi's display device, the shape of the "first regions" and the "second regions" correspond to the shapes of the green and blue pixels, respectively. Although Igarashi does not explicitly state that the pixels are rectangular, it would have been obvious to a POSITA that the pixels in Igarashi's display would be rectangular and that the structured layer would have striped or rectangular regions.

162. Igarashi states that the display device "is driven by an active matrix." A POSITA would understand that a matrix display comprises a plurality of pixels arranged in rows and columns. *See, e.g.,* Kowalsky (Ex. 1025) at 20–22. A POSITA would further understand that it was common for the individual pixels in such a display to be rectangular. Figure 1 of Dresevic, reproduced below, provides an example of such an arrangement.



Dresevic, Fig. 1. As Dresevic explains, display devices “commonly used” this type of matrix array of rectangular pixels:

In displays commonly used for computer applications, each pixel on a color LCD display usually comprises three non-square elements, i.e., red, green and blue (RGB) pixel sub-components. . . . LCD displays of this type comprise a series of RGB pixel sub-components which are *commonly arranged to form stripes along the display*. The RGB stripes normally run the entire length of the display in one direction. The resulting RGB stripes are sometimes referred to as “RGB striping”.

Id., 2:3–13 (emphasis added).

163. This same pixel layout was also common in OLED display devices. For example, Figure 6a of Murdoch, reproduced below, shows “a typical prior art RGB stripe arrangement of OLEDs” in a display. Murdoch (Ex. 1016), 4:27–28.

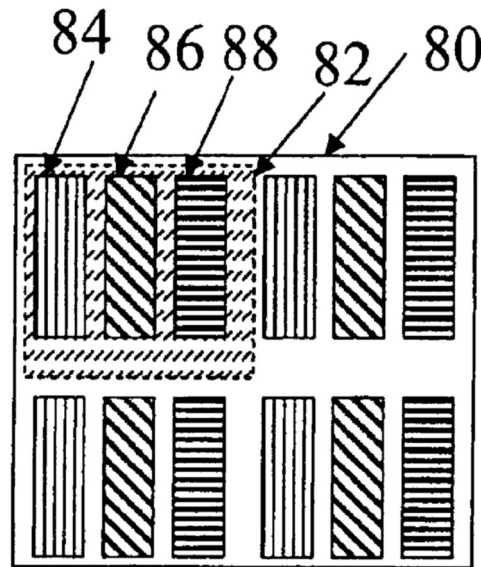
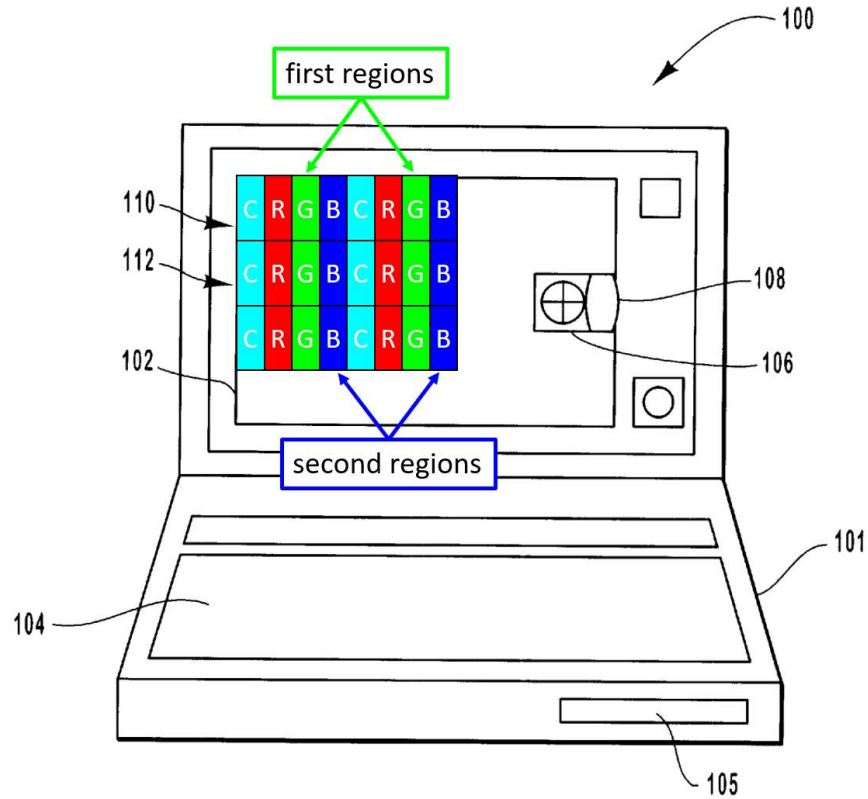


FIG. 6a
(PRIOR ART)

Id., Fig. 6a. As in Dresevic, each of the pixels has a rectangular shape.

164. Igarashi’s display devices employ four different colored pixels—cyan, red, green, and blue (denoted C, R, G, and B, respectively). In this context, the pixels would naturally take the form of a CRGB striped arrangement, as shown in the figure below, which is based on Figure 1 of Dresevic.



The use of such striped arrangements in four-color displays was also well-known in the art. Figure 8a of Murdoch, reproduced below, is an example.

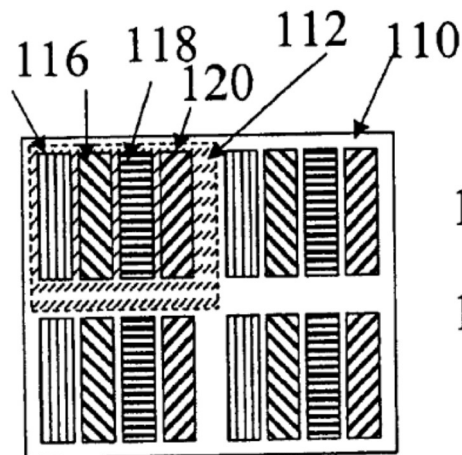


Fig. 8a

Murdoch, Fig. 8a.

165. A POSITA would have been motivated to implement Igarashi's display with rectangular pixels arranged as "RGB stripes" as shown in Dresevic and would have had a reasonable expectation of success in doing so. A POSITA implementing Igarashi's display would necessarily choose a shape and an arrangement for the pixels in the display. The use of rectangular pixels arranged in RGB stripes was a well-known practice in the design of OLED displays, used in many prior art displays. Not only was this arrangement common, it would also have been straightforward and least expensive to implement. For example, an active matrix display requires data lines to provide signals to each of the pixels. Arranging the pixels in an orderly striped arrangement simplifies the routing of the data lines across the display.

166. My opinions are consistent with those of the Examiner during prosecution of the '547 patent. The examiner initially rejected (what was then) claim 15 as being obvious over Krummacher. According to the examiner:

Regarding claim 15, Krummacher teaches wherein the structured layer may have any desired shape, but is silent as to a specific shape. However, one of ordinary skill in the art would have reasonably contemplated having the shapes be rectangular in order to provide a pixelated appearance. Therefore, it would have been obvious to one of ordinary skill in the art to have the structured layer have the shapes be rectangular in order to provide a pixelated appearance.

Ex. 1002 (File History) at 512. I agree with the Examiner. The Examiner’s analysis (which the applicants did not dispute) is equally applicable to Igarashi’s display device.

167. Therefore, it is my opinion that it would have been obvious for the “structured layer” in Igarashi’s display device to have “at least one of striped, crossed-striped, circular, triangular, and rectangular regions.”

D. Ground IV: Claims 1–5, 8–10, and 13 Are Obvious Based on Shiotani

1. Independent Claim 1

a. Preamble: An optoelectronic device, comprising:

168. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 1 is limiting. However, if the preamble is limiting, it is my opinion that Shiotani discloses the limitation.

169. Shiotani’s title is “Display Device.” Shiotani at 1. Shiotani’s abstract states that the patent is intended “[t]o provide a display device capable of color display with high light energy utilization efficiency and low power consumption.” *Id.*, Abstract. Shiotani states that “[t]he present invention relates to a display device, and in further detail, relates to a liquid crystal display device provided with a color conversion layer capable of color display, which can be used for both reflective and

transmissive applications.” *Id.* ¶ (0001). In my opinion, Shiotani’s display device is “[a]n optoelectronic device,” as required by claim 1.

170. When used as a transmissive device, light is generated in Shiotani by “EL light-emitting element 3,” Shiotani at ¶ (0021), which is an OLED device “formed by sequentially laminating a front electrode 18 made of transparent ITO, an organic EL light-emitting layer 19, and a light-reflective rear electrode 20 across the entire display region on the rear surface of an EL substrate 22 made of transparent glass,” *id.* at ¶ (0021). The organic EL material “generates blue light when a predetermined voltage is applied between the front and rear electrodes 18 and 20.” *Id.* at ¶ (0022). In the embodiment of Figure 7, the display comprises yellow, magenta, and cyan pixels. *Id.* at ¶ (0040). Each pixel includes a “color conversion layer” that absorbs the blue light emitted by the OLED and emits light of the desired color. *Id.* Shiotani’s display is capable of reproducing a wide range of different colors by combining light from the different pixels: “the colors of each pixel can be mixed and displayed by modulating the electric field of the liquid crystal cell 2. In particular, a wide chromaticity range can be achieved by controlling the gradation of each color.” *Id.* at ¶ (0031).

171. Since Shiotani’s display device is an electronic device that emits light, it is, in my opinion, an optoelectronic device.

b. Element 1[a]: an organic layer sequence which emits an electromagnetic radiation having a first wavelength spectrum during operation; and

172. In my opinion, Shiotani discloses this element. Shiotani's "EL light-emitting element 3" comprises an "organic layer sequence" as that term is used in the '547 patent. The '547 patent states that "the organic layer sequence can be embodied in particular as an organic light-emitting diode (OLED)," '547 patent, 4:33–34. The '547 patent further states:

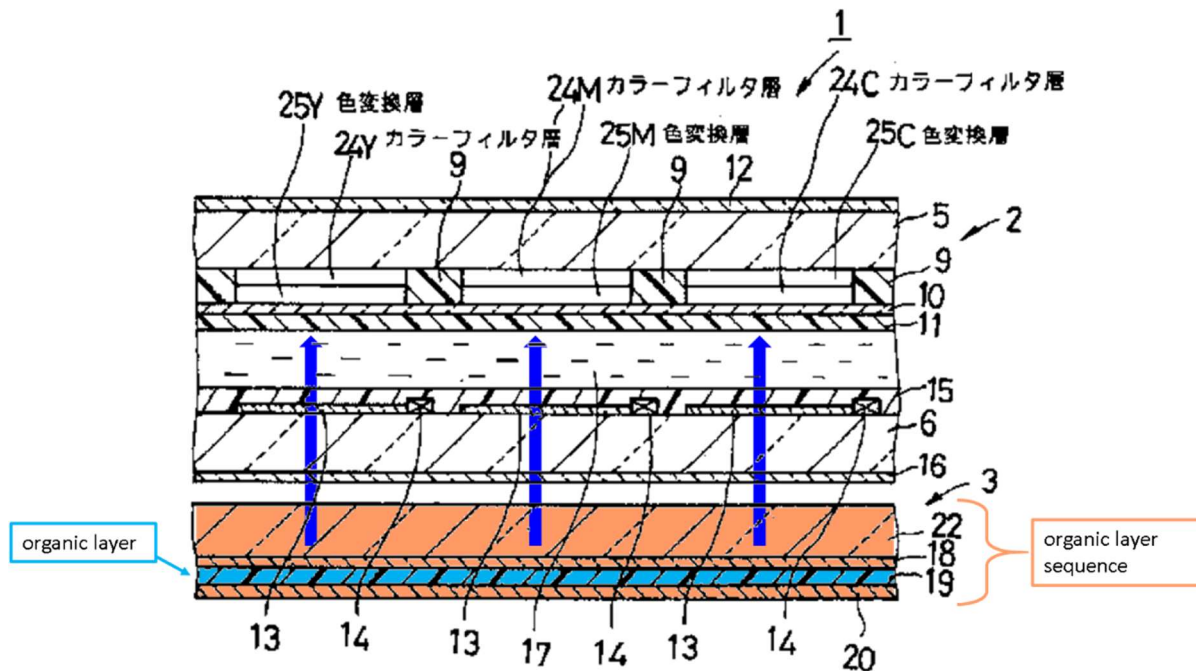
In this case, an OLED can have an organic layer or a layer sequence comprising at least one organic layer, having an active region that can emit electromagnetic radiation during operation. Furthermore, an OLED can have a first electrode and a second electrode, wherein the organic layer or the layer sequence comprising at least one organic layer having the active region can be arranged between the first and second electrodes.

'547 patent, 4:34–42.

173. Shiotani's "EL light-emitting element 3" is such an OLED. Shiotani states:

[a]s shown in FIG. 1, the EL light-emitting element 3 is formed by sequentially laminating a front electrode 18 made of transparent ITO, an organic EL light-emitting layer 19, and a light-reflective rear electrode 20 across the entire display region on the rear surface of an EL substrate 22 made of transparent glass.

Shiotani ¶ (0021). The EL light-emitting element in the embodiment shown in Shiotani's Figure 7 has the same structure. *See* Shiotani ¶ (0039) ("Since the configuration of other parts is the same as that in embodiment 1, the same symbols are used and descriptions are omitted."). In the figure below, Figure 7 of Shiotani has been annotated to highlight EL light-emitting element 3 and organic EL light-emitting layer 19. The blue arrows indicate the beam path of the emitted light.



Shiotani, Fig. 7 (annotated).

174. Shiotani further discloses that “organic EL light-emitting layer 19” is an organic layer sequence composed of multiple organic layers. Shiotani ¶ (0022). As described in Shiotani, organic EL light-emitting layer 19 comprises a “hole transport layer,” a “light-emitting layer,” and an “electron transport layer.” *Id.* Shiotani describes the structure of organic EL light-emitting layer 19 as follows:

Here, the organic EL light-emitting layer 19 is formed of an organic EL material that generates blue light when a predetermined voltage is applied between the front and rear electrodes 18 and 20. The organic EL light-emitting layer 19 is configured from three layers which are, in order from the front electrode 18 side, a hole transport layer comprising N, N'-di(α -naphthyl)-N, N'-diphenyl-1, 1'-biphenyl-4, 4'-diamine (hereinafter α -NPD), a light-emitting layer comprising 4, 4'-bis(2, 2'-diphenylbinylene)biphenyl (hereinafter DPVBi) of 96 wt% and 4, 4'-bis(2-carbazolevinylene)biphenyl (hereinafter BCzVBi) of 4 wt%, and an electron transport layer comprising tris(8-hydroxyquinoline)aluminum (hereinafter Alq3).

Shiotani ¶ (0022).

175. Shiotani's organic EL light-emitting layer 19 "emits an electromagnetic radiation having a first wavelength spectrum during operation," as required by this claim element. Organic EL light-emitting layer 19 includes "a light-emitting layer" made from a DPVBi host and a BCzVBi dopant. Shiotani ¶ (0022). A POSITA would understand that BCzVBi was a blue dopant commonly employed in blue OLEDs, and Shiotani explains that organic EL light-emitting layer 19 "generates blue light when a predetermined voltage is applied between the front and rear electrodes 18 and 20." *Id.* The inclusion of organic hole and electron transport layers in the quotation from Shiotani (above) is one signature of an OLED. The spectrum of light (or "electromagnetic radiation") emitted by organic EL light-emitting layer 19 is the required "first wavelength spectrum."

176. Therefore, it is my opinion that Shiotani's EL light-emitting element 3 comprises an "organic layer sequence" satisfying all of the requirements of claim element 1[a].

177. As I noted above with respect to ground I, some portions of the '547 patent appear to include the OLED's first and second electrodes in the "organic layer sequence." To the extent that the "organic layer sequence" limitation in the '547 patent requires the OLED's electrodes, Shiotani would still satisfy this limitation, as Shiotani's EL light-emitting element 3 includes front electrode 18 and rear electrode 20. Shiotani ¶ (0021).

c. Element 1[b]: a structured layer disposed downstream of the organic layer sequence in a beam path of the electromagnetic radiation emitted by the organic layer sequence and including first and second regions;

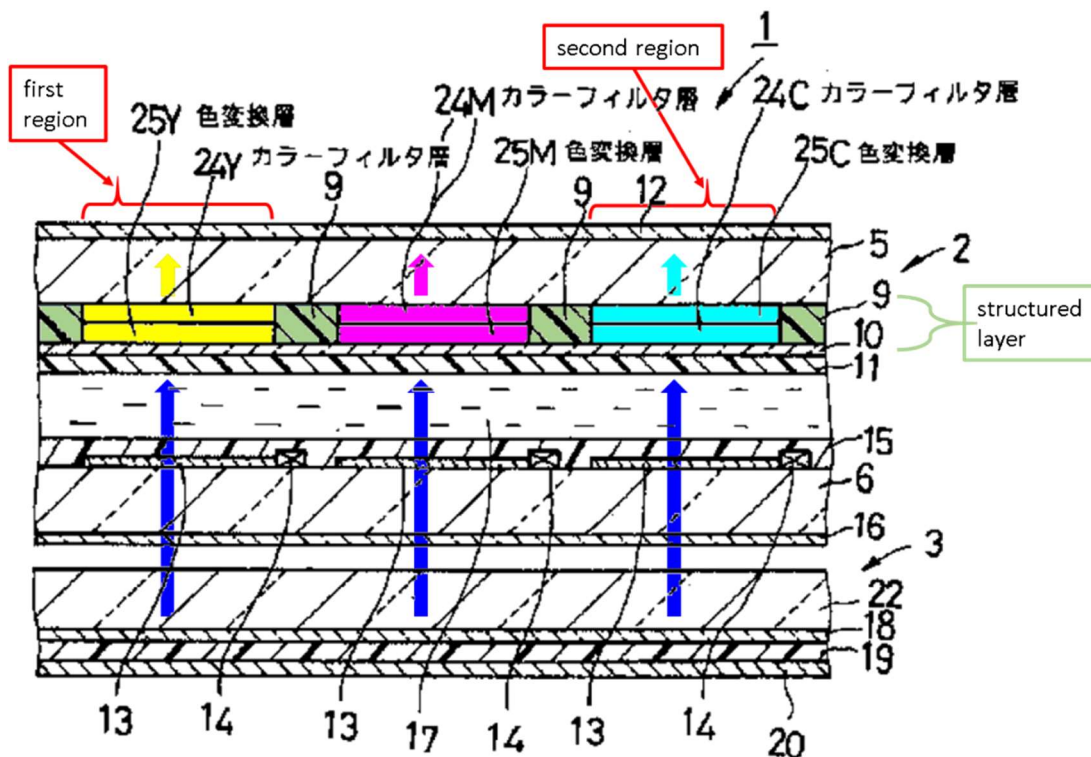
178. In my opinion, Shiotani discloses this element. As shown in Shiotani's Figure 7, the display includes a "structured layer" that includes: (i) color filter layers 24Y, 24M, and 24C, (ii) color conversion layers 25Y, 25M, and 25C, and (iii) black mask layer 9. Shiotani ¶ (0040). Each of the color filter layers is laminated to the corresponding color conversion layer. *Id.* Shiotani describes the color filter layers and color conversion layers as follows:

Three types of color filter layers are arranged in this embodiment: a color filter layer 24Y that transmits only the Y component; a color filter layer 24M that transmits only the M component; and a color filter layer 24C that transmits only the C component. Three types of color

conversion layers are arranged: a color conversion layer 25Y that converts the B (blue) component light into Y component light; a color conversion layer 25M that converts the B component light into M component light; and a color conversion layer 25C that converts the B component light into C component light. As shown in the figure, the color filter layer 24Y and the color conversion layer 25Y are laminated, the color filter layer 24M and the color conversion layer 25M are laminated, and the color filter layer 24C and the color conversion layer 25C are laminated.

Shiotani ¶ (0040).

179. In the figure below, Shiotani's Figure 7 is annotated so as to highlight the "structured layer."



Shiotani, Fig. 7 (annotated).

180. In Shiotani, the “structured layer” has “first regions,” which are the regions corresponding to the yellow pixels. The “structured layer” also has “second regions,” which are the regions corresponding to the cyan pixels. The first and second regions are shown in the annotated figure above.

181. In Shiotani, “a plurality of pixel regions are set within the display device.” Shiotani ¶ (0018). Shiotani also states that the pixel electrodes “are formed in a matrix.” Shiotani ¶ (0019). A POSITA would understand that such displays typically has thousands, if not millions, of pixels of each color, arranged in columns and rows (*i.e.*, as a “matrix”). Shiotani’s display device requires a plurality of pixels of each color in order to function as a display. Each yellow pixel has a corresponding “first region.” Each cyan pixel has a corresponding “second region.” Therefore, to the extent that the claim requires multiple “first regions” and/or multiple “second regions,” Shiotani’s display satisfies this requirement.

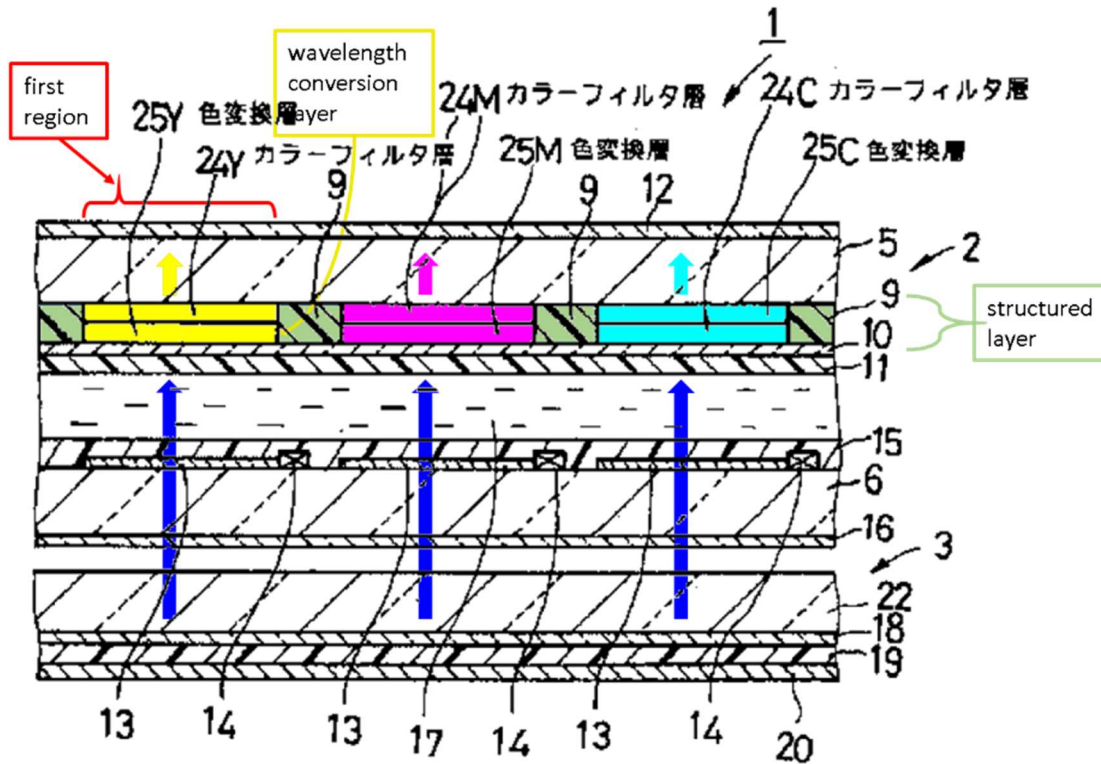
182. Shiotani’s “structured layer” is “disposed downstream of the organic layer sequence in a beam path of the electromagnetic radiation emitted by the organic layer sequence” as required by the claim. As discussed above with respect to claim element 1[a], Shiotani’s organic EL light-emitting layer 19 is the required “organic layer sequence.” According to Shiotani, “the light generated from EL light-emitting element is blue light,” Shiotani ¶ (0045), and serves as a “backlight of the liquid

crystal cell 2,” *id.* ¶ (0028). “This blue light is converted to the long wavelength side by the color conversion layers 25Y, 25M, and 25C to obtain Y, M, and C light.” *Id.* ¶ (0045). The light then passes through the color filter layers and “the Y light, the M light, and the C light are emitted as complementary rays of the three primary colors with excellent color purity.” *Id.* In the annotated figure above, the colored arrows indicate the direction of the beam path of the electromagnetic radiation. As shown, the “structured layer” is downstream of the “organic layer sequence.”

183. Therefore, it is my opinion that Shiotani’s display device includes a “structured layer” satisfying all of the requirements of claim element 1[b].

d. Element 1[c]: wherein the first regions each include a wavelength conversion layer configured to convert at least partially electromagnetic radiation having a first wavelength spectrum into an electromagnetic radiation having a second wavelength spectrum;

184. In my opinion, Shiotani discloses this element. Shiotani’s color conversion layer 25Y is the required “wavelength conversion layer.” As I discussed above for claim element 1[b], Shiotani’s “structured layer” includes “color conversion layers 25Y, 25M, and 25C.” Shiotani ¶ (0045). The “first region” is the portion of the structured layer corresponding to the yellow pixel. Therefore, as shown in the annotated figure below, color conversion layer 25Y is included in the first region.

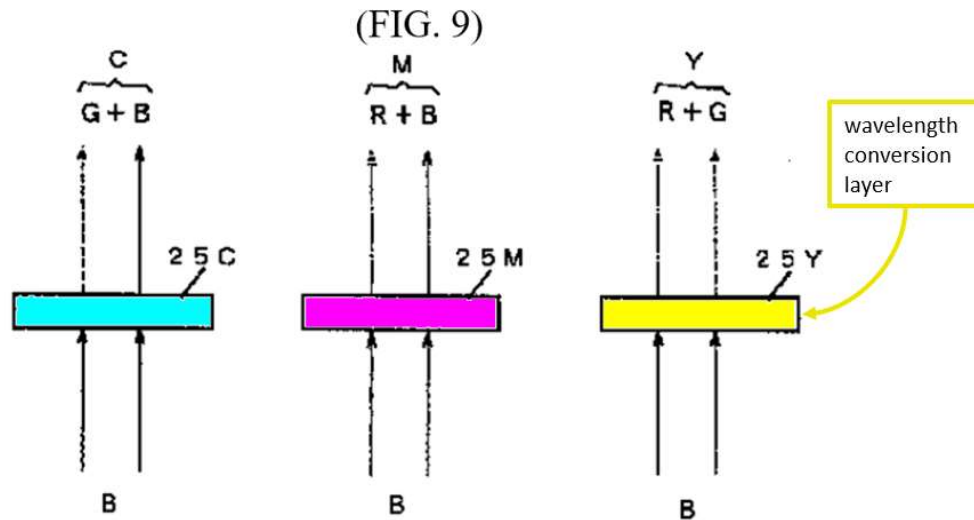


Shiotani, Fig. 7 (annotated).

185. Color conversion layer 25Y is a “wavelength conversion layer.” According to Shiotani, the “blue light [from EL light-emitting element 3] is converted to the long wavelength side by the color conversion layers 25Y, 25M, and 25C to obtain Y, M, and C light.” Shiotani ¶ (0045). Shiotani further explains the structure and function of color conversion layer 25Y:

the color conversion layer 25Y is a mixture of a color conversion layer that converts the B component light into R component light and a color conversion layer that converts the B component light into G component light to obtain Y, a color mixture of the R and G component light.

Id. ¶ (0041). The operation of the wavelength conversion layer is illustrated in Figure 9, reproduced below.



Id., Fig. 9 (annotated).

186. Therefore, color conversion layer 25Y constitutes a wavelength conversion layer that is configured to convert at least partially the blue light emitted by the organic layer sequence (*i.e.*, “electromagnetic radiation having a first wavelength spectrum”) into yellow light in the form of a mixture of red and green light. The light emitted from color conversion layer 25Y is the required “electromagnetic radiation having a second wavelength spectrum.”

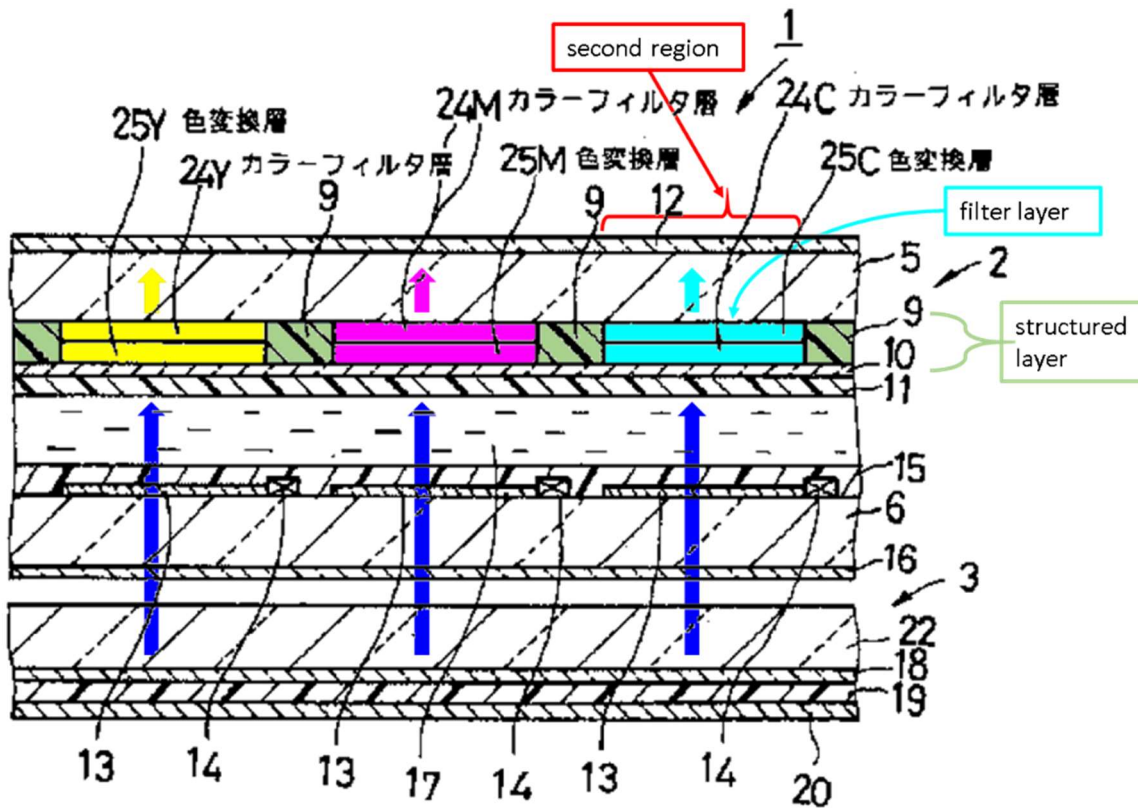
187. To the extent that this claim element requires more than one “first regions” and more than one “wavelength conversion layers,” Shiotani discloses a display having “a plurality of pixel regions are set within the display area.” Shiotani ¶¶ (0018), (0019). Shiotani also states that its display device is “capable of

multicolor display.” *Id.* ¶¶ (0005), (0053). A POSITA would understand that such a display would typically have thousands, if not millions, of pixels of each color. Each of the yellow pixels has a “first region” including a “wavelength conversion layer.” Indeed, Shiotani’s display device would need to have a plurality of pixels, including a plurality of yellow pixels, in order to function as a multicolor display.

188. Therefore, it is my opinion that Shiotani’s display device satisfies all of the requirements of claim element 1[c].

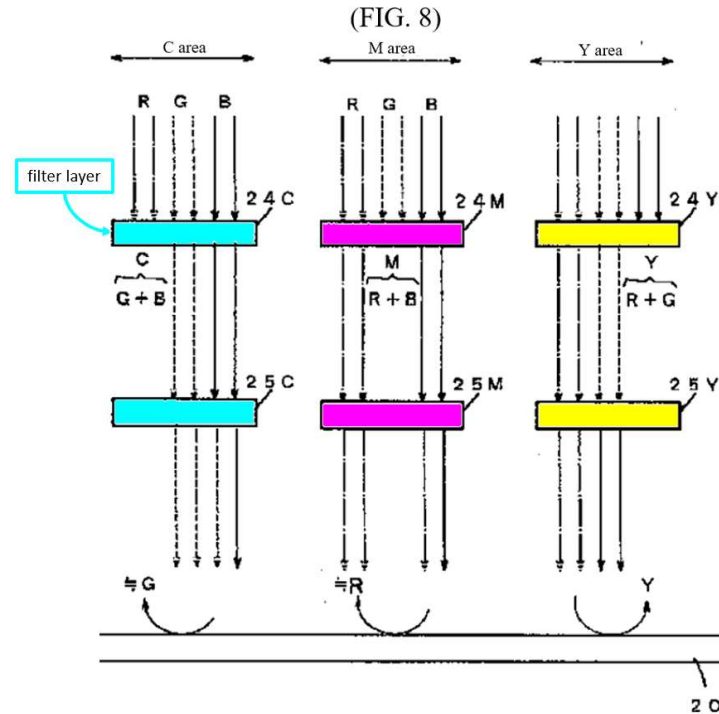
- e. **Element 1[d]: wherein the second regions each include a filter layer which is at least partially opaque to an electromagnetic radiation having a third wavelength spectrum which corresponds to at least one part of the second wavelength spectrum;**

189. In my opinion, Shiotani discloses this element. Shiotani’s “color filter layer 24C” is the required “filter layer.” As discussed above for claim element 1[b], Shiotani’s “structured layer” includes “color filter layers 24Y, 24M, and 24C.” Shiotani ¶ (0045). The “second region” is the portion of the structured layer corresponding to the cyan (light blue) pixel. Therefore, as shown in the annotated figure below, cyan color filter layer 24C is included in the second region.



Shiotani, Fig. 7 (annotated).

190. Shiotani’s color filter layer 24C “is at least partially opaque to an electromagnetic radiation having a third wavelength spectrum which corresponds to at least one part of the second wavelength spectrum.” As discussed above for claim element 1[c], the “second wavelength spectrum” is the yellow light emitted from color conversion layer 25Y, which is “a color mixture of the R and G component light.” Shiotani ¶ (0041). According to Shiotani, “color filter layer 24C . . . transmits only the C component” (*i.e.*, cyan light). *Id.* ¶ (0040). As shown in Figure 8, reproduced below, the filter transmits green and blue light but is (at least partially) opaque to red light.



Shiotani, Fig. 8 (annotated). The red light blocked by Shiotani’s color filter layer 24C is the required “third wavelength spectrum.”

191. The filter is at least partially opaque to red light (*i.e.*, electromagnetic radiation having the third wavelength spectrum), including the red light emitted by color conversion layer 25Y. The red light is, therefore, the required “at least one part of the second wavelength spectrum.”

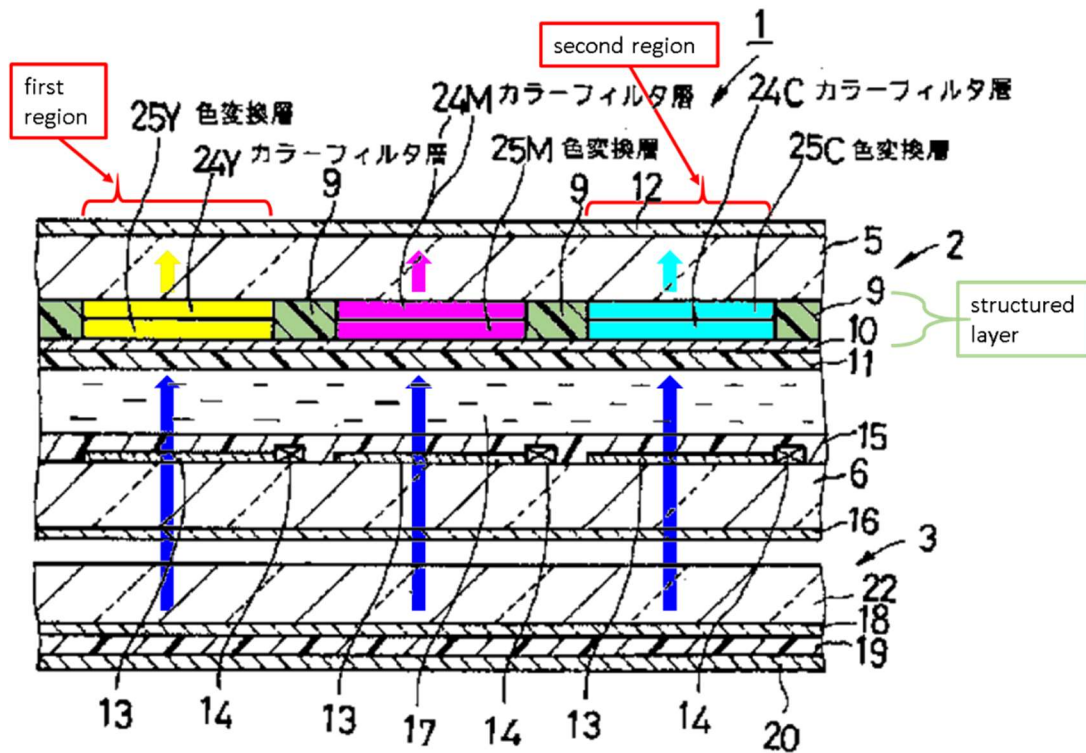
192. To the extent that this claim element requires more than one “second regions” and more than one “filter layers,” Shiotani discloses a display having “a plurality of pixel regions [that] are set within the display area.” Shiotani ¶¶ (0018), (0019). Shiotani also states that its display device is “capable of multicolor display.” *Id.* ¶¶ (0005), (0053). A POSITA would understand that such a display would

typically have thousands, if not millions, of pixels of each color. Each of the yellow pixels has a “first region” including a “wavelength conversion layer.” Indeed, Shiotani’s display device would need to have a plurality of pixels, including a plurality of yellow pixels, in order to function as a multicolor display.

193. Therefore, it is my opinion that Shiotani’s display device satisfies all of the requirements of claim element 1[d].

f. Element 1[e]: wherein the first and second regions of the structured layer are arranged laterally in a beam path of the optoelectronic device; and

194. In my opinion, Shiotani discloses this claim element. In the figure below, Shiotani’s Figure 7 has been annotated so as to highlight the “first and second regions of the structured layer.” Also, a “beam path of the optoelectronic device” has been highlighted with colored arrows.



Shiotani, Fig. 7 (annotated).

195. Shiotani’s “first and second regions of the structured layer” are arranged “in a beam path of the of the optoelectronic device.” According to Shiotani, “the light generated from E1 light-emitting element 3 is blue light,” Shiotani ¶ (0045), and serves as a “backlight of the liquid crystal cell 2,” *id.* ¶ (0028). “This blue light is converted to the long wavelength side by the color conversion layers 25Y, 25M, and 25C to obtain Y, M, and C light.” *Id.* ¶ (0045). The light then passes through the color filter layers and “the Y light, the M light, and the C light are emitted as complementary rays of the three primary colors with excellent color purity.” *Id.* In the annotated figure above, the colored arrows indicate the direction of the beam path of the electromagnetic radiation. As shown, the first and second regions are in

a beam path of the optoelectronic device. Figure 7 also illustrates that “the first and second regions of the structured layer are arranged laterally” in the beam path, as the first and second regions are arranged from left to right.

196. Therefore, it is my opinion that Shiotani’s display device satisfies all of the requirements of claim element 1[e].

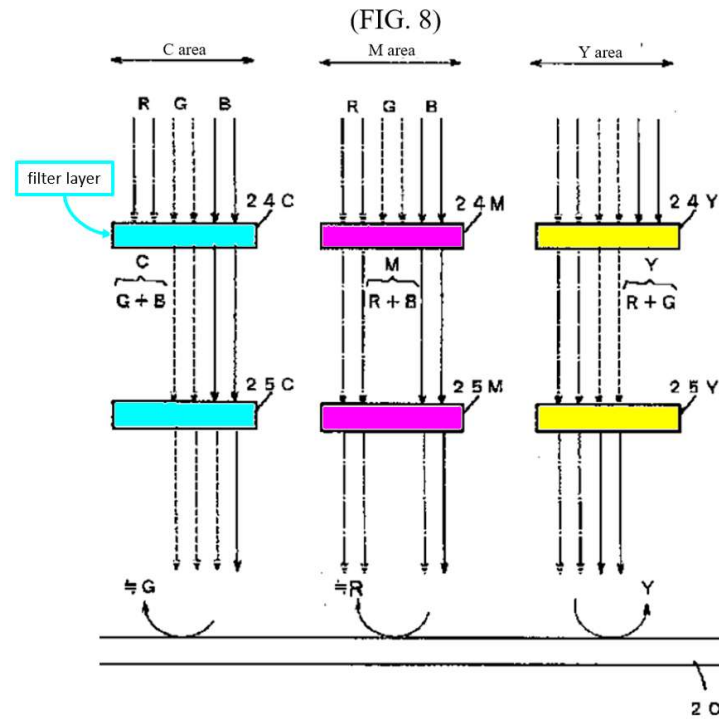
g. Element 1[f]: wherein the filter layer is transparent to the electromagnetic radiation having the first wavelength spectrum.

197. In my opinion, Shiotani discloses this claim element. As discussed above for claim element 1[c], Shiotani’s “color filter layer 24C” is the required “filter layer.” The “first wavelength spectrum” is the blue light emitted by organic EL light-emitting layer 19.

198. As I discussed above, “transparent” generally means that objects on the far side of the material are seen clearly through the material. The optical properties of materials are often characterized in terms of the optical transmittance of the material—*i.e.*, the percentage of light that passes through the material. A transparent material is one with high optical transmittance. This understanding is consistent with the use of the term “transparent” in the ’547 patent.

199. Shiotani discloses that color filter layer 24C is transparent to the blue light emitted by organic EL light-emitting layer 19. In discussing the color filter layers, Shiotani explains that “[t]he G component light and the B component light

pass through the C area,” teaching that the filter is transparent to blue light. Shiotani ¶ 0042. This is further confirmed by Figure 8, reproduced below, showing that blue light passes through the cyan color filter.



Shiotani, Fig. 8 (annotated).

200. This conclusion is reinforced by the fact that *Shiotani* also states that “a reflectance of up to 66% can be obtained, excluding losses in the liquid crystal” when the display device is used as a reflective display. Shiotani ¶ (0044). When used in reflective mode, the EL light-emitting element is turned off and the only light from the display is reflected ambient light. The ambient light passes through the color filter layers and color conversion layers before being “reflected by the 20 rear electrode of the EL light-emitting element 3.” *Id.* ¶ (0044). “The reflected light is

then emitted back along the same path once more,” meaning that the light must pass through both the color conversion layers and the color filter layers a *second* time. *Id.* In order to obtain a total reflectance of 66%, the color filters must be transparent. Even if the transmittance of the filters was 80%, a maximum of 64% of the light would be reflected by the display. When absorption and scattering by the color conversion layers and the rear electrode are also accounted for, the actual amount of light reflected by the display would be significantly lower. Therefore, a POSITA would understand that Shiotani’s color filter layer 24C (i.e. the “filter layer”) is highly transmissive (i.e., transparent) to the blue light emitted by organic EL light-emitting layer 19 (i.e., “electromagnetic radiation having the first wavelength spectrum”).

201. Although the evidence shows that Shiotani’s color filter layer 24C is “transparent to the electromagnetic radiation having the first wavelength spectrum,” even were that not the case, it would have been obvious for a POSITA to use such a transparent filter. As Shiotani states:

Also, up to 66% transmittance can be obtained, excluding losses in the liquid crystal mode. This can greatly reduce the power consumption of the EL light-emitting element 3 as a backlight.

Shiotani, ¶ [0045]. That is, Shiotani states clearly the necessity for high transmittance of all optical components in the optical train between the color conversion layer and the observer. As discussed above, the color conversion layer

itself will have poor transmittance to blue light itself because its function is to convert blue light into another color. However, once the desired color has been generated, then all optical components that follow must be as transparent to that color as possible to minimize the loss of light of the desired wavelengths. An incentive for doing so is, as mentioned by Shotani, to “reduce the power consumption of the EL light-emitting element 3 as a backlight.” Shiotani ¶ [0045].

202. As discussed above with respect to Igarashi, by the time of the '547 patent, filters transparent to blue light emitted by OLEDs were well known in the art, including both color glass filters and interference filters. A POSITA would have been motivated to modify Shiotani to use such filters in order to increase the brightness, improve the efficiency, and extend the lifetime of the display. A POSITA would have had a reasonable expectation of success in modifying Shiotani to use such a filter for the reasons discussed above for Ground I. In particular, replacing one common, commercially available filter with another would be a simple matter that would not require any significant changes to the manufacturing process, and would use conventional materials according to their accepted use.

2. Dependent Claim 2: The optoelectronic device as claimed in claim 1, wherein the first wavelength spectrum comprises a blue wavelength range and the second wavelength spectrum comprises a yellow wavelength range.

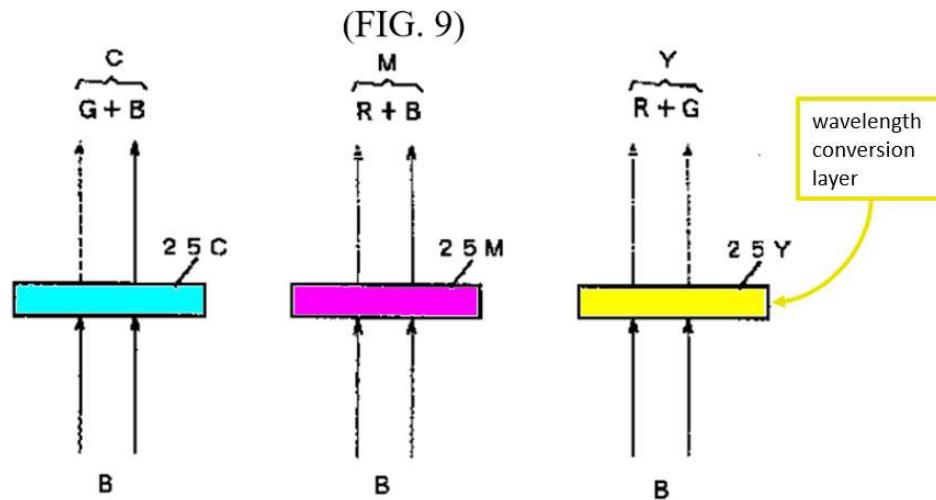
203. In my opinion, Shiotani discloses an optoelectronic device satisfying the limitations of claim 2.

204. As discussed above for claim element 1[a], the spectrum of light emitted by Shiotani's organic EL light-emitting layer 19 is the "first wavelength spectrum." Shiotani states that the light-emitting layer "generates blue light when a predetermined voltage is applied between the front and rear electrodes." Shiotani ¶ (0022). Therefore, "the first wavelength spectrum comprises a blue wavelength range" as required by this claim element.

205. As discussed above for claim element 1[c], the spectrum of light emitted by Shiotani's color conversion layer 25Y is the "second wavelength spectrum." Shiotani discloses that this layer "converts the B (blue) component light into *Y component [i.e., yellow] light*." Shiotani ¶ [0040] (emphasis added). According to Shiotani, "the color conversion layer 25Y is a mixture of a color conversion layer that converts the B component light into R component light and a color conversion layer that converts the B component light into G component light to obtain Y, a color mixture of the R and G component light." *Id.* ¶ [0041]. Consequently, a POSITA would understand Shiotani's color conversion layer 25Y as converting electromagnetic radiation into a second wavelength spectrum that comprises a yellow wavelength range, for at least two reasons.

206. First, a POSITA would understand that a "wavelength spectrum comprises a yellow wavelength range" if the light within that spectrum is perceived by humans to be yellow. Light having a wavelength between approximately 570 and

590 nm will be perceived as yellow. The proper combination of red and green light will also be perceived as yellow light. Shiotani explains that its color conversion layer 25Y is specifically designed to produce a spectrum of red and green light that is perceived as yellow. Shiotani ¶¶ [0040], [0042]. Shiotani's Figure 9 further depicts the light emitted by color conversion layer 25Y as yellow light.



Shiotani, Fig. 9 (annotated).

207. Second, if the patent claim were interpreted to require that the second wavelength spectrum comprises electromagnetic radiation with a wavelength between approximately 570 and 590 nm, the wavelength spectrum of Shiotani's color conversion layer 25Y comprises such a wavelength range. A POSITA would understand that Shiotani's "color conversion layer that converts the B component light into G component light," Shiotani ¶ [0041], would be formed from a phosphor. As discussed above for Ground I, phosphors generally have an emission spectrum shaped like a bell curve. Although the emission peak corresponds to green light, the

spectrum also extends into shorter wavelengths and longer wavelengths and includes light between 570 and 590 nm. *See, e.g.,* Igarashi ¶ [0006], Fig. 10.

208. In addition, if the claim were interpreted to require that the second wavelength spectrum comprise electromagnetic radiation with a wavelength between approximately 570 and 590 nm, it would have been obvious to a POSITA to modify Shiotani's color conversion layer 25Y to use a yellow phosphor having an emission spectrum that peaks in the wavelength range between approximately 570 and 590 nm. Phosphors that absorb blue light (such as that produced by Shiotani's EL light-emitting element 3) and emit light between approximately 570 and 590 nm were well-known in the prior art. *See, e.g.,* Ex. 1026. As discussed earlier, yellow-orange phosphors have been used in LED lamps for almost two decades. In addition, Boerner identifies a variety of different phosphors that were "suitable color converting materials" for use in OLED displays, including four phosphors that produce yellow light. Ex. 1013, ¶ [0032], Table 1. A POSITA would have been motivated to use a yellow phosphor in order to reduce costs and simplify the manufacturing processes. Creating Shiotani's color conversion layer 25Y from multiple phosphors would require additional processing steps which could be avoided by using a single yellow phosphor. A POSITA would have a reasonable expectation of success in modifying Shiotani to use a yellow phosphor, as the

replacement of phosphors is routine in industry whenever phosphors having higher conversion efficiencies or preferable emission spectra become available.

209. Therefore, it is my opinion that Shiotani's display device satisfies the additional limitations of claim 2. In the alternative, it would have been obvious to modify Shiotani's color conversion layer 25Y to use a phosphor that emits yellow light in the 570–590 nm wavelength region.

3. Dependent Claim 3: The optoelectronic device as claimed in claim 1, wherein the optoelectronic device has a non-yellow color impression.

210. In my opinion, Shiotani discloses an optoelectronic device satisfying the limitations of claim 3. As I discussed above for Ground I, a POSITA would understand that the claimed “non-yellow color impression” refers to the color impression when the device is turned off. However, a POSITA would understand that Shiotani's display had a non-yellow color impression both when in the “switched-off” state and when in the “switched-on state.” Therefore, it is my opinion that, regardless of how the claim is interpreted, Shiotani meets this limitation.

211. Shiotani's display comprises cyan, magenta, and yellow pixels separated by a black mask layer. *See, e.g.*, Shiotani ¶¶ (0008), (0039)–(0045), Fig. 7. When in the switched-off state, the light reflecting off the black mask and transmitted by the color filter layers in the pixels (*i.e.*, room light that reflects from the color filter front surfaces or passes through the filters, is reflected by the color

conversion layer, and returns to the room through the color filter(s)) will form a “superimposition of electromagnetic radiation.” ’547 patent, 3:40–45. As shown in Figure 7 of Shiotani, the black matrix occupies a significant portion of the area on the display. If black matrix material is also placed between the rows of pixels (i.e. perpendicular to the plane of Figure 7), the majority surface of the display would be covered by the black mask. A POSITA would understand that the inclusion of the black matrix results in a screen that would appear black or dark grey. Regardless of the amount of black mask, however, Igarashi’s display “has a non-yellow color impression.” Even in the absence of any black mask, the superimposition of the light reflecting off of the cyan, magenta, and yellow pixels would produce a whitish-gray color impression.

212. I note that the fact that some of the individual pixels produce or reflect yellow light does not imply or suggest that the display would have an overall yellow color impression. The ’547 patent recognizes that some of the light emitted or reflected by the claimed display, particularly electromagnetic radiation 16, will be from a “yellow wavelength range.” ’547 patent, 13:43. However, the patent notes that because the yellow light is combined with blue light, the net result is a “whitish color impression”:

Since the converted electromagnetic radiation 16 from a yellow wavelength range and the converted electromagnetic radiation 19 and/or 19A from a blue wavelength range are emitted jointly, a whitish

color impression of the optoelectronic device once again arises as a result of these radiation portions, both in the switched-off state and in the switched-on state.

Id., 13:42–48. The same is true of Shiotani’s display. A POSITA would understand that the combined light reflected from the cyan, magenta, and yellow pixels would produce a whitish-gray color impression.

213. At a minimum, it would have been obvious to a POSITA to implement Shiotani’s display to have a non-yellow color impression when in the “switched-off state.” Such flat panel displays invariably appear black (or dark grey) when the pixels are off in order to maximize the contrast of the display. It would have been obvious to implement Shiotani’s display in the standard way such that it appears black (or dark grey) when it is off. Indeed, the function of the black matrix is to create a black screen so as to increase contrast. Such a display produces black image content by turning off the associated pixels. A display that had a yellow color impression when turned off would be unable to display black. Such a display would have a low-contrast appearance and would produce a yellow tint to any image shown on the display. A black screen also has the beneficial effect of reducing the amount of energy required to drive the display and increasing the visibility of the display in ambient lighting.

214. My opinions are consistent with those of the Examiner during prosecution of the ’547 patent. The examiner initially rejected (what was then) claim

4 as being obvious over the flat-panel OLED display of Kobori. According to the examiner:

Regarding claim 4, Kobori is silent as to the color of the device when it is turned off, but *one of ordinary skill in the art would have reasonably contemplated having the display appear black to an observer as is expected for flat panel displays*. Therefore, it would have been obvious to one of ordinary skill in the art to have the display appear black to an observer in order to meet flat panel display appearance expectations.

Ex. 1002 (File History) at 513 (emphasis added). I agree with the Examiner. The Examiner's analysis (which the applicants did not dispute) is equally applicable to the Shiotani's display.

215. Even if the claim were interpreted to require that “the optoelectronic device has a non-yellow color impression” when in the switched-on state, it is my opinion that Shiotani discloses a display that satisfies this requirement. A POSITA would understand that, when in operation, such a display is intended to reproduce a wide range of colors (*i.e.*, visible light). The large number of colors of which the display is capable of generating is known as the “palette” or “gamut”. Shiotani states that its display is “capable of multicolor display.” Shiotani ¶ (0053). In particular, a “white display is possible through mixing of the color components Y, M, and C.” *Id.* ¶ (0045). At a minimum, this limitation would have been obvious. As explained by Murdoch, for example:

In a common OLED color display device a pixel includes red, green, and blue colored OLEDs. These light emitting color primaries define a color gamut, and by additively combining the illumination from each of these three OLEDs, i.e. with the integrative capabilities of the human visual system, a wide variety of colors can be achieved.

Murdoch (Ex. 1016), 1:17–23.

216. Therefore, it would have been at least obvious to use Igarashi's display to reproduce a range of colors, which in general-purpose usage would include non-yellow colors. As a result, it would have been obvious for Igarashi's display (optoelectronic device) to have a non-yellow color impression.

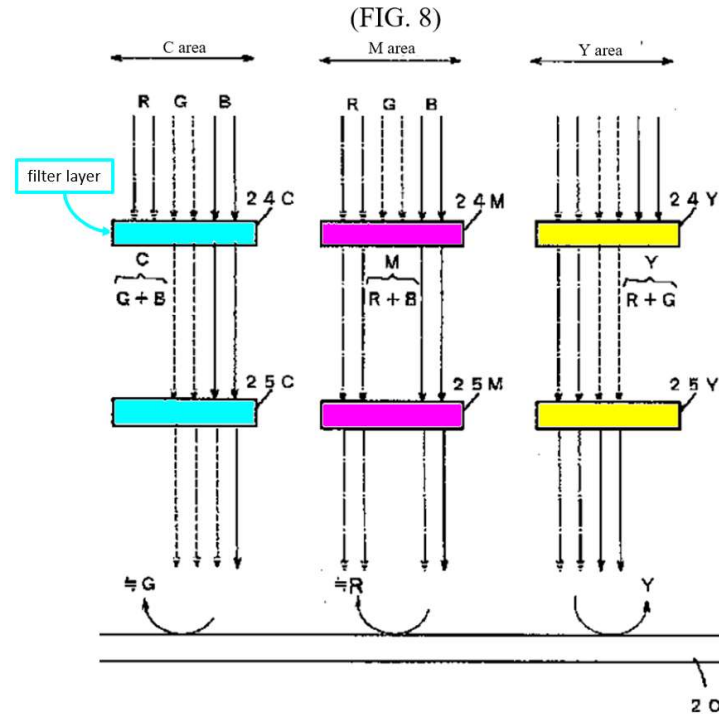
4. Dependent Claim 4: The optoelectronic device as claimed in claim 1, wherein the filter layer is configured to convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range.

217. In my opinion, claim 4 would have been obvious based on Shiotani. As discussed above for claim element 1[d], Shiotani's color filter layer 24C is the required "filter layer" and is "at least partially opaque to an electromagnetic radiation having a third wavelength spectrum."

218. The '547 patent states that one way the filter layer may "convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range" is to absorb the electromagnetic radiation, which will convert the radiation into heat (infrared

radiation). '547 patent, 3:46–65. According to the patent, a filter layer that “absorb[s] the radiation having a third wavelength spectrum” means that “the filter layer is designed to convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range” or, “[t]o put it another way, the filter layer is designed to convert electromagnetic radiation having the third wavelength spectrum into heat or thermal radiation.” *Id.*

219. A POSITA would have understood that Shiotani’s color filter layer 24C is “configured to convert the electromagnetic radiation having the third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range” in precisely this manner. Shiotani discloses that color filter layer 24C “transmits only the C component” (i.e. cyan light). As shown in Figure 8, reproduced below, the filter transmits green and blue light but is (at least partially) opaque to red light.



Shiotani, Fig. 8 (annotated).

220. Shiotani further discloses that its color filters absorb the light components that are not transmitted. According to Shiotani,

The color filter layer 7R transmits light in the red wavelength region and ***absorbs light in other wavelength regions*** when light containing light in the red wavelength region is incident, the color filter layer 7G transmits light in the green wavelength region and ***absorbs light in other wavelength regions*** when light containing light in the green wavelength region is incident, and the color filter layer 7B transmits light in the blue wavelength region and ***absorbs light in other wavelength regions*** when light containing light in the blue wavelength region is incident.

Shiotani at ¶ (0018). (emphasis added); *see also id.* at ¶ [0028] (similar), ¶ [0004] (“Furthermore, when color filters are combined with these liquid crystal devices, white light from the white light source is *selectively absorbed* by wavelength components other than R, G, and B when passing through the R, G, and B color filters.” (emphasis added)).

221. A POSITA would recognize that Shiotani’s cyan color filter layer 24C (*i.e.*, the filter layer) would likewise absorb the component that it does not transmit—*i.e.*, red light. At a minimum, it would have been obvious to use a cyan color filter that operates the same way as Shiotani’s red, green, and blue color filters, which absorb the light components that are not transmitted through the filters. Thus, it would have been obvious for Shiotani’s filter layer to be configured to absorb red light—*i.e.*, the electromagnetic radiation having a third wavelength spectrum.

222. A POSITA would also have understood that the absorption of the electromagnetic radiation converts the radiation “into an electromagnetic radiation from a non-visible wavelength range” in the form of heat or thermal radiation. For example, as Hecht explains,

if the photon’s energy matches that of one of the excited states, the atom will absorb the light, making a quantum jump to that higher energy level. In the dense atomic landscape of ordinary gases (at pressures of about 10^2 Pa and up), solids, and liquids, it’s very likely that this excitation energy will rapidly be transferred, via collisions, to random

atomic motion, thermal energy, before a photon can be emitted. This commonplace process (the taking up of a photon and its conversion into thermal energy) was at one time widely known as “absorption,” but nowadays that word is more often used to refer just to the “taking up” aspect, regardless of what then happens to the energy. Consequently, it’s now better referred to as dissipative absorption. All material media partake in dissipative absorption to some extent, at one frequency or another.

Ex. 1014 at 67.

223. Therefore, in my opinion it would have been obvious, based on Shiotani, to use a filter layer that is configured to convert the radiation having a third wavelength spectrum into an electromagnetic radiation from a non-visible wavelength range (e.g. infrared radiation) for Shiotani’s color filter layer 24C.

5. Dependent Claim 5: The optoelectronic device as claimed in claim 4, wherein the filter layer is further configured to absorb the electromagnetic radiation having the third wavelength spectrum.

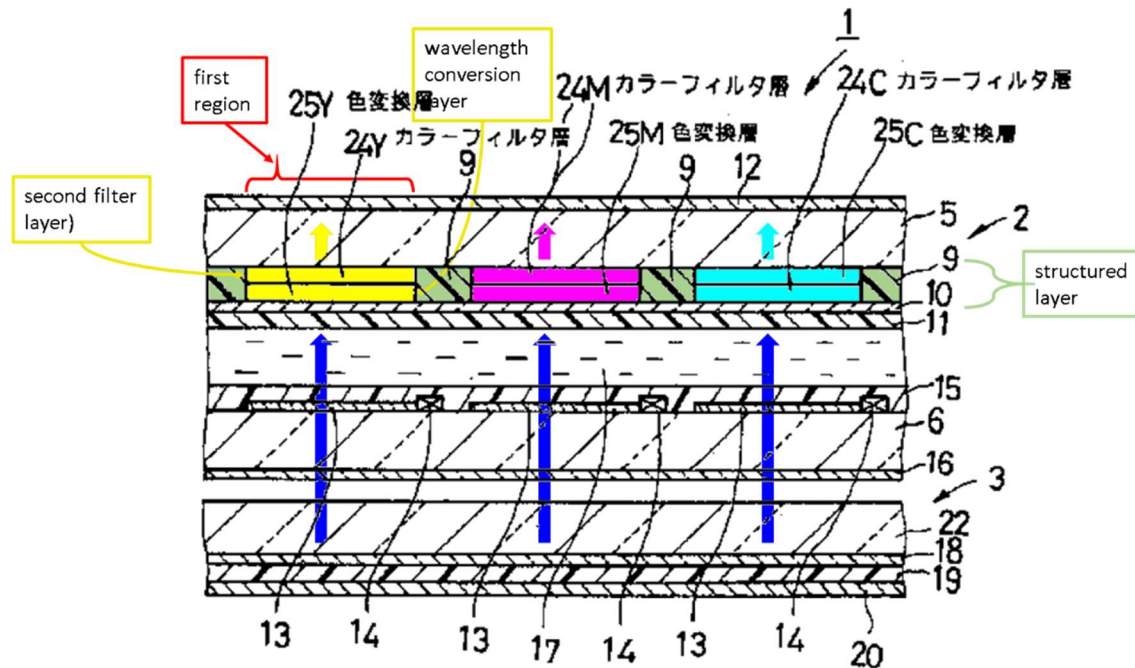
224. In my opinion, claim 5 would have been obvious based on Shiotani. As discussed above for claim 4, Shiotani’s color filter 24C is the required filter layer. Shiotani discloses that its red, green, and blue filters absorb the electromagnetic radiation that is not transmitted by the filter. Shiotani at ¶ (0018). A POSITA would understand that Shiotani’s cyan color filter layer 24C would likewise absorb the red light component that it does not transmit (i.e. “the electromagnetic radiation having

the third wavelength spectrum”). At a minimum, it would have been obvious to use a cyan color filter that operates the same way as Shiotani’s red, green, and blue color filters. Thus, it would have been obvious for Shiotani’s filter layer to be “configured to absorb the electromagnetic radiation having the third wavelength spectrum.”

6. Dependent Claim 8

- a. The optoelectronic device as claimed in claim 1, wherein the first regions each have a second filter layer disposed downstream of the wavelength conversion layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence and**

225. In my opinion, Shiotani discloses this element. Shiotani’s color filter layer 24Y is the required “second filter layer.” *See* Shiotani ¶¶ (0042), (0045). As discussed above for claim element 1[d], Shiotani’s “structured layer” includes “color filter layers 24Y, 24M, and 24C.” Shiotani ¶ (0045). The “first region” is the portion of the structured layer corresponding to the yellow pixel. Therefore, as shown in the annotated figure below, color filter layer 24Y is included in the first region.



Shiotani, Fig. 7 (annotated).

226. The figure further shows that color filter layer 24Y is “disposed downstream of the wavelength conversion layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence,” as required by the claim element.

227. Shiotani states that the light from EL light-emitting element 3 “is converted to the long wavelength side by the color conversion layers 25Y, 25M, and 25C to obtain Y, M, and C light.” Shiotani ¶ (0045). From there, the light passes through “color filter layers 24Y, 24M, and 24Y” and is “emitted as complementary rays of the three primary colors with excellent color purity.” *Id.* Because the light passes first through the color conversion layers and then the color filter layers, color filter layer 24Y is “disposed downstream of the wavelength conversion layer in the

beam path of the electromagnetic radiation emitted by the organic layer sequence,” as required by the claim.

228. To the extent that this claim element requires more than one “first regions” and more than one “second filter layer[s],” Shiotani discloses a display having “a plurality of pixel regions are set within the display area.” Shiotani ¶¶ (0018), (0019). Shiotani also states that its display device is “capable of multicolor display.” *Id.* ¶¶ (0005), (0053). A POSITA would understand that such a display would typically have thousands, if not millions, of pixels of each color. Each of the yellow pixels has a “first region” including a “wavelength conversion layer.” Indeed, Shiotani’s display device would need to have a plurality of pixels, including a plurality of yellow pixels, in order to function as a multicolor display.

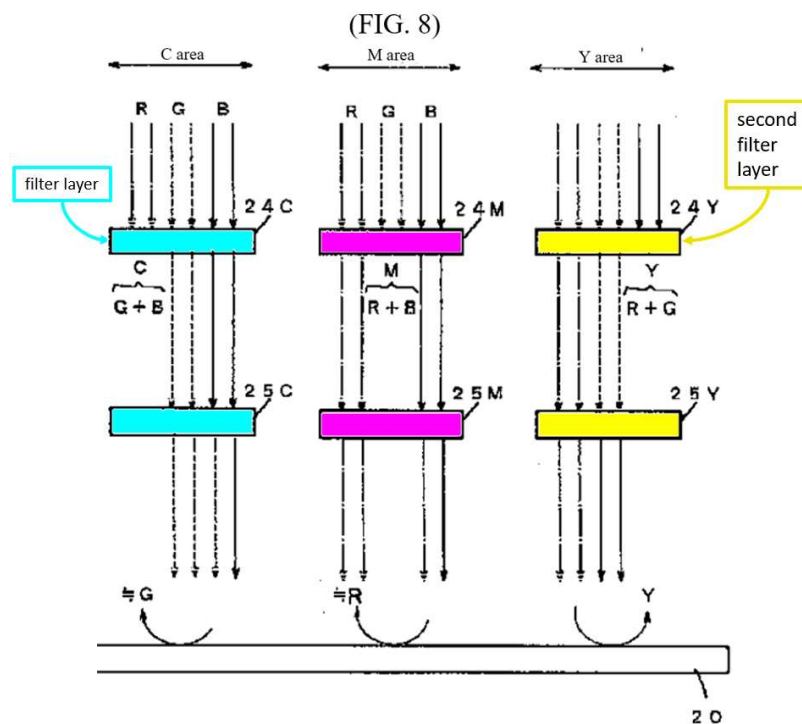
229. Therefore, it is my opinion that Shiotani’s display device satisfies all of the requirements of claim element 8[a].

b. which is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum which corresponds to at least one part of the first wavelength spectrum.

230. In my opinion, Shiotani discloses this element. As discussed above for the previous limitation, Shiotani’s color filter layer 24Y is the required “second filter layer.”

231. Shiotani’s color filter layer 24Y “is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum which corresponds

to at least one part of the first wavelength spectrum.” As discussed above with respect to claim element 1[a], the spectrum of the blue light emitted by organic EL light-emitting layer 19 is the “first wavelength spectrum.” According to Shiotani, “color filter layer 24Y . . . transmits only the Y component,” *i.e.*, the yellow light. Shiotani ¶ (0040). Shiotani further states that “as shown in [Figure 8], R component light (single-dotted lines) and G component light (dashed lines) pass through” color filter layer 24Y.” *Id.* Shiotani ¶ (0042). However, the blue light is absorbed by the filter.



Shiotani, Fig. 8 (annotated).

232. The blue light blocked by Shiotani’s color filter layer 24Y is the required “fourth wavelength spectrum.” As discussed above for claim element 1[a],

the spectrum of the blue light emitted by organic EL light-emitting layer 19 is the “first wavelength spectrum.” Shiotani’s color filter layer 24Y is at least partially opaque to the blue light emitted by organic EL light-emitting layer 19 and, therefore, is at least partially opaque to electromagnetic radiation having a fourth wavelength spectrum (blue light) which corresponds to at least one part of the first wavelength spectrum.

233. In summary, it is my opinion that Shiotani’s display device satisfies all of the requirements of claim element 8[b].

7. Dependent Claim 9: The optoelectronic device as claimed in claim 8, wherein the second filter layer is configured at least partially to absorb the electromagnetic radiation having the fourth wavelength spectrum.

234. In my opinion, claim 9 would have been obvious based on Shiotani. As discussed above with respect to claim 8, Shiotani’s color filter layer 24Y is the required “second filter layer” and the filter “is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum.” As discussed above with respect to claim 4, Shiotani discloses that its red, green, and blue filters absorb the electromagnetic radiation not transmitted by the filter. Shiotani ¶ (0018). A POSITA would understand that Shiotani’s yellow color filter layer 24Y would likewise absorb the blue light component that it does not transmit (*i.e.*, “the electromagnetic radiation having the fourth wavelength spectrum”). At a minimum, it would have been obvious to use a yellow color filter that operates the same way

as Shiotani's red, green, and blue color filters. Thus, it would have been obvious for Shiotani's filter layer to be "configured at least partially to absorb the electromagnetic radiation having the fourth wavelength spectrum."

8. Dependent Claim 10: The optoelectronic device as claimed in claim 8, wherein the second filter layer is configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum.

235. In my opinion, claim 10 would have been obvious based on Shiotani. As discussed above with respect to claim 8, Shiotani's color filter layer 24Y is the required "second filter layer" and the filter "is at least partially opaque to an electromagnetic radiation having a fourth wavelength spectrum."

236. It would have been obvious to a POSITA for color filter layer 24Y to be "configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum." A POSITA would have understood that when a beam of radiation impinges on an interface between two different transparent media, some of the light will be reflected. For example, Hecht explains that, "at an interface between two different transparent media (such as air and glass) . . . some light is always scattered backward, and we call this phenomenon reflection." Ex. 1014 at 95.

237. Thus, a POSITA would have understood that when radiation passes (propagates) from Shiotani's color conversion layer 25Y to color filter layer 25Y, a portion of the radiation will be reflected backwards rather than passing into the color

filter layer. *See* Mourad at 15 (“At the interface of an optical filter, part of the incident radiant power is lost due to *surface reflection* resulting from the discontinuity of the *refractive index*.”). This reflected radiation will comprise blue light from Shiotani’s organic electroluminescent element, given that the color conversion layer 25Y will not convert fully 100% of the blue light to yellow light. Thus, a POSITA would understand that Shiotani’s color filter layer 25Y, *i.e.*, “second filter layer,” is “configured at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum.” At a minimum, this would have been obvious to a POSITA, as such reflection is characteristic of color filters and most optical components.

238. My opinions are consistent with those of the Examiner during prosecution of the ’547 patent. The examiner initially rejected (what was then) claim 11 as being obvious over the flat-panel OLED display of Kobori. According to the examiner:

Regarding claim 11, Kobori further discloses wherein the second filter layer is designed at least partially to reflect the electromagnetic radiation having the fourth wavelength spectrum (22G; the Examiner notes that ***the interface between layers 23 and 22G will characteristically reflect some of the electromagnetic radiation emitted by the organic layer sequence***).

Ex. 1002 (File History) at 509 (emphasis added). I agree with the Examiner. The Examiner's analysis (which the applicants did not dispute) is equally applicable to Shiotani. In my opinion, some radiation from the organic layer sequence similarly is reflected at the interface between the "wavelength conversion layer" (Shiotani's color conversion layer 25Y) and "second filter layer" (Shiotani's color filter layer 24Y).

239. Therefore, it is my opinion that it would have been obvious to a POSITA that Shiotani's display device satisfies this claim element.

9. Dependent Claim 13: The optoelectronic device as claimed in claim 1, wherein the electromagnetic radiation which is emitted by the optoelectronic device corresponds to a superimposition of the electromagnetic radiation having the first wavelength spectrum and the electromagnetic radiation having the second wavelength spectrum.

240. In my opinion, Shiotani discloses an optoelectronic device satisfying the limitations of claim 13. Shiotani discloses a display comprising cyan, magenta, and yellow pixels. *See* Shiotani ¶ (0039), Fig. 7. Shiotani states that the display is capable of reproducing a wide range of different colors by combining light from the different pixels:

[T]he colors of each pixel can be mixed and displayed by modulating the electric field of the liquid crystal cell 2. In particular, a wide chromaticity range can be achieved by controlling the gradation of each color.

Shiotani ¶ (0031); Moreover, Shiotani states that a “white display is possible through mixing of the color components Y, M, and C.” *Id.* ¶ (0045).

241. A POSITA would understand that, to display white light, the light emitted by Shiotani’s display would comprise a superimposition of the electromagnetic radiation having the first wavelength spectrum and the electromagnetic radiation having the second wavelength spectrum. White light is produced by activating the yellow, magenta, and cyan pixels simultaneously.

242. Shiotani discloses that the cyan pixels emit electromagnetic radiation having the first wavelength spectrum. Cyan “is a mixture of the converted light G and the unconverted light (transmitted light) B.” Shiotani ¶ (0041). As discussed above with respect to claim element 1[a], the unconverted blue light is the electromagnetic radiation emitted by the organic layer sequence having the first wavelength spectrum.

243. As discussed above with respect to claim element 1[c], Shiotani discloses that the yellow pixels emit radiation having the second wavelength spectrum.

244. Therefore, white light or, indeed, any color formed by simultaneously activating the cyan and yellow pixels would constitute a superimposition of the electromagnetic radiation having the first wavelength spectrum and the electromagnetic radiation having the second wavelength spectrum.

245. At a minimum, it would have been obvious to use Shiotani's display to produce white light corresponding to a superimposition of the electromagnetic radiation having the first wavelength spectrum (blue light from the cyan pixels) and the electromagnetic radiation having the second wavelength spectrum (yellow light from the yellow pixels). *See* Murdoch, 1:17–23 (“These light emitting color primaries define a color gamut, and by additively combining the illumination from each of these three OLEDs, i.e. with the integrative capabilities of the human visual system, a wide variety of colors can be achieved.”).

E. Ground V: Claims 11 and 12 Are Obvious Based on Shiotani and Pilcher

1. Dependent Claim 11: The optoelectronic device as claimed in claim 1, further comprising an encapsulation one of disposed upstream and disposed downstream of the structured layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence.

246. In my opinion, this claim would have been obvious to a POSITA, based on Shiotani in light of Pilcher. It was well known in the art that the organic materials in OLED devices react to oxygen and atmospheric moisture and that, as a result, such devices must be sealed or “encapsulated” to prevent the organic materials from degrading. Klausmann, for example, states in the “Background of the Invention” that

Various types of devices may require hermetic sealing to protect the active components from atmospheric elements, such as moisture and/or gases. For example, devices which include organic active elements such as OLEDs require protection from moisture or gases.

Ex. 1023, 1:27–31; *see also id.*, 1:51–53 (“Active components, such as the cathode and organic layers in organic devices are adversely impacted by potentially deleterious components such as water, oxygen and other gaseous components.”). As another example, Cok states that “[m]ost OLED devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere.” Ex. 1024, 8:63–67.

247. A POSITA would have understood that it was necessary to encapsulate Shiotani’s EL light-emitting element 3. Without encapsulation, the organic materials in the light-emitting element begin to degrade within hours, which would render Shiotani’s devices unsuitable for practical application as displays. Shiotani itself recognizes the need to protect OLEDs from exposure, disclosing that “rear electrode 20 is preferably covered with a protective film to prevent oxidation.” Shiotani at ¶ [0023].

248. By the priority date of the ’547 patent, thin-film encapsulation was well-established and would have been known to a POSITA as a desirable form of encapsulation for OLEDs. Pilcher, for example, describes conventional, well-known methods of thin-film encapsulation. As Pilcher describes, in thin-film encapsulation, “[a] glass (or other suitable material) substrate 102 provides the support structure for OLED structure.” Pilcher, 1:24–25. Multiple thin-film layers “comprising

alternating and repeating layers of an organic (usually acrylate or the like) and a barrier layer” are deposited over the OLED structure. *Id.*, 1:21–22.

249. Additionally, it was known that thin-film encapsulation provided a number of advantages over alternative encapsulation methods, including “cost reduction and improved reliability.” Pilcher, 1:48–50. As Pilcher explains, “[u]sing direct thin-film encapsulation, the package may also be thinner and/or lighter and/or mechanically more flexible. Several structures and steps of the prior art may be excluded with this process. For example, there is no need for a separate glass plate, no need for an epoxy seal, no need for a getter (which is typical in the prior art).” *Id.* at 1:50–55.

250. A POSITA would have been motivated to encapsulate Shiotani’s EL light-emitting element 3 in order to prevent the light emitting element 3 from degrading and to extend the life of the display. A POSITA would have had a reasonable expectation of success in encapsulating the light emitting element. Encapsulation was extensively used in nearly all OLED devices and the techniques for encapsulation were well-known to a POSITA.

251. In addition, Shiotani already includes some of the elements required for encapsulation. For example, Shiotani discloses that the OLEDs are formed on “an EL substrate 22 made of transparent glass,” Shiotani at ¶ [0021], which is one of the requirements of Pilcher’s thin-film encapsulation.

252. It would have been obvious for the encapsulation to be “disposed upstream...of the structured layer in the beam path of the electromagnetic radiation emitted by the organic layer sequence.” Although Shiotani’s Figure 7 shows one embodiment in which substrate 22 is in the beam path of the radiation emitted by organic EL light-emitting layer 19, Shiotani explicitly states the substrate “may of course be provided on the rear side of the rear electrode 20.” Shiotani ¶[0052]. In this configuration, the encapsulation is deposited over front electrode 18 and, therefore, disposed both “in the beam path of the electromagnetic radiation emitted” and “upstream” of the structured layer.

253. Shiotani’s display device could be easily adapted to use Pilcher’s thin-film encapsulation without making any significant changes to the design, structure, or operation of the display. Shiotani also already discloses “a protective film to prevent oxidation” of the materials used in the OLED. Shiotani at ¶ [0023]. It would have been straightforward for a POSITA to use thin-film encapsulation by adding the organic and barrier layers disclosed in Pilcher in order to better protect the reactive materials in Shiotani’s EL light-emitting element. As discussed previously, another advantage of adopting thin film encapsulation is that much of the structure of Shiotani’s OLED display is manufactured (and was manufactured before the ’547 patent) by thin-film deposition techniques. Employing thin-film deposition

processes and tools to produce the encapsulation would be very attractive to a POSITA.

2. Dependent Claim 12: The optoelectronic device as claimed in claim 11, wherein the encapsulation comprises a thin-film encapsulation.

254. In my opinion, this claim would have been obvious to a POSITA based on Shiotani in light of Pilcher. As discussed above for Claim 11, a POSITA would have understood that it would have been necessary to encapsulate the OLEDs in Shiotani's display device in order "to protect the OLED device from the damaging environmental effects—primarily from oxygen and moisture." Pilcher, 1:8–10. Moreover, thin-film encapsulation would have been obvious based on its numerous advantages, including "cost reduction and improved reliability." *Id.* 1:48–49. A POSITA would have been motivated to combine Shiotani and Pilcher and would have had a reasonable expectation of success in doing so for the reasons explained above.

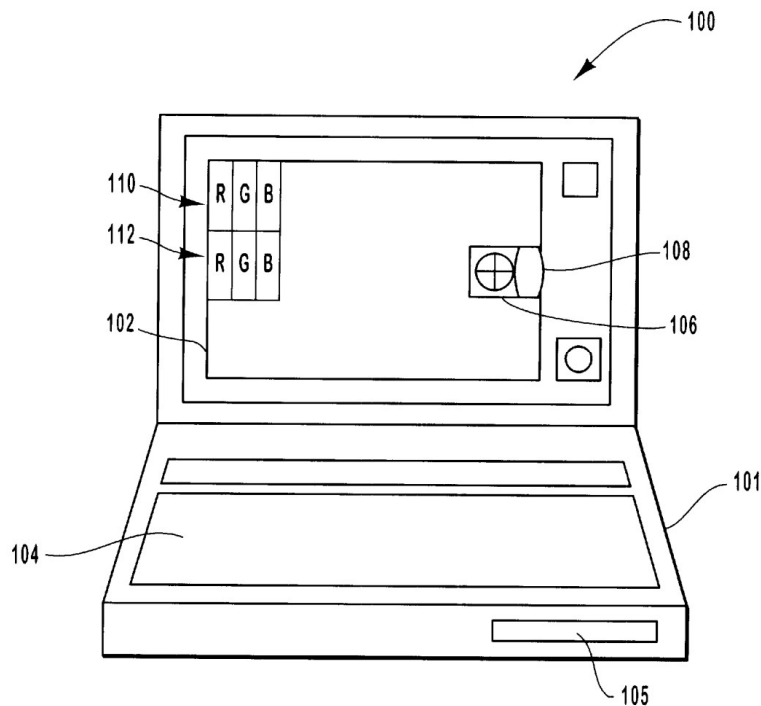
F. Ground VI: Claim 14 Is Obvious Based on Shiotani and Dresevic

1. Dependent Claim 14: The optoelectronic device as claimed in claim 1, wherein the structured layer has at least one of striped, crossed-striped, circular, triangular, and rectangular regions.

255. In my opinion, this claim would have been obvious to a POSITA based on Shiotani in view of Dresevic. In Shiotani's display device, the shape of the "first regions" and the "second regions" correspond to the shapes of the yellow and cyan

pixels, respectively. Although Shiotani does not explicitly state that the pixels are rectangular, it would have been obvious to a POSITA that the pixels in Shiotani's display would be rectangular and that the structured layer would, therefore, have striped or rectangular regions.

256. Shiotani discloses that the pixels are arranged in a "matrix." Shiotani, ¶[0019]. A POSITA would understand that a matrix display comprises a plurality of pixels arranged in rows and columns. *See, e.g.*, Kowalsky (Ex. 1025) at 20–22. A POSITA would further understand that it was common for the individual pixels in such a display to be rectangular. Figure 1 of Dresevic, reproduced below, provides an example of such an arrangement.



Dresevic, Fig. 1. As Dresevic explains, display devices “commonly used” this type of matrix array of rectangular pixels:

In displays commonly used for computer applications, each pixel on a color LCD display usually comprises three non-square elements, i.e., red, green and blue (RGB) pixel sub-components. . . . LCD displays of this type comprise a series of RGB pixel sub-components which are *commonly arranged to form stripes along the display*. The RGB stripes normally run the entire length of the display in one direction. The resulting RGB stripes are sometimes referred to as “RGB striping”.

Id., 2:3–13 (emphasis added).

257. This same pixel layout was also common in OLED display devices. For example, Figure 6a of Murdoch, reproduced below, shows “a typical prior art RGB stripe arrangement of OLEDs” in a display. Murdoch (Ex. 1016), 4:27–28.

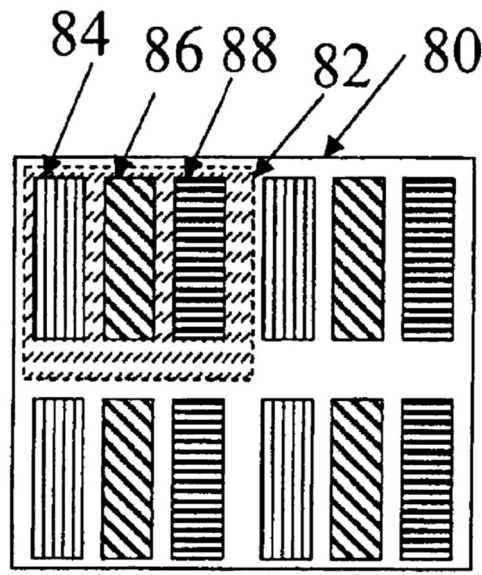
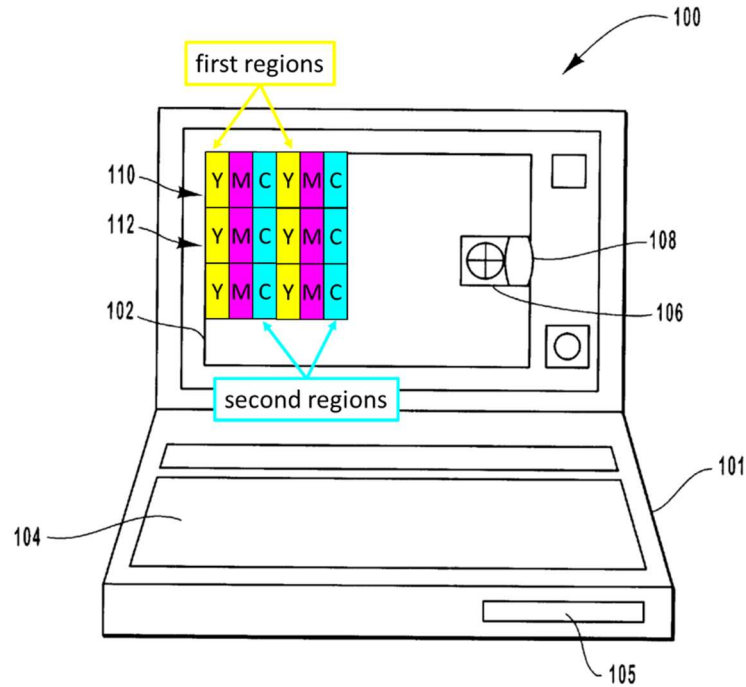


Fig. 6a
(Prior Art)

Id., Fig. 6a. As in Dresevic, each of the pixels has a rectangular shape.

258. Shiotani's display devices uses, yellow, magenta, and cyan pixels instead of red, green, and blue pixels. But the display would naturally take the form of a YMC striped arrangement, as shown in the figure below, which is based on Figure 1 of Dresevic.



259. A POSITA would have been motivated to arrange the pixels in Shiotani's display as YMC stripes as shown in Dresevic and would have had a reasonable expectation of success in doing so. A POSITA implementing Shiotani's display would be required to choose a shape and an arrangement for the pixels in the display. The use of rectangular stripes was a well-known practice in the design of OLED displays, used in many prior art displays. Not only was this arrangement common, it would also have been the simplest to implement. For example, an active matrix display requires data lines to provide signals to each of the pixels. Arranging the pixels in an orderly striped arrangement simplifies the routing of the data lines across the display.

260. My opinions are consistent with those of the Examiner during prosecution of the '547 patent. The examiner initially rejected (what was then) claim 15 as being obvious over Krummacher. According to the examiner:

Regarding claim 15, Krummacher teaches wherein the structured layer may have any desired shape, but is silent as to a specific shape. However, one of ordinary skill in the art would have reasonably contemplated having the shapes be rectangular in order to provide a pixelated appearance. Therefore, it would have been obvious to one of ordinary skill in the art to have the structured layer have the shapes be rectangular in order to provide a pixelated appearance.

Ex. 1002 (File History) at 512. I agree with the Examiner. The Examiner's analysis (which the applicants did not dispute) is equally applicable to Shiotani's display device.

261. Therefore, it is my opinion that it would have been obvious for the "structured layer" in Shiotani's display device to have "at least one of striped, crossed-striped, circular, triangular, and rectangular regions."

X. SECONDARY CONSIDERATIONS OF NON-OBVIOUSNESS

262. I understand that no secondary considerations evidence has been identified for the '547 patent at this time. I am not aware of any such evidence that would apply to the challenged claims.

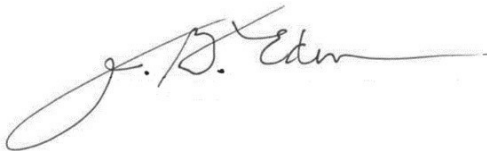
XI. CONCLUSION

263. For the reasons discussed above, in my opinion claims 1–5 and 8–14 of the '547 patent would have been obvious to a POSITA.

* * *

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.

Executed on: May 7, 2024

A handwritten signature in cursive script, appearing to read "J. B. Eden", written in dark ink.

J. Gary Eden, Ph.D.

APPENDIX A

CURRICULUM VITAE

J. GARY EDEN

APRIL 2024

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PERSONAL INFORMATION

Born: October 11, 1950: Washington, D.C.
Marital Status: Married, three children, nine grandchildren

BIOGRAPHICAL SKETCH

J. Gary Eden received the B.S. degree in Electrical Engineering from the University of Maryland (College Park) and the M.S. and Ph.D. degrees (also in Electrical Engineering) from the University of Illinois, Urbana, in 1973 and 1976, respectively, and was appointed a National Research Council Postdoctoral Research Associate at the U.S. Naval Research Laboratory (Washington, DC) in 1975. As a research physicist in the Laser Physics Branch (Optical Sciences Division) of NRL from 1976 to 1979, he made several contributions to the area of visible and ultraviolet lasers and laser spectroscopy, including the co-discovery of the KrCl rare gas-halide excimer laser (222 nm), and received a Research Publication Award (1979) for his work at NRL in which he co-discovered the proton beam pumped laser (Ar-N₂, XeF). Since joining the faculty of the University of Illinois in 1979, he has been engaged in research in atomic, molecular and ultrafast laser spectroscopy and optical physics, the discovery, development, and applications of visible/ultraviolet/vacuum ultraviolet lasers and lamps, laser fusion energy (LFE), and the science and technology of microcavity plasma devices. He has served as Assistant Dean in the College of Engineering, Associate Dean of the Graduate College, and Associate Vice-Chancellor for Research. Currently, he is the Intel Alumni Endowed Chair Emeritus in the Department of Electrical and Computer Engineering and Director of the Laboratory for Optical Physics and Engineering, as well as Research Professor in the Coordinated Science Laboratory, and the Holonyak Micro and Nanotechnology Laboratory (HMNTL). He has also held faculty affiliate appointments with the Departments of Bioengineering, Materials Science and Engineering, and Nuclear, Plasma, and Radiological Engineering. Dr. Eden has authored more than 340 refereed, archival publications, 105 awarded U.S. and international patents, and the book *Photochemical Vapor Deposition* (1992), is a member of four honorary organizations, and is a Fellow of the IEEE, the Optical Society of America, the American Physical Society (APS), the American Association for the Advancement of Science (AAAS), and the SPIE. He has served as Editor-in-Chief of the *IEEE Journal of Quantum Electronics*, and Editor-in-Chief of *Progress in Quantum Electronics*. He also served as an Associate Editor of the APS journal *Applied Physics Reviews* and is currently a member of the Advisory Board. In 1998, he served as President of the IEEE Lasers and Electro-Optics Society (LEOS), following earlier service as a member of the LEOS Board of Governors, and as the Vice-President for Technical Affairs. Dr. Eden received the LEOS Distinguished Service Award in 1996, was awarded the IEEE Third Millennium Medal in 2000, and

was named a LEOS Distinguished Lecturer for 2003-2005. Between 2015 and 2017, he also served as a Distinguished Lecturer for the American Physical Society Division of Plasma Physics. From 1996 through 1999, he was the James F. Towey University Scholar at the University of Illinois and, in 2005, he received the IEEE/LEOS Aron Kressel Award. He was awarded the C.E.K. Mees Medal of the Optical Society of America in 2007, and was the recipient of the Fulbright-Israel Distinguished Chair in the Natural Sciences and Engineering for 2007-2008. He is a co-founder of Eden Park Illumination (2007), EP Purification (2010), Cygnus Photonics (2018), EPL Power Electronics (2020), the Eden Park Foundation (2019), and Perseid Medical (2023), and was named the recipient of the Harold E. Edgerton Award of SPIE for 2010. He has directed the research and dissertations of 65 individuals who have received the Ph.D. degree in Electrical and Computer Engineering, Physics, Bioengineering, Materials Science and Engineering, Chemistry, Nuclear, Plasma, and Radiological Engineering, or Environmental Engineering. In 2014, he was elected into the National Academy of Engineering and the National Academy of Inventors. He received the Distinguished Alumnus Award from the Department of Electrical and Computer Engineering at the University of Maryland (College Park) in 2016 and was named the Intel Alumni Endowed Chair at the University of Illinois in 2017. In 2020, Prof. Eden was inducted into the Innovation Hall of Fame of the A. James Clark School of Engineering at the University of Maryland. He is also the 2022 recipient of the IEEE Plasma Science and Applications (PSAC) Award, and was recently appointed Vice-President for Laser and Optical Science of the Xcimer Energy Corporation. He was also awarded a Hagler Fellowship at the Institute for Advanced Study at Texas A&M University for 2024-2025.

His current research focuses on excimer lasers for laser fusion energy, UV/VUV lamp development and applications in photolithography as well as exposure, deposition and etching tools, coupled optical coherences in atoms, stimulated Brillouin scattering (SBS), atomic clocks and quantum memories, growth and processing of wide bandgap semiconductor materials and other photonic materials, and VUV-driven solid-state and liquid photochemistry for optical, electronic, and biomedical device fabrication, and laser fractal modes.

PRESENT POSITION(S)

Fellow, Hagler Institute for Advanced Study, Texas A&M University (2024-2025)
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Vice-President for Laser and Optical Science, XCIMER ENERGY CORP., Denver, CO
Co-Founder, EDEN PARK ILLUMINATION, Champaign, IL
Co-Founder, EP PURE, Champaign, IL
Co-Founder and President, CYGNUS PHOTONICS, Champaign, IL
Co-Founder, EPL POWER ELECTRONICS, Champaign, IL
Co-Founder, PERSEID MEDICAL, Champaign, IL
President, Eden Park Foundation (www.edenparkfoundation.org)

EDUCATION/TRAINING

National Research Council Postdoctoral Research Associate at the U.S. Naval Research
Laboratory, Optical Sciences Division, Washington, DC (November 1975 – November 1976).
Ph.D., Electrical Engineering, University of Illinois, Urbana (January 1976).
M.S., Electrical Engineering, University of Illinois, Urbana (August 1973).
B.S., Electrical Engineering (High Honors), University of Maryland, College Park (January 1972).

EMPLOYMENT HISTORY

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Gilmore Family Professor of Electrical and Computer Engineering, University of Illinois (April 2007 to August 2017).

Professor of Electrical and Computer Engineering, University of Illinois, Urbana, IL (August 1983 to April 2007); Associate Professor, 1981-1983; Assistant Professor, 1979-1981.

Director, Laboratory for Optical Physics and Engineering, University of Illinois (August 1995 to Present).

Professor, Coordinated Science Laboratory, University of Illinois (2011-2019).

Research Professor, Coordinated Science Laboratory, University of Illinois (August 1983 to November 2011).

Professor, Holonyak Micro and Nanotechnology Laboratory (September 2000 to Present).

Affiliate Faculty Member, Department of Materials Science and Engineering, University of Illinois (December 2004 to 2019).

Professor, Department of Nuclear, Plasma, and Radiological Engineering, University of Illinois.

Affiliate Faculty Member, Department of Bioengineering, University of Illinois.

Visiting Professor, Department of Electrical Engineering, Technion (Israel Institute of Technology), Haifa, Israel (2013, 2018).

Guest Professor, Tongji University, Shanghai, China (2012-2013).

Adjunct Professor, University of Maryland, Institute of Physical Science and Technology (1992 - 2005).

Adjunct Professor, Mawson Institute, University of South Australia, Adelaide, Australia (July 2008-June 2011).

Fulbright-Technion Visiting Professor, Department of Physics, Technion (Israel Institute of Technology), Haifa, Israel (2007-2008).

Associate Vice-Chancellor for Research, University of Illinois, Urbana, IL (2000-2003).

Associate Dean of the Graduate College, University of Illinois (1994-1996).

Assistant Dean for Academic Programs, College of Engineering, University of Illinois (1992-1993).

Associate Professor, Department of Electrical and Computer Engineering, University of Illinois (August 1981-August 1983).

Assistant Professor, Department of Electrical and Computer Engineering, University of Illinois (August 1979-August 1981).

Research Physicist, U.S. Naval Research Laboratory, Optical Sciences Division (November 1976-August 1979).

National Research Council Postdoctoral Research Associate, U.S. Naval Research Laboratory (November 1975-November 1976).

Research Assistant, University of Illinois (June 1972-November 1975).

Teaching Assistant, University of Illinois (January-June 1972).

Laboratory Assistant, Department of Electrical Engineering, University of Maryland (November 1968-January 1972).

HONORS AND AWARDS

Fellow, Hagler Institute for Advanced Study, Texas A&M University, College Station, Texas (2024-2025)

Special Issue of *Progress in Quantum Electronics* “in honor of the 70th birthday of Professor J. Gary Eden” (M. Dawson, D. B. Geohegan, T. M. Spinka, and C. Jagadish, eds., *Prog. Quantum Electron.* 81 (2022) 100366)

IEEE Plasma Science and Applications Award (2022)

Innovation Hall of Fame, A. James Clark School of Engineering, University of Maryland (2020).

Intel Alumni Endowed Chair, University of Illinois, Department of Electrical and Computer Engineering (2017).

Distinguished Alumnus Award, University of Maryland, Department of Electrical and Computer Engineering (2016).

Member, National Academy of Engineering (2014).

Fellow, National Academy of Inventors (2014).

Member, Naval Studies Board, National Academy of Sciences (2015-2020).

Member, Army Research Laboratory Panel on Ballistics Science and Engineering, National Academy of Sciences (2015-2017).

Member, Army Research Laboratory Panel on Assessment and Analysis, Laboratory Assessments Board, National Academy of Sciences (2018, 2020).

Nanqiang Lecture, Xiamen University, Xiamen, China (2015).

Advisory Board, *Applied Physics Reviews* (2019-Present).

Associate Editor, *Applied Physics Reviews*, American Institute of Physics (2016-2019).

Editorial Board, *Scientific Reports* (2015-2016).

Distinguished Lecturer, American Physical Society, Division of Plasma Physics (2015-2017).

Visiting Professor, Faculty of Electrical Engineering, Technion (Israel Institute of Technology), Haifa, Israel (2013, 2018).

Guest Professor, College of Engineering, Tongji University, Shanghai, China (2012-2013).

Special Issues of *Progress in Quantum Electronics* and the *IEEE Journal of Quantum Electronics* “in honor of Professor J. Gary Eden on the occasion of his 60th birthday” (2012).

Fellow, SPIE (2011) “For achievements in laser physics, ultrafast science, and molecular spectroscopy.”

Harold E. Edgerton Award, SPIE (2010) “In recognition of his major contributions in demonstrating optical techniques for observing physical phenomena, including his seminal work in atomic, molecular, and ultrafast spectroscopy.”

C.E.K. Mees Medal, Optical Society of America (2007) “For seminal interdisciplinary contributions to ultraviolet lasers, photochemical vapor deposition, ultrafast spectroscopy and microplasma devices, and for strengthening international collaborations in these areas of optics and photonics.”

Fulbright-Israel Distinguished Chair in the Natural Sciences and Engineering; Visiting Professor, Department of Physics, Technion (Israel Institute of Technology), Haifa, Israel (2007-2008).

Gilmore Family Endowed Professorship in Electrical and Computer Engineering, University of Illinois (2007-2017).

Editor-in-Chief, *Progress in Quantum Electronics* (2006-2015).

Aron Kressel Award, IEEE Lasers and Electro-Optics Society (2005) “For sustained contributions to the development of ultraviolet coherent and incoherent sources, and to excimer laser and microplasma devices.”

Distinguished Lecturer, IEEE Lasers and Electro-Optics Society (2003-2005); Emeritus Lecturer (2008).

Fellow, American Association for the Advancement of Science (2008). “For seminal interdisciplinary contributions to ultraviolet lasers, photochemical vapor deposition, ultrafast spectroscopy and microcavity plasma devices.”

Multi-Year Faculty Achievement Award, College of Engineering, University of Illinois (2007).

Fellow, American Physical Society (1992) “For contributions to our understanding of the spectroscopy of rare gas dimers and the physics of ultraviolet lasers.”

Engineering Council Award for Excellence in Advising, University of Illinois (2001, 2004, 2006, 2007, 2011).

Third Millennium Medal, Institute of Electrical and Electronics Engineers (IEEE) (2000).

Distinguished Service Award, IEEE Lasers and Electro-Optics Society (1996).

Innovation Discovery Award, Champaign County (IL) Economic Development Corporation (2009).

Editor-in-Chief, *IEEE Journal of Quantum Electronics* (1996-2002).

Faculty Outstanding Teaching Award, University of Illinois, Department of Electrical and Computer Engineering (2000).

James F. Towey University Scholar, University of Illinois (1996-1999).

Research Publication Award, U.S. Naval Research Laboratory, Washington, DC (1978).

IBM Research Award, University of Illinois (1994).

Beckman Research Award, University of Illinois (1989).

Fellow, Institute of Electrical and Electronics Engineers (1988) “For contributions in the discovery of visible and ultraviolet lasers, and the development of laser techniques for the spectroscopy of excimer lasers.”

Associate, Center for Advanced Study, UIUC (1987-88).

Fellow, Optical Society of America (now known as *Optica* - 1986).

Rank Prize Funds Lecturer (Photochemical Vapor Deposition), Malvern, England, April 1984.

Member: Sigma Xi, Tau Beta Pi, Eta Kappa Nu.

UIUC Incomplete List of Teachers Rated as Excellent (listed multiple times).

Listed in *Who's Who in the World* (23rd-32nd eds., 2005-2014), *Who's Who in America* (46th-68th eds., 1990-2014), *Who's Who in Science and Engineering* (2nd-11th eds., 1994-2012), *Who's Who in American Education* (7th, 8th eds., 2005-2007), *Who's Who in the Midwest* (25th, 27th-41st eds., 1996, 2000-2014), *Who's Who in Technology* (5th-7th eds., 1984-1995), *Who's Who in Engineering Education* (2002), *American Men and Women of Science* (14th-21st eds., 1979-2002), *Who's Who Among America's Teachers* (5th, 6th eds., 1998-2000), *Who's Who in Finance and Business* (35th-37th eds., 2005, 2007, 2009).

EDITORSHIPS

Advisory Board, *Applied Physics Reviews*, American Institute of Physics (2020-2023).

Associate Editor, *Applied Physics Reviews*, (2016-2019).

Editorial Board, *Scientific Reports*, (2015-2016).

Editor-in-Chief, *Progress in Quantum Electronics*, 2006-2015.

Guest Co-Editor, *Journal of Physics D: Applied Physics*, Cluster Issue on Microplasmas, June 2005.

Editorial Advisory Board, *Encyclopedia of Modern Optics* (Academic Press), 2000-2003.

Editorial Advisory Board, *Advanced Materials–Chemical Vapor Deposition* (VCH Publishers, Weinheim, Germany), 1995-2003.

Editor-in-Chief, *IEEE Journal of Quantum Electronics*, 1996-2002.

Editor, *Gas Laser Technology*, Milestone Volume 159 (SPIE Optical Engineering Press, Bellingham, WA, 2000).

Advisory Board, *CRC Handbook Series of Laser Science and Technology*, 1996-2000.

Associate Editor, *IEEE Photonics Technology Letters* (1988-1994).

Guest Co-Editor, *IEEE Journal of Quantum Electronics*, Special Issue on Electronic Transition Gas Lasers, September 1990.

Guest Co-Editor, *IEEE Journal of Selected Topics in Quantum Electronics*, Issue on Short Wavelength Lasers and Applications, November/December 1999.

Editor, *IEEE Journal of Selected Topics in Quantum Electronics*, 1996.

PH.D. STUDENTS

The following list gives the names, year of graduation, and dissertation title for each of the individuals that have received the Ph.D. degree (in Electrical and Computer Engineering, Materials Science and Engineering, Physics, Bioengineering, Chemistry, Civil and Environmental Engineering, or Nuclear, Plasma, and Radiological Engineering) under the direction of Prof. Eden.

1. **M. L. Dlabal** (1981) – “Discharge pumped iodine monofluoride laser: Operating parameters and collisional kinetics” – Electrical and Computer Engineering.
2. **A. W. McCown** (1983) – “Optical processes in xenon: Multiphoton ionization and ultraviolet photodissociation of the dimer ion” – Physics.
3. **J. F. Osmundsen** (1985) – “Low temperature growth of semiconductor thin films by ultraviolet laser induced chemical vapor deposition” – Electrical and Computer Engineering.
4. **D. E. Johnson** (1985) – “Ultraviolet and visible absorption spectra of potassium and potassium-xenon mixtures” – Physics.
5. **M. N. Ediger** (1985) – “Excitation spectroscopy of krypton molecular Rydberg states” – Electrical and Computer Engineering.
6. **K. P. Killeen** (1985) – “Transient Rydberg absorption spectroscopy of electron beam excited rare gases” – Electrical and Computer Engineering.
7. **D. P. Greene** (1985) – “Cadmium and zinc monoiodide: New discharge-pumped metal halide oscillators and amplifiers” – Electrical and Computer Engineering.
8. **D. B. Geohegan** (1986) – “Optical processes in Kr and Kr₂F: Absolute cross sections for multiphoton ionization of Kr(¹S₀), photoionization of metastable Kr* and Kr₂*, and absorption of Kr₂F (4²Γ)” – Physics.
9. **D. J. Kane** (1989) – “Inter-Rydberg spectroscopy of argon and neon dimers” – Physics.
10. **C. C. Abele** (1989) – “Inter-Rydberg excitation spectroscopy of krypton dimers” – Electrical and Computer Engineering.
11. **D. C. Shannon** (1989) – “Time-resolved absorption spectroscopy of the rare gas dimer Rydberg states” – Electrical and Computer Engineering.

12. **J. H. Schloss** (1989) – “Photoassociation of krypton and fluorine collision pairs” – Electrical and Computer Engineering.
13. **K. K. King** (1990) – “Multiphoton laser spectroscopy of indium monoiodide” – Physics.
14. **S. B. Kim** (1991) – “Excited state structure of Ne₂” – Electrical and Computer Engineering.
15. **C. J. Zietkiewicz** (1992) – “Multiphoton ionization photoelectron spectroscopy of iodine-bearing molecules” – Electrical and Computer Engineering.
16. **R. B. Jones** (1992) – “Photoassociative excitation spectroscopy of excimer molecules” – Electrical and Computer Engineering.
17. **G. Rodriguez** (1993) – “Femtosecond laser studies of molecular wavepacket dynamics in the cesium dimer” – Electrical and Computer Engineering.
18. **Y. Y. Gu** (1993) – “Multiphoton ionization of hydrogen iodide and molecular iodine using photoelectron spectroscopy” – Electrical and Computer Engineering.
19. **A. M. Farkas (Chojnacki)** (1994) – “Multiphoton ionization and photoelectron spectroscopy of hydrogen iodide with fixed wavelength and tunable laser sources” – Electrical and Computer Engineering.
20. **J. J. Alwan** (1994) – “Thermal and photochemical vapor deposition of aluminum nitride and gallium nitride” – Electrical and Computer Engineering.
21. **R. D. Fraser** (1997) – “Excited state spectroscopy of HgCl, HgBr, HgI, and CdI” – Electrical and Computer Engineering.
22. **H. C. Tran** (1997) – “Group IIB dimers: Spectroscopy of molecular cadmium and gain demonstration in molecular mercury” – Physics.
23. **P. C. John** (1997) – “Ultrafast dynamics and nonlinear interactions in alkali atoms and diatomics” – Electrical and Computer Engineering.
24. **C. M. Herring** (1998) – “Excited state spectroscopy of diatomic argon” – Electrical and Computer Engineering.
25. **J. Gao** (1998) – “Quantum electrodynamic theory of optical high order harmonic generation” – Physics.
26. **J. W. Frame** (1998) – “Microdischarge devices fabricated in silicon” – Electrical and Computer Engineering (co-advised with T. A. DeTemple).
27. **D. S. Funk** (1999) – “Optical processes and laser dynamics in holmium and neodymium upconversion-pumped visible and ultraviolet fluorozirconate fiber lasers” – Physics.
28. **A. L. Oldenburg** (2001) – “Dynamics of electronic wavepackets in atomic rubidium” – Physics.
29. **A. A. Senin** (2003) – “Study of wavepacket dynamics in rubidium vapor by means of time-frequency analysis” – Electrical and Computer Engineering.
30. **F. Shen** (2004) – “Theoretical investigation of photoassociative excitation spectroscopy of xenon monoiodide” – Physics.
31. **N. P. Ostrom** (2004) – “Photodetection in silicon pyramidal microdischarges” – Electrical and Computer Engineering.
32. **C. J. Wagner** (2004) – “Spectroscopy of electronically excited xenon dimers” – Physics.
33. **J. M. Hafez** (2005) – “Modulation technique for magneto-optic imaging of weak magnetic fields with rare-earth iron garnet films” – Electrical and Computer Engineering.
34. **Y. Xiao** (2007) – “Probing the dissociation of the rubidium dimer by wavepackets and parametric four-wave mixing” – Electrical and Computer Engineering.

35. **K.-F. Chen** (2008) – “Microplasma transistor with quasi metal-oxide-semiconductor (MOS)/metal-insulator-metal (MIM) electron emitters” – Electrical and Computer Engineering.
36. **K. S. Kim** (2009) – “Microstructural control of aluminum/aluminum oxide electrochemistry: aluminum/aluminum oxide photonic devices” – Materials Science and Engineering.
37. **P. A. Tchertchian** (2010) – “Hybrid plasma-semiconductor devices” – Electrical and Computer Engineering.
38. **T. M. Spinka** (2010) – “Nonlinear optical processes and the nearest neighbor distribution in rubidium vapor” – Electrical and Computer Engineering.
39. **J. D. Readle** (2010) – “Atomic alkali lasers pumped by the dissociation of photoexcited alkali-rare gas collision pairs” – Electrical and Computer Engineering.
40. **S. H. Sung** (2010) – “Coupled phenomena in arrays of microplasma devices and microchannel plasma devices as antennas” - Electrical and Computer Engineering.
41. **K. E. Keister** (2010) – “Microwave interferometric measurements of electron density in laser-generated plasma channels” - Physics.
42. **J. Zheng** (2011) – “Optically tunable external cavity ring laser” – Electrical and Computer Engineering.
43. **B. J. Ricconi** (2012) – “Quantum beat observations in rubidium vapor” – Electrical and Computer Engineering.
44. **B. Li** (2012) – “Performance and analysis of the plasma bipolar junction transistor: Control of the surface electrical properties” – Electrical and Computer Engineering.
45. **J. D. Hewitt** (2013) – “Alkali-rare gas photodissociation lasers: Applications to laser physics and atom-atom interactions” – Electrical and Computer Engineering.
46. **T. J. Houlihan, Jr.** (2014) – “Pulsed plasma microjets: a new tool for the investigation of plasma kinetics and molecular spectroscopy” – Electrical and Computer Engineering.
47. **T. C. Galvin** (2015) – “Markov-Airy method for electromagnetic fields in layered structures and microsphere-stabilized resonators” - Electrical and Computer Engineering.
48. **A. E. Mironov** (2016) – “Laser physics and spectroscopy in alkali vapor-noble gas mixtures” - Electrical and Computer Engineering.
49. **J. A. Rivera** (2017) – “Stimulated emission from biological materials and novel optical resonators for diagnostic and imaging applications” - Biomedical Engineering.
50. **W.W. Chen** (2017) – “Experimental and theoretical studies of the ScI, YI, Hg₂, and XeI diatomic molecules” - Electrical and Computer Engineering.
51. **J. H. Ni** (2017) – “Optoelectronic devices based upon the integration of semiconductor and gas-phase devices” – Electrical and Computer Engineering.
52. **W. Goldschlag** (2017) – “Dynamics of interfering wave packets in rubidium by high resolution quantum beat spectroscopy” – Electrical and Computer Engineering.
53. **B. C. Masters** (2018) – “Development of a ferroelectric plasma source through material degradation studies and characterization of volume and surface discharges” – Nuclear, Plasma, and Radiological Engineering.

54. Z. S. B. **Wiersma** (2018) – “Analytical evaluation of microplasma technologies for production of hydrogen fuel from water” – Chemistry.
55. C. **Shin** (2018) – “Microplasma chemical reaction enhancement by laser modification of dielectric surface topography” – Electrical and Computer Engineering.
56. Y. **Huang** (2019) – “Hybrid microplasma-semiconductor transistor and frequency modulator”- Electrical and Computer Engineering.
57. O. A. **Sonoiki** (2019) – “Photolithography and surface modification applications of a 172 nm xenon microplasma excilamp” – Electrical and Computer Engineering.
58. H.-J. **Yang** (2019), “Reconfigurable antennas based on microplasma as a time-varying dielectric or conductor” - Electrical and Computer Engineering.
59. P. P. **Sun** (2019), “Design of multidimensional microplasma array for biofilm removal and dynamic photonic crystals” – Environmental Engineering in Civil Engineering; Electrical and Computer Engineering.
60. S.-H. **Park** (2019), “Diatomic excimer dynamics in microplasma lamps and alkali lasers” – Electrical and Computer Engineering.
61. R. **Su** (2020), “Probing weakly bound long-range Rydberg molecules by quantum beating experiments in rubidium vapor” – Electrical and Computer Engineering.
62. J.-H. **Kim** (2021), “Microplasma – driven, atomic layer deposition of flexible electronic and photonic nanofilms” – Electrical and Computer Engineering.
63. A. W. **Steinforth** (2022), “Stable and unstable resonators within Fabry-Perot optical cavities containing microlenses: Laser arrays, low-coherence imaging and fractal laser modes” – Electrical and Computer Engineering.
64. K. V. **Desai** (2023), “Stimulated Raman scattering, lasing, and molecular energy transfer mechanisms in KXe probed by laser spectroscopy”– Electrical and Computer Engineering.
65. J. A. **Michaels** (2023), “Etching for quantum-ready surfaces” – Electrical and Computer Engineering.

Numerous students have also received the M.S. degree under Prof. Eden’s direction, and Dr. Eden’s laboratory at UIUC currently comprises 6 graduate students, two postdoctoral scientists and three undergraduate students.

PROFESSIONAL OFFICES AND ACTIVITIES

1. SOCIETY OFFICES HELD

President, IEEE Lasers and Electro-Optics Society (1998).

Elected Member, Board of Governors of IEEE Lasers and Electro-Optics Society (LEOS), 1991-1993.

Vice President for Technical Affairs, IEEE Lasers and Electro-Optics Society, 1993-1995.

American Physical Society Representative to Joint Council on Quantum Electronics, 1996-1998.

Treasurer, Joint Council on Quantum Electronics, 1996-1998.

Joint Council on Quantum Electronics — Liaison to CLEO Steering, 1996-1998.

Chair, Tellers Committee, Optical Society of America (2009); Member (2008, 2010).

Chair, Committee on Short Wavelength and Gas Lasers, IEEE LEOS.

Member, Publications Council, IEEE Photonics Society (2011-2015).

Member, Executive Committee, American Physical Society, Division of Atomic, Molecular and Optical Physics, 1991-1992.

Member, "Launch Committee" on Laser Physics for the Journal of the Optical Society of America B.

Chair, Fellow Evaluation Committee, IEEE Photonics Society.

Member, Fellow Evaluation Committee, IEEE Nuclear and Plasma Science Society (2015, 2016).

2. TECHNICAL CONFERENCE LEADERSHIP AND ORGANIZATION

Program Committee, 55th Annual Meeting of the APS Division of Plasma Physics (DPP 2013), American Physical Society, Denver, CO (November 2013).

International Advisory Committee, International Symposium on Molecular Spectroscopy (ISMS), Urbana, IL (2015-2017).

Conference Co-Chair, Engineering Conferences International (ECI) Conference on Fundamentals and Applications of Microplasmas, San Diego, CA (March 2009).

Program Committee, International Meeting on Information Display (IMID), Daegu, South Korea (August 2007); Seoul, South Korea (2009).

Plasma Displays Program Committee, 8th International Mtg. on Information Display, International Display Manufacturing Conf., and Asia Display, Ilsan, Korea (October 2008).

International Scientific Committee, International Conference on Phenomena in Ionized Gases, 2005-2011.

Advisory Committee, 1st International Symposium on Ceramic Microsystems: Materials, Fabrication and Applications, American Ceramic Society, Baltimore, MD, April 2005.

Program Committee, Optical Components and Materials Conference II (OE02), International Symposium on Integrated Optoelectronic Devices 2005, San Jose, CA, January 2005.

Co-Organizer, Second International Workshop on Microplasmas (IWM-2004), Stevens Institute of Technology, Hoboken, NJ, October 2004.

Organizing Committee, Third International Workshop on Basic Aspects of Non-Equilibrium Plasmas Interacting With Surfaces, Awaji-Yume-Butai, Japan, February 2003.

Program Committee, International Quantum Electronics Conference (IQEC 2002), Moscow, Russia, June 2002.

Co-Organizer, Symposium on Biomedical Imaging, University of Illinois (2002).

Conference Co-Chair, IEEE/LEOS Summer Topical Conference on Ultraviolet and Blue Lasers, Copper Mountain, CO (July 2001).

Advisory Board, International Photonics Conference, Taiwan (September 2000).

Program Committee, Conferences on Optical Devices for Fiber Communication I, II, SPIE Intl. Symposium on Voice, Video, and Data Communications, Boston, MA (September 1999, November 2000).

Program Committee, Conference on Lasers and Electro-Optics (CLEO), 1982, 1983, 1988, 1989, 1994-1997.

Chair, Physics of Laser Sources Subcommittee, Fifteenth Interdisciplinary Laser Science Conference (ILS XV), Santa Clara, CA (September 1999).

Organizing Committee, International Conference on Pulsed Atomic and Molecular Lasers, Tomsk, Russia (1994, 1997, 1999, 2001, 2009, 2013, 2018).

Program Committee, Conference on Solid State Lasers, SPIE Annual Symposium (Photonics West), San Jose, CA 1995-2003.

Program Committee, Lasers '88, '89 (New Orleans, LA).

Scientific Committee, Symposium on Photon-Assisted Processing of Surfaces and Thin Films, Meeting of the European Materials Research Society (E-MRS), Strasbourg, France (May 1994).

Program Committee, Annual Meeting of the Lasers and Electro-Optics Society (LEOS), 1988-2005.

Program Committee, Fourteenth Interdisciplinary Laser Science Conference (ILS XIV), Baltimore, MD (October 1998).

Program Vice-Chair, Fifth Interdisciplinary Laser Science Conference (ILS V), Stanford, CA (August 1989).

Program Chair, Sixth Interdisciplinary Laser Science Conference (ILS VI), Minneapolis, MN (September 1990).

Conference Vice-Chair, Seventh Interdisciplinary Laser Science Conference (ILS VII), Monterey, CA (September 1991).

Conference Chair, Eighth Interdisciplinary Laser Science Conference (ILS VIII), Albuquerque, NM (September 1992).

Program Chair, IEEE Lasers and Electro-Optics Society Annual Meeting (LEOS '90), Boston, MA (November 1990).

Co-Founder and Chairman of Engineering Foundation Conference, "Future Prospects and Applications for UV and VUV Lasers," Santa Barbara, CA – February 1987; Co-Chairman, February 1990 and February 1994 Meetings.

Organizing Committee, OSA Conference on Compact Blue-Green Lasers, Albuquerque, NM (February 1992).

Conference Chair, 1992 Annual Meeting of the IEEE Lasers and Electro-Optics Society (LEOS '92), Boston, MA (November 1992).

Liaison, Annual Meeting of the Optical Society of America – Interdisciplinary Laser Science Conference (American Physical Society), Dallas, TX (October 1994).

Co-Chairman of the SPIE Meeting on "Excimer Lasers, Their Applications, and New Frontiers in Lasers," Arlington, VA (April 1984).

Plenary Chair, International Conference on the Applications of Lasers and Electro-Optics (ICALEO 1993).

3. AWARD COMMITTEES

Member, Optical Society of America Stephen Fantone Distinguished Service Award (2016, 2017).

Member, Fellows Committee, IEEE Nuclear and Plasma Sciences Society (2015, 2016).

Member, Optical Society of America C. E. K. Mees Medal Committee (2012).

Member, SPIE Harold Edgerton Award Committee (2011-2013).

Member, IEEE Photonics Award Committee (2008-2010).

Chair, IEEE LEOS Aron Kressel Award Committee (2007, 2008).

Member, IEEE LEOS Distinguished Lecturers Award Committee (2007).

Chair, IEEE LEOS Awards and Lecturers (2003, 2004).

Chair, Optical Society of America William F. Meggers Award Committee (2001).

Chair, Fellows Committee, IEEE Photonics Society (2000, 2001, 2012).

Member, William F. Meggers Award Committee, Optical Society of America (2000).

Member, IEEE LEOS Quantum Electronics Award Committee (1998).

Member, Arthur Schawlow Prize Committee, American Physical Society (1991-1993).

Member, Fellow Committee, American Physical Society, Laser Science Topical Group (1993, 1994).

4. DEPARTMENTAL AND INSTITUTE REVIEW COMMITTEES

University of Maryland (College Park) Institute for Research in Electronics and Applied Physics, March 2017.

University of Wisconsin (Madison) Department of Electrical and Computer Engineering, 2008.

University of Maryland (College Park), Department of Electrical and Computer Engineering, 2010.

5. FEDERAL CLEARANCE/LICENSES

Active Security Clearance (Secret): National Academies of Science, Engineering, and Medicine (also held at the University of Illinois)

FCC First Class Commercial Radiotelephone License (since 1972).

FCC Amateur Extra Class Radio License (since 1968).

SELECTED ACCOMPLISHMENTS

1. Co-invention (with S.-J. Park) of high-power VUV/UV “light tiles” that are efficient, thin and flat. Average powers up to 35 W and 5 W at 172 nm and 222 nm (respectively) can now be produced from 10 cm x 10 cm (4”x4”) flat lamps. Co-Founder of Eden Park Illumination (www.edenpark.com; 2007), recipient of the Red Herring North America 100 Award (2009), the Technology Innovation Award (National Association of Broadcasters) in 2012, and the “Best Light of Show” Award from the National Association of Broadcasters (2013) for 1 ft² visible lamps. Lamps emitting in the 172-351 nm spectral range are being manufactured for materials identification, atomic clocks, medical therapeutics, and industrial photochemistry. During the COVID-19 pandemic, Eden Park lamps have been used in restaurants, transit systems, a military installation, and other public spaces to disinfect room air and surfaces.
2. Discovery (or co-discovery) and development of numerous ultraviolet, visible and near-infrared atomic and molecular lasers, including the KrCl ultraviolet (excimer) laser at 222 nm, the optically-pumped XeF, HgCl, and rare gas lasers and the CdI, CdBr, ZnI, Li, Fe, and Cd visible and near-infrared lasers; demonstration of the first long pulse ($> 1 \mu\text{s}$) excimer laser (351 nm); demonstration of the first lasers (Ar – N₂, XeF) pumped by a proton beam. The excimer lasers are now used worldwide in deep-UV photolithography, surgical procedures (such as corneal refractive correction), and micromachining of materials.
3. Discovery and analysis of the interference between atomic coherences produced in Rb at 384 and 386.1 THz; Demonstrated control of the phase of interfering atomic coherences; Demonstration of atomic wavepackets as a detector of molecular dissociation dynamics, and atomic interactions at long range - a new approach to molecular spectroscopy and chemical dynamics; demonstration of the production and THz modulation of coherent ultraviolet and visible radiation by an atomic wavepacket.
4. Discovery and theoretical confirmation of two classes of fundamental and high-order laser fractal modes in microresonators; observation of high-order modes up to $m=5$; conception and development of speckle-free lasers, stabilized by two-dimensional photonic crystals comprising microspheres. This concept yields hundreds or thousands of uncorrelated laser beams from a common resonator and peak output pulse powers of ~ 1 MW; developed for confocal microscopy and LIDAR.
5. Spin polarization of alkali atomic excited states with a circularly-polarized pump; manipulation of atomic laser state degeneracy by spin polarization; discovery of the excimer-pumped atomic lasers (lasing on the D₁ and D₂ lines of Na, Cs, and Rb) for laser guide stars and mesosphere probing by LIDAR, and the discovery of the alkali-rare gas excimer lasers.
6. First observation (by laser spectroscopy) of Rydberg series for the rare gas diatomics (Ne₂, Ar₂, Kr₂, Xe₂) and the first measurement of the rotational constants for Ne₂ and Ar₂, as well as the vibrational constants for Ne₂⁺. Measurement of absolute photoionization cross-sections for electronically excited Xe₂ and Kr₂, as well as rare gas atoms. These molecules have a direct bearing on the performance of lasers, lamps, and plasma processes employing the rare gases.

7. Co-Founder and President of Cygnus Photonics (www.cygnusphoton.com; 2018), manufacturer of compact photolithographic systems (exposure and stepper tools) based on flat VUV/UV lamps; Co-inventor of resist-free photolithography at 172 nm, and low temperature, oxide film deposition from liquid precursors.
8. Co-invented arrays of microchannel plasmas for efficient generation of ozone for water disinfection and wastewater treatment; Co-founded EP Purification (now EP Pure) in 2010 - company products are now disinfecting drinking water in more than 30 countries worldwide. Other products disinfect water in swimming pools, treat “grey” (waste) water, and produce ozone for lifetime extension of agricultural products. EP Purification is the recipient of the Wells Fargo/DOE Clean Energy Grand Prize (2014) and the Governor’s Award (Illinois) in the export category (2018).
9. Co-discovered the treatment of otitis media (human ear infections) with microplasma traversal of the eardrum.
10. Co-Founder of Eden Park Foundation (www.edenparkfoundation.org; 2019), a 503(c)-nonprofit devoted to the dissemination of microplasma water disinfection technology in off-grid communities in the developing world. A partnership of EPF with the Safe Water and AIDS Project (SWAP) in Kenya and the University of Illinois-Chicago School of Environmental Health (Prof. Sam Dorevitch) recently received a Global Water Award from the President of the United Arab Emirates for large-scale water purification systems in Kenya.
11. Co-invented plasma photonic crystals, operating in the microwave/mm-wave region (120-300 GHz) and serving as narrow-band filters, resonators, and phase shifters. These are the first 3D plasma photonic crystals, and the first dynamic photonic crystals of any kind. Observation of mode-splitting and plasma-induced transparency in plasma/metal/dielectric crystals.
12. Discovery of the laser excitation spectroscopy of photoassociation (the absorption of optical radiation by free atomic pairs) of thermal atoms as a probe of the structure of transient molecules.
13. Demonstration (with graduate students) of the first ultraviolet and violet glass fiber lasers. These are two of the three shortest wavelength fiber lasers in existence.
14. Co-discovery of the plasma bipolar junction transistor, the microplasma optical modulator, and the microplasma/semiconductor photodetector.
15. Demonstration of a microwave method for measuring absolute photoionization cross-sections for atoms and small molecules; applicable to measurements of the absolute photoionization cross-sections for any electronically-excited molecule.
16. Measurements of rate constants, cross-sections, and molecular lifetimes that are key to the performance of the excimer lasers. These fundamental constants are widely used today in computational models of the excimer lasers.
17. Discovery of lasers in the biological molecules Flavin Mononucleotide (FMN) and R-Phycoerythrin in the visible. Demonstration of the first FRET/plasmonic lasers.
18. Pioneered the development of microcavity plasma devices and arrays in silicon, Al/Al₂O₃, glass, ceramics, and multilayer metal/polymer structures; demonstration of first microplasma arrays, flexibility, large area, and in several systems, transparency; demonstrated microplasma photonic crystals in the mm-wave range (120-300 GHz), photodetectors, the first microplasma-driven optical amplifier, the first discharge excited by a reverse-biased pn junction, the microplasma mixer/modulator, and electromagnetic reflectors and absorbers. Demonstration of the smallest, cavity-confined plasmas (< 3 μm). These devices represent a new photonic technology for

electromagnetic components, high resolution displays, chemical sensors, and medical phototherapeutics.

19. Demonstration of the growth of germanium, silicon, GaN, and GaAs films by ultraviolet photochemical vapor deposition. These were among the earliest experiments in this area.

20. Demonstration and development (with J. Kim and S.-J. Park) of microplasma-assisted ALD.

Professor Eden's research has been featured in *Laser Focus*, *Photonics Spectra*, *Electronics Weekly* (UK), the *Bulletin of the Materials Research Society*, *Microwaves*, *Optical Spectra*, *Electro-Optical Systems Design*, *Optics and Laser Technology*, *Electronics*, *Optics News*, *Lasers and Optronics*, *IEEE Potentials*, *IEEE Spectrum*, and *IEEE Circuits and Devices*. Photographs of his experiments or photonic devices have appeared on the cover of *Laser Focus World* (April 2005, July 2010), *Applied Physics Letters* (June 23, 2003), the *Journal of Physics D: Applied Physics* (June 7, 2005), *Plasma Processes and Polymers* (twice) and *Circuits and Devices* magazine (twice). His work was highlighted in the National Academy of Sciences report *Plasma 2010*, published in 2007.

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J. Gary Eden, “Advances in Microplasma Array Lamps,” *SPIE Newsroom*, Article No. 10.1117/2.1200711.0850, 2007.

RECENT INVITED PRESENTATIONS

The following is a partial list of more recent invited talks (previous 28 years):

1. J. G. Eden, “Advances in microcavity plasma science and applications: VUV photolithography, atomic clocks, and 3D photonic crystals”, Asia-Pacific Conference on Plasma and Terahertz Science (APCOPTS), Busan National University, Busan, South Korea (August 26, 2023).
2. J. G. Eden, A. E. Mironov, K. D. Kabelitz, C. Galloway, A. Valys, C. Herring, A. Steinforth, and E. M. Campbell, “Krypton fluoride (248 nm) as the laser driver for inertial fusion energy (IFE)”, Plenary talk, International Fusion Plasma Conference, Busan, South Korea (August 24, 2023).
3. J. G. Eden, “Vacuum ultraviolet photolithography with flat 172 nm microplasma lamps, atomic clocks, imaging with speckle-free lasers, and other fascinating topics in optical

physics and engineering”, Princeton-TAMU Summer School on Quantum Physics, Casper College, Casper, Wyoming (July 21, 2023).

4. J. G. Eden, “Speckle-free optical imaging, vacuum ultraviolet photolithography, disinfection of air in public spaces, atomic clocks, and other recently-developed commercial, biomedical, and humanitarian applications of lasers and low temperature plasma”, Department of Electrical and Computer Engineering, Baylor University, Waco, Texas (April 24, 2023).
5. J. G. Eden, “Recent advances in ultraviolet photolithography, Deep-UV disinfection of air in public spaces, speckle-free optical imaging, and the pursuit of electrical power production by laser fusion energy”, Distinguished Speaker Seminar, Department of Electrical and Computer Engineering, Texas A&M University, College Station, Texas (April 19, 2023).
6. J. G. Eden, “Fractal laser modes, speckle-free optical imaging, water optics, and other fascinating topics in optical physics and engineering”, Institute for Quantum Science and Engineering (IQSE) AMO Quantum Optics Seminar, Texas A&M University, College Station, Texas (November 8, 2022).
7. S.-J. Park and J. G. Eden, “Disinfection of room air and surfaces during COVID-19 with deep-ultraviolet lamps”, 66th International Atomic Energy Agency (IAEA) General Conference, Vienna, Austria (September 28, 2022).
8. W. Chen, J. H. Cho, J. Kim, A. E. Mironov, S. Park, P. P. Sun, S.-J. Park, and J. G. Eden, “Arrays of microcavity plasmas: The unique properties and commercial impact of low-temperature plasma confined to mesoscopic-scale cavities”, Plenary Presentation, International Conference on Plasma Science (ICOPS), Seattle, WA (May 23, 2022).
9. A. W. Steinforth and J. G. Eden, “Low-coherence lasers for high-resolution imaging of dynamic targets”, WD2.1, 2021 IEEE Research and Applications of Photonics in Defense (RAPID) Conference (August, 2021).
10. J. G. Eden, “What’s new in optical physics and engineering”, Balticon 55, Baltimore, MD (May 28, 2021).
11. J. G. Eden, “Electromagnetic (mm-wave) and nanofabrication applications of microcavity plasmas”, 10th International Conference on Plasma Nanoscience (iPlasmaNano X), Porec, Croatia (September 15, 2019).
12. J. G. Eden, J. A. Rivera, T. C. Galvin, A. W. Steinforth, A. E. Mironov, and S. H. Park, “New lasers emitting fractal modes or based on biomolecules or free-free transitions of atomic pairs”, 49th Winter Colloquium on the Physics of Quantum Electronics (PQE 2019), Snowbird, Utah (January 10, 2019).
13. J. G. Eden, “Recent developments in the fundamental science, applications, and commercialization of microcavity plasma arrays”, Asia-Pacific Conference on Plasma and Terahertz Science (APCOPTS), Xi’an, China (August 15-18, 2018).
14. J. G. Eden, “Biological lasers and fractal, multi-beam lasing from hybrid optical resonators”, Russell Berrie Nanotechnology Institute, Technion-Israel Institute of Technology, Haifa, Israel (April 25, 2018).

15. J. G. Eden, “Fundamental science and the commercialization of microcavity plasma technology: microwave filters, VUV lamps, and water disinfection systems”, 4th International Workshop on Plasma Science and Entrepreneurship, Orleans, France (November 30, 2017).
16. J. G. Eden, “Recent experiments in optical physics: atomic wavepackets, spin-polarized atoms, fractal laser modes, and novel optical resonators”, Department of Physics, Florida International University, Miami, FL (October 27, 2017).
17. J. G. Eden, “Microplasmas and the role of plasma/surface interactions”, 30th International Vacuum Nanoelectronics Conference (IVNC), Regensburg, Germany (July 10, 2017).
18. J. G. Eden, “Recent experiments in laser physics: Biomolecular lasers, spin-polarized atoms and novel optical resonators”, iOptics Seminar, University of Illinois (February 10, 2017).
19. J. G. Eden, “Internal cooling of fiber and disc lasers by radiation balancing and other optical and phonon processes”, Photonics West, San Francisco, CA (February 2, 2017).
20. J. G. Eden, “Going where no plasma has gone before: Arrays of microcavity plasmas and their impact on lighting, water disinfection, and medical therapeutics”, Colloquium, Department of Physics and Astronomy, University of West Virginia, Morgantown, WV (March 3, 2016).
21. J. G. Eden, “Selected achievements of microcavity plasmas in fundamental science and technology: Molecular physics, cooled plasmas, high power VUV lamps, and transistors”, Quo Vadis Complex Plasmas Conference, Hamburg, Germany (August 3, 2016).
22. J. G. Eden, “Going where no plasma or laser has gone before: Microcavity plasmas, microphotonic resonators, and biomolecular lasers,” Booz Allen Hamilton Distinguished Colloquium, Department of Electrical and Computer Engineering, University of Maryland, College Park, MD (December 4, 2016).
23. J. G. Eden, “Microlasers, amplifiers, and plasmas: A new generation of photonic and chemical devices“, Nanqiang Lecture, Xiamen University, Xiamen, China (April, 2015).
24. J. G. Eden, “Going where no plasma has gone before: Microplasmas and their impact on lighting, water disinfection, and medical therapeutics,” Seminar, Department of Nuclear, Plasma, and Radiological Engineering, University of Illinois (February 18, 2014).
25. J.G. Eden and S.J. Park, “Microplasma light tiles for videography and commercial and residential interior lighting,” 26th IEEE Photonics Conference, Bellevue, WA, September 9, 2013.
26. J.G. Eden, “Probing plasma – surface interactions with the TEM or the plasma bipolar junction transistor,” 4th International Symposium on Plasma Nanoscience (iPlasmaNano – IV), Asilomar, CA, August 27, 2013).
27. J. G. Eden, “Plasma science in the limit of the small: Microcavity plasmas and their applications,” Department of Optics and Optical Engineering, Fudan University, Shanghai, China, January 16, 2013.
28. J. G. Eden, “Plasma science and applications in the spatial realm below 1 mm: Recent advances in microcavity/microchannel plasmas,” 59th American Vacuum Society (AVS) International Symposium, Tampa, Florida, October 29, 2012.

29. J. G. Eden, "Recent advances in microcavity plasma science and its applications in lighting, water disinfection, and medical therapeutics," Department of Materials Science and Engineering, University of Illinois, Urbana, Illinois, October 8, 2012.
30. J. G. Eden, "Optically-pumped atomic alkali lasers," Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai, China, September 26, 2012.
31. J. G. Eden and S. -J. Park, "Complex Plasmas," 3rd Graduate Summer Institute, Seton Hall University, South Orange, New Jersey, August 7, 2012.
32. J. G. Eden and S. -J. Park, "Plasma science in the limit of the small: Recent advances in microcavity plasmas and their applications," Plenary address, 39th IEEE International Conference on Plasma Science (ICOPS 2012), Edinburgh, Scotland, (UK), July 9, 2012.
33. J. G. Eden, "Quantum beating as a probe of atom-atom interactions and molecular dissociation," 42nd Winter Colloquium on the Physics of Quantum Electronics (PQE 2012), Snowbird, Utah, January 4, 2012.
34. J. G. Eden, "Microcavity plasma science and recent applications: Bound-free coupling, transistors and illumination," Michigan Institute for Plasma Science and Engineering, University of Michigan, Ann Arbor, MI, October 26, 2011.
35. J. G. Eden, "Hybrid plasma-semiconductor transistors, bound-free plasma interactions, and other topics," Department of Electrical and Computer Engineering, Clemson University, Clemson, SC, September 19, 2011.
36. J. G. Eden and S. -J. Park, "Recent advances in microcavity plasmas: Transistors, coupled arrays, and light tiles for general illumination," International Conf. on Luminescence (ICL '11), Ann Arbor, MI, June 27, 2011.
37. J. G. Eden, "Recent advances in microcavity plasmas: Transistors, coupled arrays, and light tiles for general illumination," Dept. of Nuclear, Plasma, and Radiological Engineering, University of Illinois, Urbana, IL, February 15, 2011.
38. J. G. Eden, J. D. Readle, and J. D. Hewitt, "Three body photoassociation in the pumping of atomic lasers by free→free optical transitions" Plenary, 41st Winter Colloquium on the Physics of Quantum Electronics (PQE 2011), Snowbird, Utah, January 3, 2011.
39. J. G. Eden, "Progress in microplasma applications," Summer Plasma Physics School, Greifswald, Germany, August 2010.
40. J. G. Eden and S. -J. Park, "Microcavity plasma lighting: Thin sheet lamps for general illumination," 12th Intl. Symposium on the Science and Technology of Light Sources, Eindhoven, The Netherlands, July 13, 2010.
41. J. G. Eden, "Microcavity plasma arrays and coupling of semiconductor and gas phase plasmas," 40th Winter Colloquium on the Physics of Quantum Electronics (PQE 2010), Snowbird, Utah, January 7, 2010.
42. J. G. Eden, "Recent advances in large arrays of microcavity plasma devices: Physics and applications," Varian Semiconductor Equipment Associates, Gloucester, MA, November 6, 2009.
43. J. G. Eden, "Large arrays of microplasmas: Science, applications, and the road ahead," 62nd Gaseous Electronics Conference, Saratoga Springs, NY, October 23, 2009.
44. J. G. Eden, "Opportunities at the confluence of microplasmas and nanomaterials," Colloquium on Nanoscience and Plasmas," Center for Nanoscience and Engineering, Albany, NY, October 21, 2009.

45. J. G. Eden, "Arrays of microcavity plasmas for flexible displays and lighting," 2009 KAIST CAFDC International Workshop on Flexible Displays, Daejeon, South Korea, June 25, 2009.
46. J. G. Eden, "Large arrays of microcavity plasmas and their applications," Department of Physics, Central Michigan University, Mt. Pleasant, MI, March 19, 2009.
47. J. G. Eden, "Recent developments in large arrays of microcavity plasma devices: Physics and applications," IEEE/LEOS Distinguished Lecture, LEOS Santa Clara Valley Chapter, Milpitas, CA, September 18, 2008.
48. J. G. Eden, "Emerging photonics applications of large, flexible arrays of microcavity plasma devices," IEEE/LEOS Distinguished Lecture, LEOS Rochester Chapter, Corning Sullivan Research Park, Corning, New York, September 4, 2008.
49. J. G. Eden, "Emerging photonics applications of large, flexible arrays of microcavity plasma devices," International Conference on Electronic Materials 2008 (ICEM 2008), Sydney, Australia, July 30, 2008.
50. J. G. Eden, "Probing fundamental atomic and molecular processes by femtosecond laser spectroscopy: Window onto dipole-dipole interactions and molecular dissociation," Department of Physics Colloquium, Technion (Israel Institute of Technology), Haifa, Israel, May 15, 2008.
51. J. G. Eden, "Arrays of microcavity plasma devices: Hybrid, non-equilibrium plasma/photonic devices for displays and photochemical processing," 5th Asia-Pacific International Symposium on the Basics and Applications of Plasma Technology, Kaohsiung, Taiwan, December 11, 2007.
52. J. G. Eden and S.-J. Park, "Arrays of microcavity plasma devices: Hybrid, non-equilibrium plasma/photonic devices for displays and photochemical processing," 29th International Symposium on Dry Process, Tokyo, Japan, November 13, 2007.
53. J. G. Eden and S.-J. Park, "Recent developments in large arrays of microcavity plasma devices," 4th International Workshop on Microplasmas, Tainan, Taiwan, October 29, 2007.
54. J. G. Eden, "Arrays of microcavity plasmas: Hybrid, non-equilibrium plasma/photonic devices for display, lighting, and photochemical applications," Sandia National Laboratories, Albuquerque, NM, September 5, 2007.
55. J. G. Eden, "Laser spectroscopy and microcavity plasma devices: Tools for improving HID lamp performance," International Seminar on LEDs, Displays, and Lighting (ISLDL 2007), Seoul, Korea, May 30, 2007.
56. J. G. Eden, "Microcavity plasma devices for display applications: Lightweight and inexpensive structures for the next generation," U.S. Army Research Laboratory, Adelphi, MD, November 16, 2006.
57. J. G. Eden, "New opportunities for plasma science in nonequilibrium, low temperature plasmas confined to microcavities: There's plenty of room at the bottom," Stevens Institute of Technology, Hoboken, NJ, October 11, 2006.
58. J. G. Eden, "New opportunities for plasma science in nonequilibrium, low temperature plasmas confined to microcavities: There's plenty of room at the bottom," Department of Nuclear, Plasma, and Radiological Engineering, University of Illinois, Urbana, IL, September 26, 2006.
59. J. G. Eden and S.-J. Park, "Arrays of microcavity plasma devices: Versatile platform for the next generation of plasma displays," International Meeting on Information Display/

International Display Manufacturing Conference (IMID/IDMC 2006), Daegu, Korea, August 24, 2006.

60. J. G. Eden, "Promoting innovation in a public university: Recent initiatives at the University of Illinois," Symposium on Innovation, G-8 Summit, Moscow, Russia, July 11, 2006.
61. J. G. Eden, "Dipole-dipole interactions between excited atoms probed by molecular wavepackets and parametric four wave mixing," International Workshop on Correlated and Many-Body Phenomena in Dipolar Systems, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, May 30, 2006.
62. J. G. Eden, "Nonequilibrium Plasmas Confined to Microcavities: New Opportunities in Plasma Science and Its Applications (There's Plenty of Room at the Bottom)," Dept. of Chemical Engineering, Case Western Reserve University, Cleveland, OH, March 9, 2006.
63. J. G. Eden, "Nonequilibrium Plasmas Confined to Microcavities: A New Realm of Plasma Science and Its Applications," Dept. of Physics, Ruhr-Universität Bochum, Bochum, Germany, February 6, 2006.
64. J. G. Eden, "Arrays of Microcavity Plasma Devices: New Opportunities for Plasma Science and Its Applications," Invited paper G-2B-1, 6th Int. Conf. on Reactive Plasmas and 23rd Symp. Plasma Proc., Matsushima/Sendai, Japan, January 25, 2006.
65. J. G. Eden, "Nonequilibrium Plasmas Confined to Microcavities: New Opportunities in Plasma Science and Its Applications," Invited Paper RI2 5, 47th Annual Meeting of the American Physical Society Division of Plasma Physics, Denver, CO, October 27, 2005.
66. J. G. Eden, "Microcavity Discharge Devices and Arrays: A Photonic Platform for Photodetectors, Optical Amplifiers and Displays," Invited Paper LT2 1, 58th Gaseous Electronics Conference, San Jose, CA, October 18, 2005.
67. J. G. Eden, "Microcavity Plasma Devices and Arrays: A New Realm of Plasma Physics and Photonics Applications," Electromagnetics Seminar Series, University of Illinois, Urbana, IL, September 13, 2005.
68. J. G. Eden, "Microcavity Plasma Devices: A New Frontier in Plasma Science and Its Applications," Invited Plenary, International Conf. on Phenomena in Ionized Gases, Eindhoven, The Netherlands, July 18, 2005.
69. J. G. Eden, "Microcavity Plasma Devices and Arrays Fabricated in Semiconductor, Ceramic, or Metal/Polymer Structures: A New Realm of Plasma Physics and Photonics Applications," Invited Plenary, 32nd European Phys. Soc. Conf. on Plasma Physics, Tarragona, Spain, June 28, 2005.
70. J. G. Eden, "New opportunities in photonics applications: Microcavity discharge devices and arrays as emitters and photodetectors," Physics Dept., Bilkent University, Ankara, Turkey (LEOS Turkey Chapter) (May 2, 2005).
71. J. G. Eden, "New opportunities in photonics applications: Microcavity discharge devices and arrays as emitters and photodetectors," Koç University, Istanbul, Turkey (April 28, 2005).
72. J. G. Eden, "New opportunities in photonics applications: Microcavity discharge devices and arrays as emitters and photodetectors," LEOS Italy Chapter, Dipartimento Elettronica, University of Pavia, Pavia, Italy (April 27, 2005).
73. J. G. Eden, "New opportunities in photonics applications: Microcavity discharge devices as emitters and photodetectors," IEEE/LEOS Distinguished Lecturer Series, LEOS Denver/Boulder Chapter, Boulder, CO (April 14, 2005).

74. J. G. Eden, "New opportunities in photonics applications: Microcavity discharge devices as emitters and photodetectors," IEEE/LEOS Distinguished Lecturer Series, University of Dayton, Dayton, OH (April 1, 2005).
75. J. G. Eden, "New opportunities in photonics applications: Microplasma devices and arrays fabricated in semiconductors, ceramic, and polymer/metal multilayer structures," LEOS Los Angeles Chapter, University of California-Los Angeles (November 18, 2004).
76. J. G. Eden, "Microdischarge devices: A photonic building block for lighting, displays and biomedical diagnostics," 60th Anniversary Technical Symposium, APL Engineered Materials, Urbana, IL (September 21, 2004).
77. J. G. Eden, "New opportunities in photonics applications: Microplasma devices and arrays fabricated in semiconductors, ceramic, and polymer/metal multilayer structures," LEOS Dallas Chapter, University of Texas at Dallas (September 16, 2004).
78. J. G. Eden, "New opportunities in photonics applications: Microplasma devices and arrays fabricated in semiconductors, ceramic, and polymer/metal multilayer structures," Gordon Research Conference on Plasma Processing Science, Holderness School, Plymouth, NH (August 17, 2004).
79. J. G. Eden, "Microplasma devices in semiconductors, ceramic and polymer/metal multilayer structures: Photodetectors, optical amplifiers, and arrays," IEEE/LEOS Distinguished Lecturer Series, Wroclaw University of Technology, Wroclaw, Poland (June 1, 2004).
80. J. G. Eden, "Microplasma devices in semiconductors, ceramic and polymer/metal multilayer structures: Photodetectors, optical amplifiers, and arrays," IEEE/LEOS Distinguished Lecturer Series, Benelux Chapter, Technical University of Eindhoven, The Netherlands (May 28, 2004).
81. J. G. Eden, "Microplasma devices in semiconductors, ceramic and polymer/metal multilayer structures: Photodetectors, optical amplifiers, and arrays," IEEE/LEOS Distinguished Lecturer Series, Scottish Chapter, Heriot-Watt University, Edinburgh, Scotland (May 26, 2004).
82. J. G. Eden, "Microplasma arrays: Photonic devices for emission and photodetection," IEEE/LEOS Distinguished Lecturer Series, University of Central Florida (February 26, 2004).
83. J. G. Eden, "Microplasma arrays in semiconductors, ceramic and polymer/metal multilayer structures: Photonic devices for emission and detection," Graduate Seminar, Department of Electrical and Computer Engineering, University of Illinois, Urbana, IL (February 19, 2004).
84. J. G. Eden, "Microplasma arrays: Photonic devices for emission and photodetection," IEEE/LEOS Distinguished Lecturer Series, Montréal LEOS Chapter, Centre de Recherche Informatique de Montréal, Montréal, Quebec, Canada (November 25, 2003).
85. J. G. Eden, "Microplasma arrays: Photonic devices for emission and photodetection," IEEE/LEOS Distinguished Lecturer Series, Center for High Technology Materials (CHTM), University of New Mexico, Albuquerque, NM (October 24, 2003).
86. J. G. Eden, "Microplasma arrays: Photonic devices for emission and photodetection," IEEE/LEOS Distinguished Lecturer Series, LEOS Denver Chapter and Opt. Soc. of Am. Rocky Mountain Chapter, Colorado State University, Ft. Collins, CO (October 23, 2003).
87. J. G. Eden, "Microplasma devices in ceramic and multilayer structures: Photonic devices for emission and detection," 204th Meeting of the Electrochemical Society, Orlando, FL (October 16, 2003).

88. J. G. Eden, "Microdischarge arrays in ceramic and semiconductor multilayer structures: Photonic devices for emission and detection," Ceramic Interconnect Tech. 2003, Int. Microelectron. Packaging Soc., Denver, CO (April 9, 2003).
89. J. G. Eden, "Microdischarge devices fabricated in silicon, ceramic, and metal/polymer structures: Arrays, emitters, and photodetectors," Plenary Lecture, The 3rd International Workshop on Basic Aspects of Non-Equilibrium Plasmas Interacting with Surfaces (BANPIS 2003), Awaji, Hyogo, Japan (February 7, 2003).
90. J. G. Eden, "Planar microdischarge arrays: A new family of photonic devices," Anvik Corp., Hawthorne, NY (February 27, 2002).
91. E. M. Beltran, A. A. Senin, and J. G. Eden, "Visible solid state lasers and amplifiers," IEEE/LEOS Summer Topical Conference on Ultraviolet and Blue Lasers and Their Applications, Copper Mountain, CO (July 2001).
92. J. G. Eden, "Nonlinear optics in intense, femtosecond time scale fields: High order harmonic generation and detection of atomic wavepackets by four wave mixing," Indiana University and Purdue University at Indianapolis (IUPUI), Indianapolis, IN (March 29, 2001).
93. J. G. Eden, "Microdischarge arrays: A new family of photonic devices," Motorola Research Laboratories, Tempe, AZ (March 22, 2001).
94. Andrey A. Senin, A. L. Oldenburg, and J. G. Eden, "Time-frequency analysis of the ultraviolet signal resulting from probe pulse scattering by atomic wavepackets," 11th Int. Conf. on Lasers in Science, Technology, and Medicine, Sochi, Russia (September 2000).
95. J. G. Eden, "The light side of lasers and optics," ECE Explorations, University of Illinois (August 30, 2000).
96. Andrey A. Senin and J. G. Eden, "Analysis of the ultraviolet radiation generated by wave packets," 10th International Conference on Lasers in Science, Technology, and Medicine, Sochi, Russia (September 1999).
97. J. G. Eden, A. Oldenburg, H. C. Tran, and J. Gao, "Nonlinear optics on the 100 fs time scale: High harmonic generation and detection of atomic wavepackets by four wave mixing," Physics Colloquium, University of Illinois (March 11, 1999).
98. J. Gao, F. Shen, and J. G. Eden, "A new theoretical approach to high order harmonic generation," Annual Meeting of the IEEE Lasers and Electro-Optics Society, Orlando, FL (December 1998).
99. J. G. Eden and D. S. Funk, "Diode-pumped upconversion fiber lasers: Recent developments in the green, blue, and infrared," Annual Meeting of the IEEE Lasers and Electro-Optics Society, Orlando, FL (December 1998).
100. J. G. Eden, "Lasers in a new light: Ultraviolet and visible lasers in lithography, surgery, and other fascinating applications," University of Illinois (November 18, 1998).
101. J. G. Eden and D. S. Funk, "Recent developments in visible upconversion fiber lasers," International Conference on Applications of Photonic Technology (ICAPT '98), Ottawa, Canada (July 28, 1998).
102. J. G. Eden, "Fiber lasers in a new light: Upconversion fiber lasers in the green, blue, and ultraviolet," University of Toronto, Toronto, Canada (March 4, 1998).
103. J. G. Eden, "Fiber lasers in a new light: Upconversion fiber lasers in the green, blue, and ultraviolet," Sarnoff Corp., Princeton, NJ (March 3, 1998).

104. J. G. Eden, "Waveguides and wavepackets: Recent experiments in the generation of coherent visible and UV radiation," Corporate Sponsored Colloquium, Department of Electrical Engineering, University of Nebraska, Lincoln, NE (October 1997).
105. J. G. Eden, "Fiber lasers operating in the visible and ultraviolet," Purdue University, Department of Electrical and Computer Engineering, West Lafayette, IN (October 9, 1996).
106. D. S. Funk and J. G. Eden, "Upconversion lasers operating in the visible and ultraviolet," SPIE 1996 International Symposium on Optical Science, Engineering, and Instrumentation, Denver, CO (August 4-9, 1996).

BOOK REVIEWS

- Excimer Lasers, 2nd Edition*, C. K. Rhodes. ed., Springer-Verlag, Topics in Applied Physics, vol. 30, 2nd ed., 194 pp., reviewed February 1985 (*J. Opt. Soc. Am. B*₂, p. 390, February 1985).
- Electrical Breakdown and Discharges in Gases - Fundamental Processes and Breakdown*, E. E. Kunhardt and L. H. Luessen, eds., 466 pp. (Plenum Publishing Corp., 1983), review published in *Fusion Technology*, March 1985.
- Chemical Processing with Lasers* by Dieter Bauerle, vol. 1, Springer Series in Material Science, Aram Mooradian and Morton B. Panish, eds., 245 pp. (Springer-Verlag, 1986), review published in *Optical Engineering* 26:8, August 1987.
- Laser Processing of Thin Films and Microstructures* by Ian Boyd, Springer-Verlag Series in Materials Science, vol. 3, 1st Edition, 320 pp. (Springer-Verlag, 1987), reviewed for *IEEE Circuits and Devices Magazine*, January 1988.
- Pulsed Gas Lasers* by G. A. Mesyats, V. V. Osipov, and V. F. Tarasenko, 374 pp. (SPIE Optical Engineering Press, Bellingham, WA, 1995), review published in *Optics and Photonics News*, Optical Society of America, pp. 48, 49, 50, 54, December 1995.

REVIEWER FOR:

Academic Press	Journal of the Electrochemical Society
AFOSR	Journal of the Optical Society of America B
Applied Physics	Journal of Vacuum Science and Technology
Applied Physics Letters	Lasers and Particle Beams
ARO	NASA
Australian Academy of Sciences	NSERC (Canada)
Australian Research Council	NSF
Austrian Science Fund	Optics Letters
Canadian Journal of Physics	Petroleum Research Fund
Chilean Research Organization	Physical Review A
City University of Hong Kong	Physical Review Letters
Hong Kong University of Science & Technology	Science Foundation Ireland
IEEE Journal of Quantum Electronics	US-Israel Binational Science Foundation
IEEE Photonics Technology Letters	Zeitschrift Für Physik D
IEEE Press	External Examiner for:
Israel Science Foundation	University of Toronto
John Wiley and Sons	Macquarie University (Sydney, Australia)
Journal of Applied Physics	Windsor University (Windsor, Ontario)
Journal of Chemical Physics	Nanyang Technological University (Singapore)
Journal of Laser Applications	University of Western Ontario (London, ON)
Journal of Physical Chemistry	

OTHER PROFESSIONAL POSITIONS

A. TECHNICAL CONSULTANT/EXPERT WITNESS

- Prof. Eden has been or is a consultant and/or expert witness for numerous legal firms in the United States, Canada, and the UK, including: Steptoe and Johnson (New York), Norton Rose Fulbright (Dallas), Brooks Kushman (Ann Arbor), Flaster Greenberg (Philadelphia), Goodwin Procter (Boston), Kirkland & Ellis (Chicago), Jones Day (Chicago), Alston & Bird (Charlotte), Condo, Roccia & Koptiw (Philadelphia), Latham & Watkins (Washington, D.C., San Francisco, New York, Chicago); Wilmer – Hale (Boston and Washington, DC); Nutter, McClennan & Fish (Boston, MA); Wilson, Sonsini, Goodrich & Rosati (Palo Alto, CA); McCutchen, Doyle, Brown & Enersen (San Francisco, CA); Osha Liang (Houston); Piasetzki & Nenniger (Toronto, Canada); Lovell, White & Durrant (London, UK); Smart and Biggar (Ottawa, Canada); Morrison and Foerster (San Francisco, CA and Washington, D.C.); Morris, Polich & Purdy (Los Angeles, CA), Harness, Dickey & Pierce (St. Louis, MO) and Parisi and Bellavia (Rochester, NY). He has prepared expert reports concerning patent infringement and validity, been deposed, and has testified in four trials held at the International Trade Commission (ITC) and Federal Courts in both the U.S. and Canada. The matters in which he has been involved are:
 1. Summit Technology, Inc. v. VISX, Inc., Civil Action No. 95-524 SLR, United States District Court, District of Delaware (expert report, deposition), 1996-1997.
 2. United States Federal Trade Commission, Docket No. 9286, *In the Matter of Summit Technology, Inc. and VISX, Inc.* (expert report, deposition, and trial testimony), 1998-1999.
 3. Autonomous Technologies, Inc. v. Pillar Point Partners, Civil Action No. 96-515, United States District Court, District of Delaware (expert report), 1998.
 4. United States International Trade Commission, Washington, DC, Investigation No. 337-TA-419, VISX v. NIDEK (expert reports, deposition, trial testimony), 1999.
 5. Federal Court of Canada — Trial Division, Montréal, Action No. T-195-94, VISX v. NIDEK (expert reports, deposition, trial testimony), 1998-1999.
 6. VISX, Inc. v. Lasersight, Inc., Civil Action No. 99-789-JJF, United States District Court, District of Delaware (expert report and deposition), 2001.
 7. United States District Court, Northern District of California, San Francisco Division, MDL No. 1319, NIDEK Excimer Laser Surgery Systems Patent and Antitrust Litigation (expert reports and deposition), 2002-2003.
 8. United States District Court, Northern District of California, Case No. C025601 MHP, ASM Lithography B.V. and ASM Lithography, Inc. v. Nikon Corporation and Nikon Precision, Inc. (expert reports), 2003.
 9. Atchison v. Tri-Lakes Eye Center, Case No. 04AFCV00676, Circuit Court, Taney Co., MO (deposition), 2006.
 10. Iridex Corp. vs. Synergetics USA, Inc., United States District Court, Eastern District of Missouri, Case No. 4:05CV01916CDP (expert reports, deposition), 2006-2007.
 11. Axsun Technologies, Inc., and Volcano Corp. v. Lightlab Imaging, Inc., Civil Action No. 5250 – VCS, Court of Chancery of Delaware (expert reports, deposition) 2010 – 2011.
 12. ASML Netherlands B.V., Excelitas Technologies Corp., and Qioptiq Photonics GmbH & Co. KG v. Energetiq Technology, Inc., Case No. IPR 2015-01375, U.S. Patent and Trademark Office, Patent Trial and Appeal Board (multiple IPR declarations and reports, deposition), 2015-2016.
 13. Iradion Laser, Inc. v. Novanta Corp., Case No. IPR 2017-00241, U.S. Patent and Trademark Office, Patent Trial and Appeal Board (IPR declarations, deposition), 2017.

14. Quanergy Systems, Inc. v. Velodyne LiDAR, Inc., IPR Case Nos. 2018-00255 and 2018-00256, U.S. Patent and Trademark Office, Patent Trial and Appeals Board (multiple IPR declarations, deposition), 2017-2019.
15. United States International Trade Commission, Washington, D.C., Investigation No. 337-TA-1172, "*Certain Filament Light-Emitting Diodes and Products Containing Same*", University of California Board of Regents v. IKEA, Walmart, and Amazon (expert reports, deposition; in support of IKEA), 2019-2020.
16. SATCO v. Seoul Semiconductor Co, Inc. and Seoul Viosys Co., Ltd., IPR Case No. 2020-00704, U.S. Patent and Trademark Office, Patent Trial and Appeal Board (internal notes), 2020.
17. United States International Trade Commission, Washington, D.C., Investigation No. 337-TA-1220, "*Certain Filament Light-Emitting Diodes and Products Containing Same*", University of California Board of Regents v. Respondents GE Lighting/Savant, Global Value Lighting, Home Depot USA, IKEA, Satco Products, Signify (Philips) North America, and Feit Electric (Claim construction and non-infringement expert reports, two depositions, ITC Evidentiary Hearing testimony in support of all Respondents except Feit Electric), 2020-2021.
18. Cao Lighting, Inc. v. General Electric Company, Consumer Lighting (U.S.), LLC d/b/a GE Lighting, and Current Lighting Solutions, LLC, United States District Court, District of Delaware, C.A. No. 1:20-681-MN (non-infringement reports, declaration, deposition, District Court testimony), 2021-2023; Norton Rose Fulbright, Brooks Kushman.
19. Epistar Corp. v. Lowe's Companies, Inc., and Lowe's Home Centers, LLC, United States District Court for the Western District of Texas, Waco Division, Civil Case No.: 6:20-cv-00420-ADA (invalidity and non-infringement reports, depositions), 2021-2024; Steptoe and Johnson, Jones Day, Stevens & Lee.
20. Lumentum Operations LLC v. nLight, Case No. 3:22-cv-05186-BHS, Western District of Washington, Tacoma (reports), 2023-Present; Faegre Drinker Biddle & Reath.
21. Luminex International Co. v. Signify, IPR Petition and Declaration – U.S. No. 10,299,336 (October 25, 2023); Signify v. Menard, Case No. 3:22-cv-00706-jpd (report for Luminex International Co. IPR), 2023-Present; Jones Day.
22. Samsung Display v. Pictiva Display International Ltd. (IPRs), 2024 – Present; Covington & Burlington.

Several of these matters concerned LED lighting and luminaire technology and laser technologies, including semiconductor, excimer, fiber, and solid-state systems as well as their applications to corneal refractive laser surgery (Photorefractive Keratectomy and LASIK), or cataract surgery. Other matters related to displays, photolithography, fiber optic technology, light engines for Optical Coherence Tomography (OCT), autonomous vehicle LIDAR, or laser-driven plasma lamps.

- Member, Task Force on Laser-Induced Photoionization Effects, DOD Directorate for Joint Non-Lethal Weapons (2011-2012).
- Member, Executive Advisory Board, Department of Physics, University of South Florida (Tampa, FL) 2006-2010.
- Member, Technical Advisory Board: Anvik Corp. (Hawthorne, NY) and Caviton, Inc. (Urbana, IL).
- He has also consulted for a number of companies and organizations including: Acculight, Caviton, Inc., (Urbana, IL), Motorola (Tempe, AZ), EKMS (Cambridge, MA), Anvik Corp. (Hawthorne, NY), Applied Energetics (Tucson, AZ), Eden Park Illumination (Champaign, IL), Eaton Corp. (Milwaukee, WI), Sarnoff Corp. (Princeton, NJ), General Electric, GTE-Sylvania (Government Systems Div., Mountain View, CA), the Air Force QRC Support Center (Rolling Meadows, IL),

APL Engineered Materials (Urbana, IL), the Liquid Air Corp., the Northrop-Grumman Corp. (Rolling Meadows, IL), Ewing Technology Associates (Bellevue, WA), Kirtland AFB (Albuquerque, NM), Acumen (Santa Barbara, CA.), Eden Park Illumination, and Light Age, Inc., in lasers, ultraviolet, visible and infrared lamps, materials processing, laser spectroscopy, semiconductor device fabrication, and intellectual property management.

- Prof. Eden has taught numerous short courses on lasers (fiber and planar waveguide, short wavelength), electro-optics, and semiconductor processing at international conferences for 20 years and at the George Washington University (Washington, DC), 1977-78.

B. MAJOR CAMPUS RESPONSIBILITIES

Associate Vice-Chancellor for Research, 2000-2003.

Research Standards Officer, UIUC, 2000-2003.

Associate Dean, Graduate College, 1994-1996.

Assistant Dean, College of Engineering, 1992-1993.

Faculty Excellence Review Committee, 2008-2010.

Chair, College of Engineering Forward Planning Committee, 1993.

Chair, Management of Technology Program Development Committee.

Chair, College of Engineering Task Force on Diversity, 1999-2000.

Elected Member, University Senates Conference, 1999-2001.

Elected Member, Urbana-Champaign Faculty Senate (served 2 terms).

College of Engineering Awards Committee.

Department of Electrical and Computer Engineering Advisory Committee.

Assembly Hall Advisory Committee.

Oversight Committee: CU Aerospace, 2001-2003 , Powerworld, 2001-2003.

Campus Radiation Safety Committee 2003 - 2006.

Advisory Committee on Endowed Appointments, College of Engineering, 2007-2009.

Faculty Technical Advisory Board, Applied Research Institute, 2014 – 2015.