

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GIESECKE+DEVRIENT GMBH, GIESECKE+DEVRIENT CURRENCY
TECHNOLOGY GMBH, AND PAPIERFABRIK LOUISENTHAL GMBH
Petitioners

v.

LUMENCO, LLC
Patent Owner

U.S. Patent No. 10,901,191
IPR No. 2024-00838

DECLARATION OF LAMBERTUS HESSELINK, PH.D.

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EXHIBIT LIST

Exhibit	Description
Ex. 1001	U.S. Patent No. 10,901,191 to Raymond (“the ’191 patent”)
Ex. 1002	File History of U.S. Patent No. 10,901,191 FH
Ex. 1003	Declaration of Lambertus Hesselink, Ph.D.
Ex. 1004	US62262767 Provisional
Ex. 1005	Reserved
Ex. 1006	DE102010048262A1 Official Translation into English (“Fuhse262”)
Ex. 1007	Reserved
Ex. 1008	U.S. Patent No. 10,639,925 to Fuhse (“Fuhse925”)
Ex. 1009	Reserved
Ex. 1010	U.S. Patent Application Publication No. 2012/0319395 (“Fuhse395”)
Ex. 1011	Reserved
Ex. 1012	WO 98/08131
Ex. 1013	2007/0110317 A1 (“Davis”)
Ex. 1014	U.S. Patent No. 5,396,559 to McGrew (“McGrew”)
Ex. 1015	Reserved
Ex. 1016	DE102010049617A1 Official Translation into English (“Fuhse617”)
Ex. 1017	Reserved

Exhibit	Description
Ex. 1018	DE102015005969A1
Ex. 1019	U.S. Patent No. 7,808,710 (“Hasen”)
Ex. 1020	U.S. Patent No. 10,525,759 (“Rahm”)
Ex. 1021	Reserved
Ex. 1022	Reserved
Ex. 1023	Reserved
Ex. 1024	Robert Morford, Wu-Sheng Shih, and JoElle Dachsteiner “Press-patterned UV-curable high refractive index coatings”, Proc. SPIE 6123, Integrated Optics: Devices, Materials, and Technologies X, 612301 (15 February 2006); https://doi.org/10.1117/12.643164 (“Morford”)
Ex. 1025	Reserved
Ex. 1026	Lee R.A., Leech P.W., “Development of Optically Variable Devices for Document Security in CSIRO Journal of the Coatings Association of Australia,” Vol. 42(8), August 2005, p. 22-27.
Ex. 1027	Hecht, E., Optics (4th Ed. 2002)
Ex. 1028	Saleh and Teich. Fundamentals of Photonics (1st Edn. 1991), Ch. 1
Ex. 1029	Ebewele, R.O. (2000). Polymer Science and Technology (1st ed.). CRC Press.
Ex. 1030	Franssila, S. Introduction to Microfabrication (1st ed. 2004)
Ex. 1031	Finale coin in the Australian Centenary of Federation Program Featuring an Optically Variable Device
Ex. 1032	Reserved
Ex. 1033	U.S. Patent Application Publication No. 2014/0285892

Exhibit	Description
	(“Sauvage-Vincent”)
Ex. 1034	Leech, P.W., Lee, R.A., and Brett, Sexton, B.A., and Smith, F., “Hot Embossing of Micrographic Elements in Polypropylene,” <i>Microelectronic Engineering</i> 84: 109–113 (2007)
Ex. 1035	Reserved
Ex. 1036	Curriculum Vitae of Lambertus Hesselink
Ex. 1037	U.S. Pat. App. Pub. No. 2014/0285892 (“Sauvage-Vincent”)
Ex. 1038	Reserved
Ex. 1039	Reserved
Ex. 1040	Reserved
Ex. 1041	Reserved
Ex. 1042	Lee, R.A. Micromanufacturing for Document Security: Optically Variable Devices. In: <i>Micromanufacturing and Nanotechnology</i> . Springer, Berlin, Heidelberg (2006).
Ex. 1043	Reserved
Ex. 1044	Reserved
Ex. 1045	Reserved
Ex. 1046	Reserved
Ex. 1047	U.S. Patent No. 4,761,253 (“Antes”)

CHALLENGED CLAIMS

Claim 1	
1Pre	A method of fabricating a security element useful on paper and coin currency and product labels, comprising:
1a	providing a substrate; and forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and, in response, displaying an image in a plane spaced a distance apart from the surface of the substrate, wherein the image comprises a plurality of pixels,
1b	wherein the array of micro mirrors includes for each of the pixels a different set of the micro mirrors each having a reflective surface oriented, in a fixed manner, with a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body, to reflect the ambient light toward a point on the plane corresponding to one of the pixels,
1c	wherein each of the different sets concurrently reflect the ambient light to concurrently generate the plurality of pixels,
1d	wherein a voxel is created at each of the point on the plane via intersection of two or more beams of the reflected ambient light, and
1e	wherein each of the created voxels produces an effect of a point source of light floating above the surface of the substrate in the plane.
Claim 2	
2	The method of claim 1, wherein the forming the array of micro mirrors comprises casting the micro mirrors with a mirror tool in contact with the surface of the substrate, wherein the substrate comprises a clear, energy-cured polymer.
Claim 3	
3	The method of claim 1, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.
Claim 4	

4	The method of claim 3, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors and wherein the surface of the substrate includes an embossable coating or layer.
Claim 5	
5a	The method of claim 1, wherein the forming the array of micro mirrors comprises filling in recessed surfaces associated with the micro mirrors with a filler comprising at least one of an ultraviolet (UV) varnish, an e-beam solvent, and a water-based varnish and
5b	wherein the filler has a refractive index of at least 1.55,
5c	whereby at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image.
Claim 6	
6Pre	A method of fabricating a security element useful on paper and coin currency and product labels, comprising:
6a.1	providing a substrate; and forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and, in response, displaying a first image and a second image in a plane spaced a distance apart from the surface of the substrate at first and second viewing angles, respectively,
6a.2	wherein the first and second images each comprises a plurality of pixels, and
6b	wherein the array of micro mirrors includes for each of the pixels a unique set of the micro mirrors each having a reflective surface rigidly oriented, by rotating a body of each of the micro mirrors about at least one of two rotation axes extending through the body, to reflect the ambient light away from the substrate toward a point on the plane corresponding to one of the pixels,
6c	wherein each of the unique sets of the micro mirrors includes a number of the micro mirrors in the range of 2 to 40, and
6d	wherein the reflected ambient light from the number of the micro mirrors intersects at the point corresponding to the one of the pixels to create a voxel, whereby the voxel acts like a point light source positioned in the plane at the point corresponding to the one of the pixels.

Claim 7	
7	The method of claim 6, wherein the forming the array of micro mirrors comprises casting the micro mirrors with a mirror tool in contact with the surface of the substrate.
Claim 8	
8	The method of claim 7, wherein the substrate comprises a clear, energy-cured polymer.
Claim 9	
9	The method of claim 6, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.
Claim 10	
10	The method of claim 9, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors.
Claim 11	
11	The method of claim 10, wherein the surface of the substrate includes an embossable coating or layer.
Claim 12	
12a	The method of claim 6, wherein the forming the array of micro mirrors comprises filling in recessed surfaces associated with the micro mirrors with a filler comprising at least one of an ultraviolet (UV) varnish, an e-beam solvent, and a water-based varnish and
12b	wherein the filler has a refractive index of at least 1.55,
12c	whereby at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image.

I. INTRODUCTION

1. My name is Dr. Lambertus Hesselink. I have been retained by Petitioners Giesecke+Devrient GmbH, Giesecke+Devrient Currency Technology GmbH, and Papierfabrik Louisenthal GmbH (collectively, “G+D” or “Petitioners”) to provide expert opinions with respect to U.S. Patent No. 10,901,191 (the “’191 Patent”), which I understand is assigned to Patent Owner Lumenco, LLC (“Lumenco” or “Patent Owner”).

2. I am being compensated at my standard consulting rate of \$675 per hour for my time, plus reasonable out-of-pocket expenses. I have received no additional compensation for my work in this matter, and my compensation does not depend upon the content of my opinions, any testimony that I may provide, or the ultimate outcome of the matter. All of the opinions set forth in this declaration are my own.

II. BACKGROUND AND QUALIFICATIONS

3. Full descriptions of my educational background, professional work, qualifications, and publications are set forth more fully in my curriculum vitae, which is attached to this declaration as Exhibit 1036. Here, I provide a summary of my background and qualifications.

4. I am currently a Professor of Electrical Engineering in the Department of Electrical Engineering at Stanford University, and by courtesy in the Departments of Applied Physics and Aeronautics and Astronautics.

5. In 1970, I received a Bachelor of Science degree in Mechanical Engineering from the Twente Institute of Technology in Enschede, Netherlands, and a Bachelor of Science degree in Applied Physics from the same institution in 1971. The following year, I received my Master of Science degree in Mechanical Engineering from California Institute of Technology. In 1974, I obtained an Applied Mechanics engineering degree from the Twente Institute of Technology, and then I subsequently continued my studies at the California Institute of Technology and, in 1977, earned my doctorate degree in Applied Mechanics and Physics/Applied Physics.

6. My expertise is in ultra-high density optical data storage, and optical information systems generally, as well as optical communication components, nano photonics, optics and optical systems, and optical interconnects. I have been awarded several scientific awards from scientific and professional societies, including the Fulbright Scholarship, Stheeman Price Award, DARPA Award, Best Paper Awards from the Institute of Electrical and Electronics Engineers (IEEE) and OSA, Fellow of the Optical Society of America (OSA), the Society of Photo- Optical Instrumentation Engineers (SPIE), and the National Information Solutions Cooperative (NISC), among others. In addition to being an assistant, associate, or full Professor performing research in these fields for over 30 years, I am a member of the Royal Dutch Academy of Arts and Sciences, the National Academy of

Inventors, have been the keynote or invited speaker in over 290 scientific meetings, and the organizer of over 70 scientific meetings, have authored more than 500 papers in scientific journals, have written over 15 book chapters on optics, data analysis and visualization, optical storage, and image processing, and have been the editor of several scientific publications, including *Applied Optics*, *Applied Scientific Research*, and *IEEE Transaction on Visualization*.

7. I have had an intimate knowledge of the technology of optical systems since at least 1978. I have taught courses at the California Institute of Technology and Stanford University on optical systems design, modern optics, optical signal processing and digital image processing, among others, for over 40 years, covering specific topics that include the design and operation of optical display systems. Since at least the early 1980s, I have been leading research and development of 3-D displays, including autostereoscopic holographic displays, 3-D up conversion display, 3-D displays for security applications, grating-based displays, as well as data analysis of complex 3-D flow visualizations using scanning laser systems, tomography, and mathematical topology. We invented numerous 3-D display and storage devices and used interferometry to determine the 3-shape of objects using optical and X-ray scanners. Using the Stanford nano-fabrication facilities we implemented and tested our displays using CMOS fabrication technology, among others.

8. In addition to my academic experience, I have extensive corporate and consulting experience. I have founded three high-technology companies, I have been Chief Technology Officer in the Branded Products division of Western Digital, I have been a member of the Scientific Advisory Board of the United States Air Force, and I was a member of one of the two NASA Ad Hoc Advisory Committees tasked with repairing the Hubble Space Telescope just after its launch. With a broad knowledge of optics, optical systems and devices, optical storage systems, a solid grounding in 3-D displays and its underlying technologies and components, and experience with the patent and trade secret process, I believe that I am qualified to provide an accurate assessment of the technical issues addressed in this declaration.

9. In particular, as noted in Section VII below, my opinion is that a POSITA as of December 3, 2015 would have had an undergraduate degree in mechanical or electrical engineering or physics and at least two years of experience in micro-optics design. I met and exceeded those requirements as of December 2015.

10. Given my experience in the field, I am familiar with the knowledge that a person of ordinary skill in the art would have had at the time and the manner in which such a person would have viewed the available information at the time. My testimony is offered from this perspective, even if it does not specifically refer to the perspective of a person of ordinary skill in the art in every instance.

11. My opinions are also based on investigation and study of the patent at issue, its file history, and the prior art. In the course of forming my opinions, I have reviewed all the relevant exhibits submitted with the Petition, which are specifically identified in the Exhibit List and that may be additionally referenced herein.

12. I may rely upon these materials and/or additional materials to rebut arguments raised by Lumenco. Further, I may also consider additional documents and information in forming any necessary opinions including documents that may not yet have been provided to me.

III. LEGAL UNDERSTANDING

13. I understand that issues such as invalidity and claim construction are analyzed based on certain legal standards. Counsel for Petitioner has provided me with an understanding of these standards, and I have applied them in my analysis set forth in this declaration.

A. The Person of Ordinary Skill in the Art

14. I understand that a person of ordinary skill in the art (“POSITA”) is a hypothetical person who is presumed to be aware of all pertinent prior art, thinks along conventional wisdom in the art, and is a person of ordinary creativity—not an automaton.

15. I understand the level of ordinary skill in the art is evaluated based on various factors, including: the level of education and work experience of persons in

the field; the type of problems encountered in the field; and the sophistication of the technology at issue.

B. Claim Construction

16. I understand that, as a general rule, the claim terms of a patent are understood to have their ordinary and customary meaning to a POSITA at the time of the invention when read in the context of the patent and its prosecution history. I understand that there are certain exceptions to the general rule, including lexicography and disavowal, but I have not been asked to analyze those exceptions in connection with this proceeding.

C. Obviousness

17. I understand a patent claim is still invalid if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in the pertinent art.

18. I understand an obviousness determination includes the consideration of various factors, including the scope and content of the prior art, the differences, if any, between the prior art and the claimed subject matter, the level of ordinary skill in the art, and any “secondary considerations,” also called objective indicia of obviousness or non-obviousness.

19. I understand an obviousness determination can be based on a single prior art reference or a combination of multiple prior art references and the knowledge of a POSITA. I understand the prior art itself may provide a suggestion, motivation, or reason to combine or modify the teachings of the prior art, or that such a reason may come from other sources, such as the knowledge of a POSITA, common sense, and market forces. However, I understand it is impermissible to rely on hindsight or to use the claimed invention as a roadmap to reach a finding of obviousness.

20. I understand the following rationales may support a finding of obviousness:

- Combining prior art elements according to known methods to yield predictable results;
- Simple substitution of one known element for another to obtain predictable results;
- Use of known technique to improve similar devices (methods, or products) in the same way;
- Applying a known technique to a known device (method or product) ready for improvement to yield predictable results;
- “Obvious to try” – choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- Known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art;

- Some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

21. I understand an obviousness finding requires a reasonable expectation of success in achieving the claimed invention. The expectation of success need only be reasonable; a perfect implementation or commercial embodiment of the invention is not required.

22. I understand that objective indicia of obviousness or non-obviousness may include commercial success attributable to the alleged invention; a long-felt but unmet need for the alleged invention; praise of the alleged invention by others in the field; and skepticism towards the alleged invention by experts. I understand that any secondary considerations must bear a nexus to the alleged invention. I understand the nexus requirement is not satisfied if, for example, the purported commercial success is tied to features of a product that were known in the prior art rather than the alleged invention.

IV. SUMMARY OF INVALIDITY GROUNDS

23. For purposes of this declaration, I have been asked to analyze claims 1-12 (“Challenged Claims”) of the ’191 patent in view of the prior art. In my opinion, the challenged claims are obvious based on the following grounds:

- Ground 1: Claims 1 and 6 of the ’191 Patent are rendered obvious by Fuhse262 (combination of embodiments).
- Ground 2: Claims 1 and 6 of the ’191 Patent are rendered obvious by Fuhse262 in view of Fuhse925.
- Ground 3: Claims 2-4 and 7-11 of the ’191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Fuhse395.
- Ground 4: Claims 2-4 and 7-11 of the ’191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Sauvage-Vincent.
- Ground 5: Claims 5 and 12 of the ’191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Morford.
- Ground 6: Claims 2-4 and 7-11 of the ’191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Fuhse395 (Ground 3).
- Ground 7: Claims 2-4 and 7-11 of the ’191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Sauvage-Vincent (Ground 4).

- Ground 8: Claims 5 and 12 of the '191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Morford (Ground 5).

V. TECHNICAL BACKGROUND

A. Optical Security Features

1. Historical Development

24. 3-D security stickers or devices have been utilized on valuable items such as bank notes, clothing (such as NFL paraphernalia), equipment, devices, or instruments since at least the early 1990s. In the middle 1990s, I invented a holographic recording device that incorporated a security feature that could only be activated by a known optical readout with a random phase distribution. Holographic stickers have been applied to cereal boxes, toys, clothing, credit cards, banknotes even earlier. The underlying key enabling technology is based on optical readout of micro and nano structures embedded in a substrate. For holograms, it is a diffractive structure.

25. For displays, micromirrors are often utilized to create a specific optical two- or three-dimensional image that is only visible under certain readout conditions of ambient light, enabling widespread applications. One of the key requirements of the security labels is to prevent copying of the labels using readily available commercial copying machines. As these machines rely on 2-D optical readout of the information, 3-D micro- or nanostructures are the medium of choice for recording the security information. Besides holographic diffraction gratings, micromirrors are frequently embedded in a substrate to create 3-D visual displays that are difficult to copy with low-cost, commercially available copiers.

26. Optically variable devices (“OVDs”) for document anti-counterfeiting were introduced in the 1980s. For example, Australian commemorative ten-dollar plastic banknote issued in January 1988 using an OVD. EX1026, p. 22. The OVD on the 1988 banknote took the form of the schematic portrait of Captain Cook. *Id.*

27. By the late 1980’s OVDs with arrays and feature sizes on the order as those contemplated in the ’191 Patent were already being produced. For example, the Commonwealth Scientific and Industrial Research Organisation (“CSIRO”) in Australia developed a diffraction based OVD at that time, as explained in the article *Development of Optically Variable Devices for Document Security in CSIRO* (published in 2005):

“A further advance in OVD technology by CSIRO was implemented in 1989 as Pixelgram™. In this technology, the image was comprised of 30 x 30 µm or 60 x 60 µm pixel elements with the flexible allocation of a groove structure from a palette of fine gratings. Improved portraiture was among the technical capabilities of Pixelgram. By 1993, a new development of the technology was named Exelgram™. The prefix “*exel*” was derived from “*exposure element*”, a term devised to indicate that the diffraction pattern was written with the high resolution of electron beam equipment. Each Exelgram image was based on a very large number of gratings with the individual spacing of the grooves selected from a range of 10 different levels. The choice of groove spacing provided the corresponding iridescent colour in the individual 30 x 30 µm regions of the image.”

EX1026, p. 22.

28. OVDs are broadly applicable to many applications that require anti-counterfeiting, including currency, passports, ID cards, and product labels, these solutions use optical features to verify the authenticity of documents.

29. OVD technology has advanced rapidly over the years in order to “stay ahead” of rapidly advancing counterfeiting technology, including the proliferation of low-cost digital scanners and high-resolution color copiers.

2. Micro-Mirror Arrays

30. Micro-mirror arrays are structures embedded in a substrate that upon illumination of light create a visual image(s). The mirrors are typically small, on the order of 25-50 microns, so that they can be fabricated by electronic manufacturing techniques. Each of the mirrors in the array will reflect incident light in a certain direction determined by the orientation of the micro-mirror surface and the angle of incidence of the light, following well known laws of geometrical optics. By directing the reflected light of a collection of micro-mirrors 2D or 3D objects can be created floating in space. An observer of the floating images can often manipulate the images by changing the orientation of the micro-mirrors with respect to the illumination light beam. The illumination light beam is often a so-called plane wave, i.e., a beam in which all the rays are substantially parallel to each other, such as light coming from the sun. Often this light beam is referred to as ambient light. As an example,

by rotating or tilting the security label, multiple images can be visualized, or their geometry changed.

31. Micro-mirror arrays are also used for telecom applications involving optical communication beams or scanners, and in this application are often referred to as optical switches, because the orientation of the mirror surfaces can be dynamically changed by applying, for example, an electrical force. For security applications, which must be low cost for use on consumer products, the micro-mirror arrays are embedded into the substrate. To avoid copying and replication of the surface micro-mirror arrays using surface topology scanners, the micro-mirror arrays are typically covered by an optically transparent medium that is flat and smooth.

32. In the early 2000s, over a decade before the '191 Patent's earliest possible priority date, micro-mirror OVD had become well-known, which replaced diffraction gratings with arrays of micro-mirrors. Micro-mirror OVD technology advanced rapidly in the period from the early 2000s through December 2015 (the '191 Patent's earliest possible priority date).

33. As explained in the article *Development of Optically Variable Devices for Document Security in CSIRO* (published in 2005), micromirror arrays for document security and their methods of production were well-established, including the ability to individually orient each micromirror:

“A typical OVD microstructure comprised of a micro-mirror array (Figure10) may contain up to one million mirrors of dimensions 60 x

60 μm or less. **Each mirror is arranged at a predetermined angle according to the input picture in formation.**

The procedure for producing a micromirror OVD involves three main phases — i) production of an image specific mask by electron beam lithography, ii) UV exposure through the mask to produce the required micro-mirror surface relief structure in a thick layer of optical resist and iii) electroplating of this resist layer to produce a hard nickel tool.”

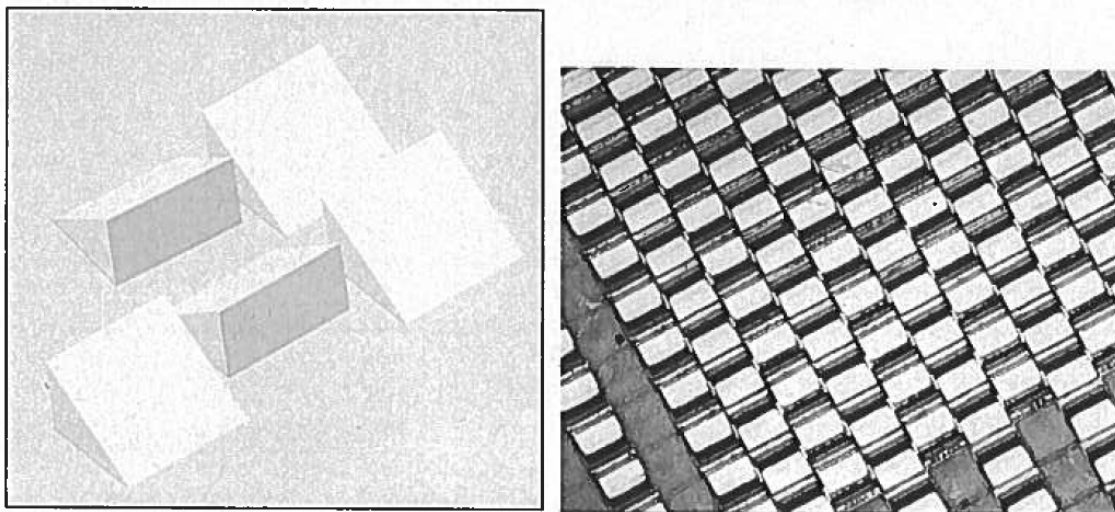


Figure 10. Optical micrograph of an experimental micro-mirror structure. Rows of micro-mirrors of opposing slopes can be seen here. In this particular case, each micro-mirror has a dimension of 30 x 30 μm .

EX1026, p. 26, FIG. 10.

34. This experimental micro-mirror OVD also provided “two angles of view” corresponding to the two images produced by the micromirror arrays.

EX1026, p. 26, FIG. 12.



B. Ray Optics

1. The Ray Model

35. The propagation of optical radiation such as solar beams, lasers and flashlights is governed by the laws of geometrical optics. Early experiments and quantitative analysis of light propagation dates back at least four hundred years ago, and rudimentary knowledge of light propagation was used by the Romans and the Greek for warfare. Three basic laws describe the propagation of rays. In this model, rays are mathematical entities with zero width along which energy flows (i.e. photons). Rays can be thought of as small pencils of light emanating in a particular direction from a source such as the sun, a laser, or a distant light in the room. Grouped together they form a bundle of light, such as a beam of light. The three laws for propagation of a light ray (i.e. a single ray, which may be part of a bundle.

The laws apply to the ray, and to a bundle when considering all the rays making up the bundle of light) are:

36. **(1)** Rays in a uniform medium (i.e. a medium that consists of one material only, such as air having the same properties everywhere) propagate along straight lines. See EX1027 (*Optics*, Hecht, 4th Edition (2002)), p. 98 (“In a medium that is uniform (homogeneous), rays are straight”); EX1028 (*Fundamentals of Photonics*, Saleh & Teich, 1st Edition (1991)), p. 4 (“*in a homogeneous medium, light rays travel in straight lines*”).

37. **(2)** Snell’s Law. A ray incident on the interface between two media, such as air and glass, follow Snell’s Law which says that the product of the sine of the angle of incidence of the ray on the medium times the index of refraction of the medium is constant across the interface of the two media. The index of refraction is a quantity that determines how much of the energy of the ray propagating in the medium gets absorbed and how fast the rays are propagating in the medium. See EX1028 (*Fundamentals of Photonics*, Saleh & Teich, 1st Edition (1991)), p. 5-6 (providing a proof of Snell’s Law).

38. **(3)** The law of reflection. This law states that the angle of incidence of a ray on a mirror is equal to the angle of reflection of the ray from the mirror. The angle of incidence and reflection are the angle between the surface normal and the incoming ray, and the angle between the reflected ray and the normal to the surface,

respectively. See EX1027 (*Optics*, Hecht, 4th Edition (2002)), pp. 98-99 (“the Law of Reflection means the “*angle-of-incidence equals the angle-of-reflection*”); EX1028 (*Fundamentals of Photonics*, Saleh & Teich, 1st Edition (1991)), p. 5 (“*the angle of reflection equals the angle of incidence*”).

39. Ray equation mathematics applied to micromirror arrays for security elements were well-known before the relevant time. For example, “Micromirror array nanostructures for anticounterfeiting applications” (published 2004) provided a derivation of the ray equations associated with a reflective micromirror, beginning with the following discussion:

2.1 Ray equations

Figure 2 shows a single reflecting pixel element of arbitrary surface form illuminated by a point light source at “A”, a distance R_{00} from a point “P” on the pixel surface and producing a reflected optical field. Point “B” is a point in the reflected optical field, a distance R_{10} from the point P. “O” is the origin of the coordinate system and X_0, Y_0, Z_0 represents the coordinates of the source point “A”, while X_1, Y_1, Z_1 are the coordinates of the point “B”. X, Y, Z are the coordinates of point P on the surface of the pixel.

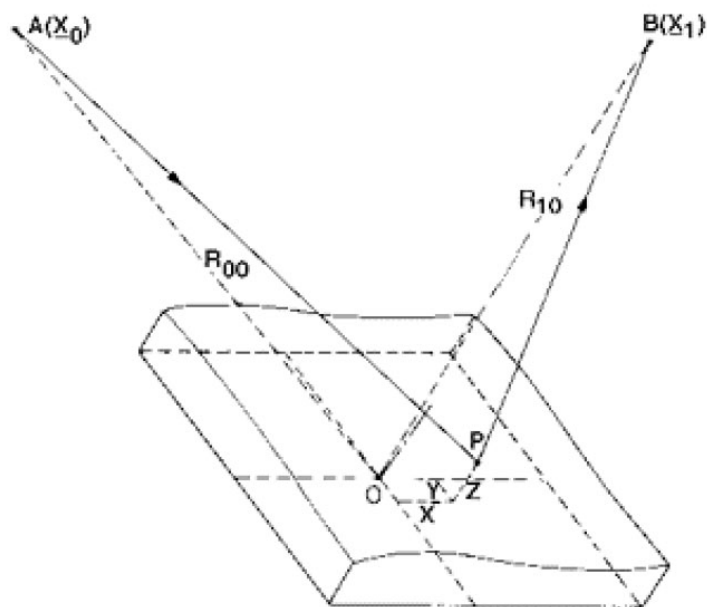


Figure 2. Pixel optical geometry

40. Additionally, CODEV and Zemax are commercially available ray trace programs that have been developed and used since the invention of digital computers for commercial applications. After the microcomputer became widely available as a personal computational tool (i.e. the Digital Equipment Corporation VAX 11-750 and VAX 11-780 from the early 1980s), these lens design programs became widely available around the world.

2. Ray Diagrams

41. Ray propagation is often visualized by drawing cartoons referred to as ray diagrams. Ray diagrams visualize the ray paths as a result of rays interacting with optical elements such as mirrors and lenses. Ray paths can be computed for a

given arrangement of lenses and mirrors using the three laws of geometrical optics.

See EX1027 (Optics, Hecht, 4th Edition (2002)), pp. 243-52.

42. As any light beam would have an infinite number of rays (they are infinitesimally thin), a theoretical framework has been developed over decades to determine which rays are critical to the (imaging) performance of the optical system.

43. This framework includes defining key rays whose paths through the optical system must be considered to determine optical performance. One of these is called a chief ray.

44. **Chief ray.** A chief ray is a ray that comes from an off-axis object point through the center of the aperture stop. The aperture stop is that stop in the system (say camera), that limits the amount of light that passes through the system from an on-axis object point. For example, cameras have variable aperture stops for adjusting the amount of light that falls on the detector. The chief ray for a micro-mirror element is the ray coming from the source, say the sun, and passing through the center of the micro-mirror. Knowing the direction at which the ray falls on the mirror (i.e. the angle between the mirror normal and the incoming light ray) the angle of reflection will be equal to the angle of incidence. *See EX1027 (Optics, Hecht, 4th Edition (2002)), p. 172.* As discussed in *Optics* (Hecht, 4th Edition (2002)), which states that “[t]he chief ray, associated with a conical bundle of rays from a point on

the object, effectively behaves as the central ray of the bundle and is representative of it.” See EX1027, p. 172.

45. When using parallel light (i.e. as used in the patent) all incident rays that are parallel to each other experience the same direction in which they are reflected.

3. Ambient Light

46. Ambient light generally refers to light in the ambient, or environment. This could be coming from the sun or a local light source. In the patent, ambient light refers to parallel light, i.e., all the rays coming from the source are parallel to each other.

C. Surface Orientations

1. Planar Surfaces

47. The position and orientation of planar surfaces with respect to a coordinate system, such as the x-y-z orthogonal coordinate system, is fully determined by its center position and the orientation of the surface as expressed by the normal vector. The vector is characterized by a length (typically normalized to one) and an orientation with respect to the coordinate system given by the projection of the vector on each of the three orthogonal coordinate axes, x, y, and z. As the normal vector to the surface is known, mathematical geometry allows computation of the so-called direction cosines, i.e. the angles the planar surface makes with respect to the coordinate axes. Each representation, based on either the direction

cosines or the normal to the planar surface is interchangeable with the other through straight forward geometrical mathematics.

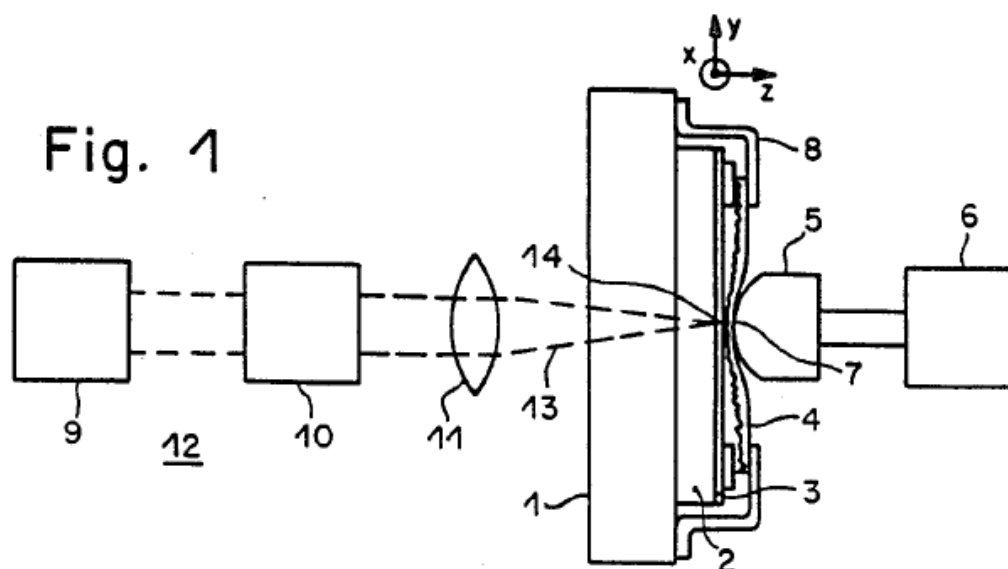
D. Fabrication Methodologies

1. Embossing

48. Various embossing techniques were conventional techniques for producing optical microstructures, including micromirrors, before the relevant date.

49. The state of the art for embossing optical structures was very advanced by 2015, as these processes had been in commercial use for many decades across different industries. For example, the mass production of optical discs (such as DVDs) involved various kinds of embossing techniques on polymer substrates.

50. For example, U.S. Patent No. 4,761,253 (“Antes”)(EX1047) assigned to Landis+Gyr was filed in 1985, and discloses methods for embossing thermoplastics to create optical diffraction gratings with “microscopic relief structures.” EX1047, Abstract, 2:43-3:15. Just like the ’191 Patent, and as shown in Figure 1 below, Antes teaches a polymer (thermoplastic layer 3) that is embossed with nickel embossing die 4. *Id.*



51. “Embossing”, and in particular “hot embossing” “is the name used for volume stamping of MEMS structures and is sometimes referred to as hot embossing lithography (HEL).” See EX1030 (*Introduction to Microfabrication*, Franssila, 1st Edition (2004)), p. 183.

52. Embossing was a conventional technique for producing microstructures such as micromirrors before the relevant period. Hot embossing may be described as follows:

“18.3.1 Hot embossing

Hot embossing involves pressing a master against a polymer at a temperature slightly above the polymer glass transition temperature. The equipment for hot embossing is shown in Figure 18.8. The process has three major issues: filling of structures by polymer (Figure 18.8(b)), reproduction fidelity and master separation and de-embossing.

Both the wafer and the master stages are heated above the polymer glass transition temperature T_g . Widely used polymers such as PMMA have a T_g of 106 °C and polycarbonate (PC) has a T_g of 150 °C. The master is then pressed against the polymer. The

embossing force is of the order of 20 to 30 kN and the hold time is of the order of one minute. De-embossing takes place after cooling below the glass transition temperature.

Polymeric materials have coefficients of thermal expansion (CTE) of the order of 20 to 100 ppm, whereas silicon has a CTE of 2.6 ppm and nickel, a typical electroplated master material, 13 ppm. Thermal cycling is mandatory for hot embossing but it should be minimized to around T_g to avoid thermal mismatch cracking.

The thickness of hot embossed structures can be varied enormously, from 150 nm to 150 μm . There is no resolution limit, and embossing can replicate structures down to 10 nm size; making the master becomes the limiting factor. The aspect ratios of embossed structures can be as high as 20:1, and up to 50:1 when special release coatings have been applied.

Hot embossing is suitable for simple structures, preferably involving only one patterning step. Various microfluidic and biomedical microdevices fall under this category, especially if they need to be cheap enough to be disposable.”

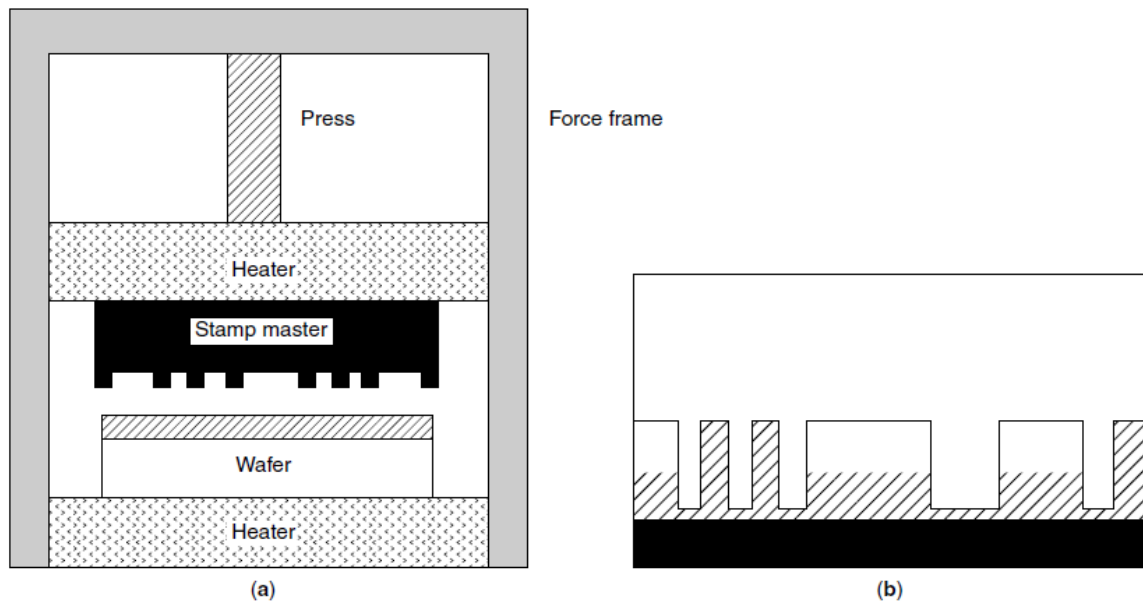


Figure 18.8 (a) Schematic hot embossing equipment and (b) unequal stamp cavity filling of variable aspect ratio structure

See EX1030 (*Introduction to Microfabrication*, Franssila, 1st Edition (2004)), pp. 187-88.

2. Micromirrors Reflective Coatings

53. Before the relevant timeframe, aluminum was prevalent and well-known as a reflective coating to produce a highly-reflecting mirror. See EX1027 (*Optics*, Hecht, 4th Edition (2002)), p. 175 (“Vacuum evaporated coatings of aluminum on highly polished substrates have become the accepted standard for quality mirrors.”).

54. Gold, silver, and aluminum were all commonly used as mirror coatings due to their high reflectivity in the visible spectrum (about 380 to 700 nanometers). The following shows the reflectivity for these three materials (as well as copper), and I have annotated to show the visible spectrum.

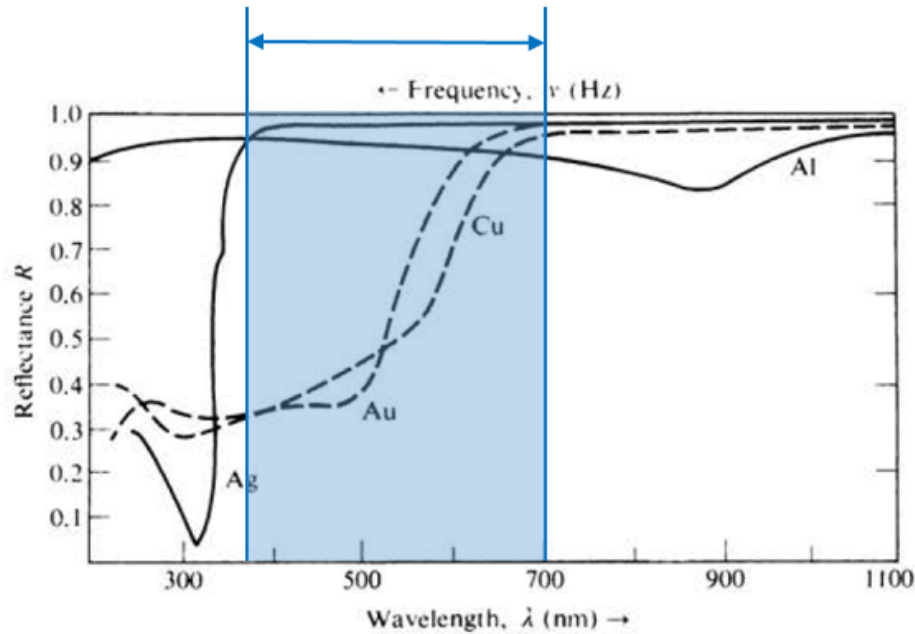


Figure 4.59 Reflectance versus wavelength for silver, gold, copper, and aluminum.

See EX1027 (*Optics*, Hecht, 4th Edition (2002)), p. 131

3. Polymer Substrates

55. Polymers are often used to produce embossed structures due to their thermal response. Thermoplastic polymers have properties that are advantageous for embossing, in particular, their ability to soften under heat (to allow the embossing tool or stamping tool to imprint the desired shape) and retain the structure while hardening once the heat is removed. This was common knowledge before the relevant time period. As explained in *Polymer Science and Technology* (2000):

“For engineering purposes, the most useful classification of polymers is based on their thermal (thermomechanical) response. Under this scheme, polymers are classified as *thermoplastics* or *thermosets*. As the name suggests, **thermoplastic polymers soften and flow under the action of heat and pressure. Upon cooling, the polymer hardens and**

assumes the shape of the mold (container). Thermoplastics, when compounded with appropriate ingredients, can usually withstand several of these heating and cooling cycles without suffering any structural breakdown. This behavior is similar to that of candle wax. Examples of thermoplastic polymers are polyethylene, polystyrene, and nylon.”

See EX1029 (Polymer Science and Technology, Ebewe, 1st Edition (2000)), p. 31.

56. Materials such as polyethylene (PE), polyethylene terephthalate (PET), and polypropylene are common polymers used as an embossing substrate.

57. Polypropylene is a polymer. *See EX1029 (Polymer Science and Technology, Ebewe, 1st Edition (2000)), pp. 18 (“Other examples of polymers of this type are ... polypropylene”), 30, 43, 80, 97-98.*

58. In particular, polypropylene is a polymer derived from the monomer Propylene:

Table 2.1 *Some Representation Addition Polymers*

$ \begin{array}{ccc} \text{H} & \text{H} & \\ & & \\ n \text{ C} = \text{C} & \longrightarrow & \left[\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{R} \end{array} \right]_n \\ & & \\ \text{H} & \text{R} & \\ \text{monomer} & & \text{polymer} \end{array} $		
R	Monomer	Polymer
H	Ethylene	Polyethylene
CH ₃	Propylene	Polypropylene
Cl	Vinyl chloride	Poly(vinyl chloride)
CN	Acrylonitrile	Polyacrylonitrile
	Styrene	Polystyrene
$ \begin{array}{c} \text{O} \\ \\ \text{C} = \text{O} \\ \\ \text{CH}_3 \end{array} $	Vinyl acetate	Poly(vinyl acetate)
$ \begin{array}{c} \text{C} = \text{O} \\ \\ \text{O} \\ \\ \text{CH}_3 \end{array} $	Methyl acrylate	Poly(methyl acrylate)

See EX1029 (*Polymer Science and Technology*, Ebewele, 1st Edition (2000)), p. 43.

59. Materials such as polypropylene have long been effective in use as substrates for hot embossing for optical security devices. For example, transparent, biaxially-oriented polypropylene (BOPP) was demonstrated as an effective embossed substrate for arrays of 30 x 30 µm optical elements:

“Micrographic features generated by electron beam lithography have been hot embossed in biaxially-oriented polypropylene (BOPP). Each micrographic element consisted of a sub-field of 30 x 30 µm with a specific configuration of symbols, lettering and graphics. The micrographic elements were integrated with arrays of diffractive gratings in the form of an optically variable device. A high quality embossing of various micrographic elements has been demonstrated in features with a linewidth dimension ≥ 365 nm and depth ≥ 255 nm. The

replication of arrays of micrographic elements was achieved uniformly over an area of 20 x 20 mm in the BOPP film by embossing at a temperature of 130 °C.”

EX1034, p. 109.

4. Protective Coatings

60. The micromirror structures are often coated with a protective layer of a transparent material, such as a high index polymer. The overcoat protects the underlying micromirror array from contamination and abrasion. Additionally, the overcoat prevents determining the structure of the micromirror array through imprinting and copying. The overcoat layer affects the ray paths of the incident ambient rays, as the incoming light is refracted at the interface of air-polymer media. The reflected ray path is further modified through refraction at the polymer-air medium when leaving the protective layer. These effects are well understood and are taken into account when designing the micromirror array.

61. The protective layer typically has a high index of refraction to reduce the effect of refraction on the ray path of the reflected rays from the micromirror array. As a result of refraction air-polymer and polymer-air interfaces, the floating height reduces to approximately $1/n$ of the height without the protective coating. This effect can be compensated for by properly orienting the micromirrors to achieve the desired floatation height of the light spots after embedding. This is a well-known effect and is well understood by a POSITA.

VI. THE '191 PATENT

62. In this section, I provide an overview of the '191 patent, a summary of the prosecution history, and a listing of the challenged claims.

63. The '191 patent is titled Method of fabricating arrays of individually oriented micro mirrors for use in imaging security devices. Ex. 1001. The '191 patent issued from United States Patent Application No. 16/203,128 ('831 application), which was filed on Nov. 28, 2018. I understand that the '831 application is a divisional of U.S. patent application No. 15/162,113, filed on May 23, 2016, now U.S. Patent No. 10,189,294 ('294 patent). *Id.* The '294 patent claims priority from Provisional Application No. 62/262,767, filed on December 3, 2015. *Id.* The '191 patent benefits from this priority date. Thus, for purposes of my analysis, I have used the provisional application filing date as the effective filing date for the challenged claims. As detailed below, all of the prior art discussed herein was filed, issued, published, or claims priority to a date before December 3, 2015.

A. Specification

64. The '191 patent concerns the problem of designing and fabricating anti-counterfeiting security elements that can be used on documents and products such as currency, and which are more difficult to replicate, and therefore more secure,

than anti-counterfeiting elements based on, e.g., moiré pattern printing and holograms. Ex. 1001, 1:19-2:19.

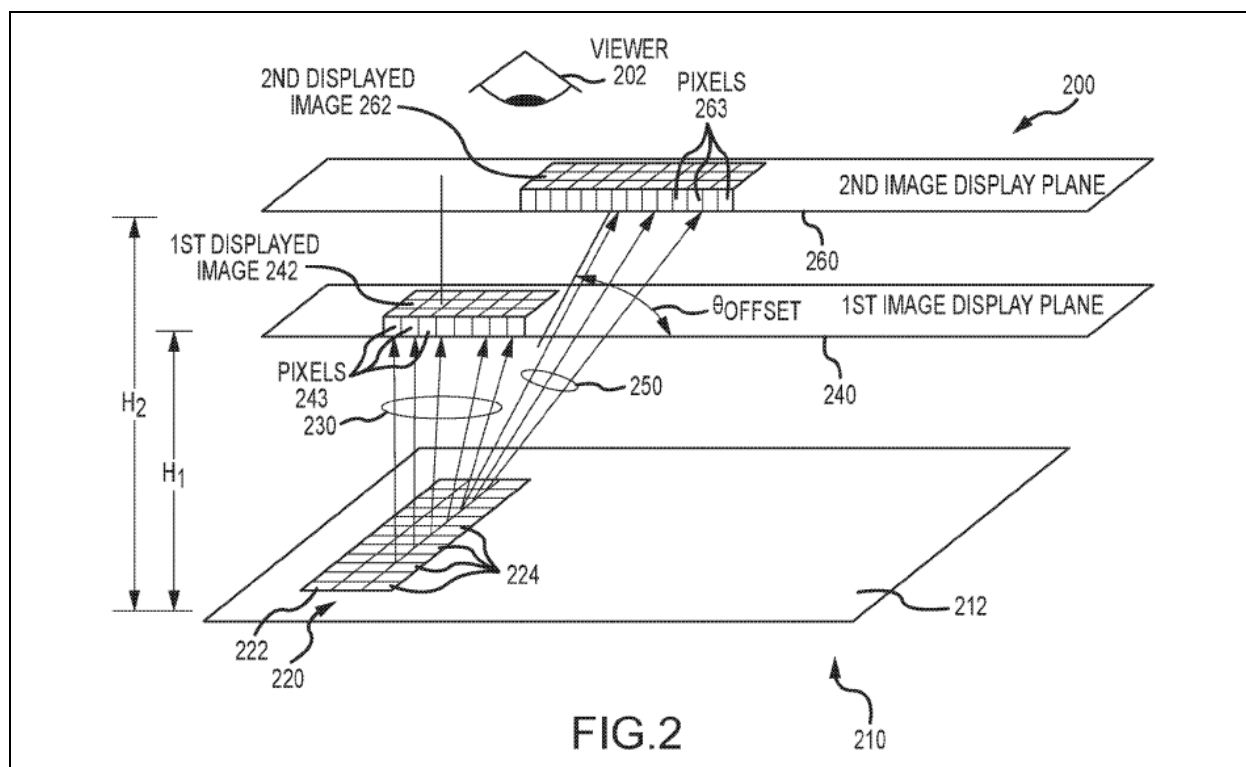
65. The solution described in the '191 patent is a security element that “is configured to ‘write’ images with light in one, two, or more spatial planes above and below the surface of an array of micro mirrors” on a substrate “which may be part of the object upon which the security element is provided such as a piece of currency or a product label”. Ex. 1001, 2:38-41, 3:14-19.

66. A micro mirror is simply a very small mirror. For example, the '191 patent states that the reflecting surface of each micro mirror may be rectangular in shape with a side length of around 50 micrometers (50×10^{-6} meters), and in other examples, it is circular in shape with a diameter of around 50 micrometers. Ex. 1001, 4:7-13. Each micro mirror “typically will be formed of a metal or metallic compound or other material chosen for its reflective properties.” Ex. 1001, 6:39-44.

67. The concept described in the '191 patent is to split the array of micro mirrors into different subsets, each of which is designed to reflect ambient light to produce a “point source of light,” or “pixel.” EX1001, 2:38-52. These pixels together form an image in a common “image display plane.” Multiple images may be produced in different image display planes. The result is to create “floating image(s)” “a height or distance above (or below in some cases) the place of the supporting surface containing the array of micro mirrors.” Ex. 1001, 5:14-6:14.

68. FIG. 2 illustrates this: a “security device 220 has an exposed or upper surface 222 that is configured to provide an array of micro mirrors 224, which may be individually oriented to provide reflection of ambient light striking the surface 222 of the security element 220 so as to display one or more floating images that can be observed by a viewer 202.” Ex. 1001, 7:35-41.

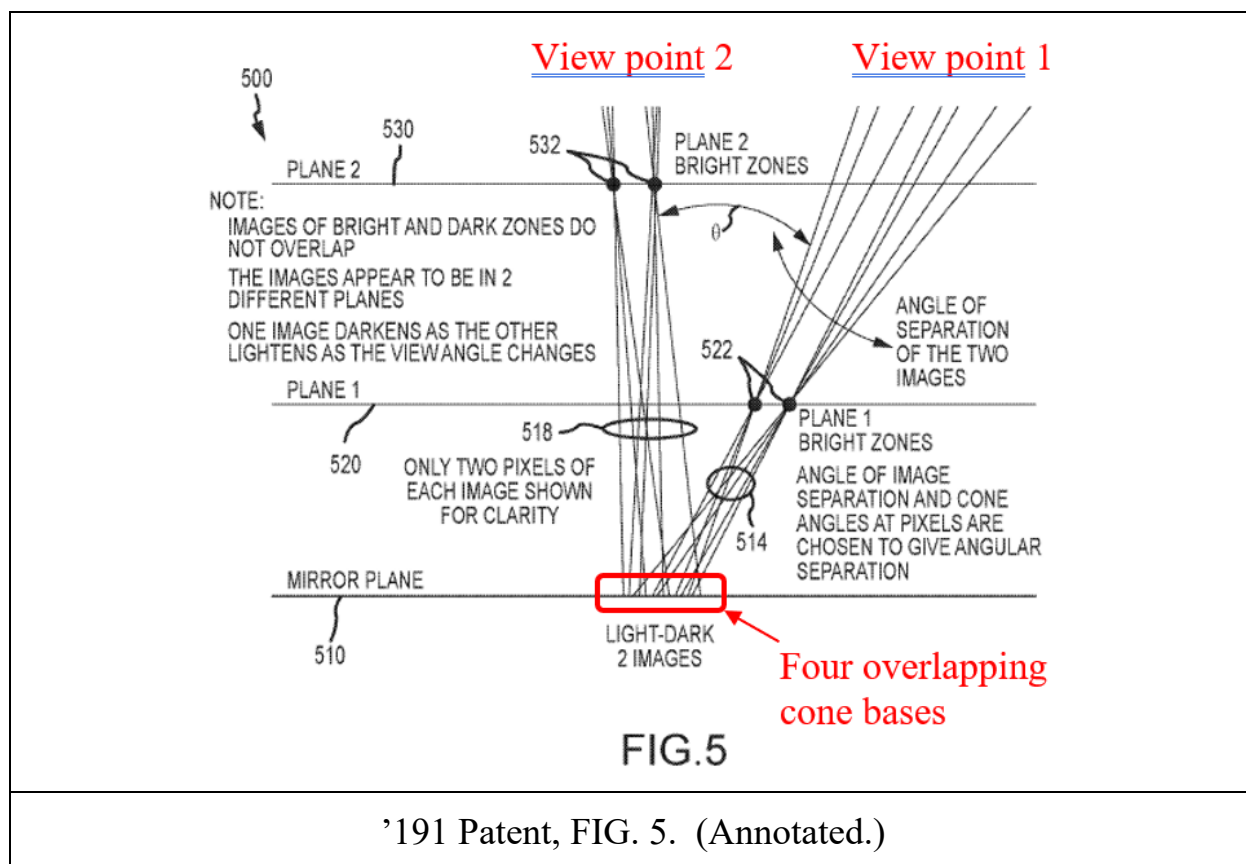
69. The micro mirrors in the subsets that create the first displayed image are oriented relative to those in the subsets that create the second displayed image “so that the pixels 243 of the first image 242 are a viewing angle offset, θ_{Offset} , (e.g., 10 to 30 degrees) from the pixels 263 of the second image 262 so that the viewer 202 typically only views one of the floating images 242, 262 at a time.” Ex. 1001, 8:2-6.



'191 Patent, FIG. 2.

70. FIG. 5 illustrates the intersection of light rays from different subsets of micro mirrors to form pixels in different image display planes. In most embodiments, each pixel can be considered the apex of a cone whose base on the substrate contains the subset of micro mirrors that produce that pixel. Ex. 1001, 7:61-65. Not all of the micro mirrors in the base of the cone that corresponds to a given pixel are contained in the subset which produces that pixel. Ex. 1001, 8:25-29.

71. In FIG. 5 all four sets of rays, i.e., the two sets of “beams/rays 514” that intersect to produce the two distinct “pixels 522” in image display plane 1 and the two sets of “beams/rays 518” that intersect to produce the two distinct “pixels 532” in image display plane 2, are reflected in four cones whose bases overlap. Ex. 1001, 9:24-50.



72. In embodiments such as that illustrated in FIG. 5, the micro mirrors are “adapted specifically to provide two light and dark images.” Ex. 1001, 9:24-27. When the security element is viewed from viewpoint 1, which is illuminated by the reflected rays that form “pixels 522”, the image in image display plane 1 will appear light and the image in image display plane 2, the rays of which are directed away from view point 1, will appear dark. When the security element is viewed from view point 2, which is illuminated by the reflected rays that form “pixels 532”, the situation reverses: “One image darkens as the other lightens as the view angle changes.” The “angle of image separation, ϕ ” (“ θ ” in FIG. 5) and the cone angles at

the pixels, i.e., the angles made by the sides of the cones where they meet at the apex, are chosen to give the angular separation between the view points. Ex. 1001, 9:51-63. Because the image can appear to change as the viewing angle changes, it is possible to produce an “animation effect.” Ex. 1001, 17:40-63.

B. Prosecution History

73. Two non-final Office Actions and one final Office Action were issued during the prosecution of the application from which the '191 patent issued.

74. On August 5, 2020, a non-final rejection was issued on claims 9-13 for indefiniteness (p. 2), claims 1 and 7 were rejected as being anticipated by US2010/0208036 (“Kaule”) (p. 3); claims 2-6 and 8 were rejected as being unpatentable as obvious over Kaule in view of US2012/0098249 (“Rahm”) (p. 5); and claims 14-20 were identified as allowable (pp. 7-8). Ex. 1002, pp. 138-47.

75. On the same day, Applicant amended claims 1, 7-9, 14, 15, and 20, cancelled claims 2, 3, 4 and 5, while other original claims remain, unamended, and added new claims 21-28. Ex. 1004, pp. 121-31. Applicant premised its response by opining that Rahm fails to overcome the deficiencies in Kaule in relation to casting the micro mirrors with a nickel or polymer tool in contact with the surface of the substrate:

“Particularly, the Office Action urges that Rahm shows the limitations added to claim 1 from claims 2 and 3 (“wherein the substrate comprises a clear, energy-cured polymer, and wherein the forming the array of micro mirrors comprises casting the micro mirrors with a nickel or polymer mirror tool in

contact with the surface of the substrate”) in paragraphs [0060]-[0062]. In the cited paragraphs, Rahm states first layer 11 may be a “radiation-cured lacquer” that has microstructures 5, 6. However, there is no teaching that the microstructures are formed by casting as called for in claim 1 or that such casting is done “with a nickel or polymer mirror tool in contact with the surface” of the layer 11. Instead, Rahm states in para. [0060] that these structures can be produced by “embossing into the UV lacquer 11” such that there is no showing of the casting of claim 1 in this portion of Rahm.

Further, according to para. [0061], the second layer 12 in Rahm is formed of “radiation curing lacquer” with “the negative form of the micro-concave mirrors 8 and the form of the microlenses 9 is embossed” (not “cast” with a mirror tool as required by claim 1). Then, “a metallization” is used to form mirrors 8 on second layer 12. Para. [0062] of Rahm again discusses embossing and is silent as to using casting as called out in claim 1.”

Ex. 1004, p. 129-30.

76. On September 15, 2020, the Examiner again issued a series of prior art rejections against claims 1, 4, 7, 8, 21-28 based on Kaule in view of Rahm (pp. 4-10); and identifies claims 9-20 as allowable (pp. 10-12). Ex. 1004, p. 99-113.

77. On the same day, Applicant amended claims 1, 8, 21, while other claims remain, unamended. Ex. 1004, pp. 86-96. Applicant again premised its response by arguing that there is no prior art teaching that the microstructures are formed by casting with a mirror tool in contact with the surface of layer 11:

“In the paragraphs cited in the final Office Action, Rahm states first layer 11 may be a “radiation-cured lacquer” that has microstructures 5, 6. However, there is no teaching that the microstructures are formed by casting as called for in claim 1 or that such casting is done “with a mirror tool in contact with the surface” of the layer 11. Instead, Rahm states in para. [0060] that these structures can be produced by “embossing into the UV lacquer 11” such that there is no showing of the casting of claim 1 in this portion of Rahm.

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Ex. 1004, p. 94.

78. On November 10, 2020, the Examiner issued prior art rejections against claims 1, 4, 7 over Kaule in view of Rahm and US2012/0098249 (“Raymond”); claim 8 over Kaule in view of Rahm, Raymond and US2008/0258457 (“Commander”); and claims 9-20 are maintained as allowed. Ex. 1004, pp. 49-61.

79. On November 11, 2020, Applicant cancelled rejected claims 1, 4, 5, 8 and 21-28, while keeping the other (allowed) claims unamended. Ex. 1004, pp. 548-55.

80. On December 15, 2020, the Examiner allowed the claims. Ex. 1004, pp. 22-30. Examiner’s statement of reasons for allowance stated as follows:

“Claim 9 is allowable over the prior art of record for at least the reason that even though the prior art discloses a method of fabricating a security element useful on paper and coin currency and product labels, comprising: providing a substrate; and forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and, in response, displaying an image in a plane spaced a distance apart from the surface of the substrate, wherein the image comprises a plurality of pixels, the prior art fails to teach or reasonably suggest, that the array of micro mirrors includes for each of the pixels a different set of the micro mirrors each having a reflective surface oriented, in a fixed manner with

a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body, to reflect the ambient light toward a point on the plane corresponding to one of the pixels, wherein each of the different sets concurrently reflect the ambient light to concurrently generate the plurality of pixels, wherein a voxel is created at each of the point on the plane via intersection of two or more beams of the reflected ambient light, and wherein each of the created voxels produces an effect of a point source of light floating above the surface of the substrate in the plane, in combination with the other limitations of claim 9.”

“Claim 14 is allowable over the prior art of record for at least the reason that even though the prior art discloses a method of fabricating a security element useful on paper and coin currency and product labels, comprising: providing a substrate; and forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and, in response, displaying a first image and a second in a plane spaced a distance apart from the surface of the substrate at first and second viewing angles, respectively, wherein the first and second images each comprises a plurality of pixels, the prior art fails to teach or reasonably suggest, that the array of micro mirrors includes for each of the pixels a unique set of the micro mirrors each having a reflective surface rigidly oriented, by rotating a body of each of the micro mirrors about at least one of two rotation axes extending through the body, to reflect the ambient light away from the substrate toward a point on the plane corresponding to one of the pixels, wherein each of the unique sets of the micro mirrors includes a number of the micro mirrors in the range of 2 to 40, and wherein the reflected ambient light from the number of the micro mirrors intersects at the point corresponding to the one of the pixels to create a voxel, whereby the voxel acts like a point light source positioned in the plane at the point corresponding to the one of the pixels, in combination with the other limitations of claim 14.”

Ex. 1004, pp. 27-29.

81. However, as will be discussed throughout this petition, these elements were known in the art.

VII. LEVEL OF ORDINARY SKILL IN THE ART

82. In my opinion, a POSITA as of December 3, 2015, would have had an undergraduate degree in mechanical or electrical engineering or physics and at least two years of experience in micro-optics design. The following factors support my opinion.

83. First, the typical level of education for persons working in the field would include an undergraduate degree in mechanical or electrical engineering or physics. Micro-optic based security features are a combination of optical and mechanical design elements. For example, I would expect a typical engineer who works for a micro-optic design company to have an undergraduate degree in one of these fields. Certain engineers will have more advanced degrees, such as a masters or Ph.D. in a more-specialized area of optics or optoelectronics, but an undergraduate degree in mechanical or electrical engineering or physics would be the typical background and would provide engineers in the field with a baseline knowledge of the optical and mechanical design principles underlying micro-optic based security features. I also note that a student on track for a degree in mechanical or electrical engineering or physics would have sufficient exposure to optics principles to then work or conduct research in that area in academia or industry.

84. Second, at least 2 years of experience in the field would be typical for a person deemed to have ordinary skill in the technology underlying the '191 patent.

This level of experience would provide an engineer with more specialized focus in optics and device structure. He or she would have been familiar with the design principles and tradeoffs underlying the subject matter of the '191 patent.

85. Third, the types of problems typically encountered in the field relate to improving anti-counterfeit ability, image quality, cost, visual appeal, and mechanical stability. An engineer with a mechanical or electrical or physics background and at least 2 years of work experience with micro-optic based security features would have been familiar with these problems and working on solutions to address them. For example, a typical engineer at that level would be tasked with evaluating different types of micro-optic based security features to decide whether they improve accuracy and detection capability and are cost-effective. He or she would also be tasked with evaluating different optics elements for the same reasons.

86. Fourth, the proposed level of skill is consistent with the sophistication of the technology claimed in the '191 Patent. The patent concerns micro-optic design, including the use of certain micro mirrors and substrates. The level of sophistication is such that an advanced degree or work experience beyond 2 years would not be necessary to understand the technology and make informed design decisions.

87. For the above reasons, it is my opinion that the appropriate level of skill in the art is an undergraduate degree in electrical engineering, mechanical

engineering, or physics and at least 2 years of experience in micro-optic based security features.

VIII. CLAIM CONSTRUCTION

88. For purposes of this proceeding, I have applied the ordinary and customary meaning of the claim terms as they would have been understood to a POSITA at the time of the alleged invention of the '191 Patent, and I have considered that meaning in the context of the patent and its prosecution history.

89. I reserve the right to offer additional claim construction opinions in other proceedings, including indefiniteness opinions that I understand are not at issue in this proceeding. I also reserve the right to respond to any claim construction positions put forward by Patent Owner.

IX. OVERVIEW OF THE PRIOR ART

90. In this section, I provide an overview of the prior art references that I have relied on to inform my opinions.

A. German Patent No. DE102010048262 (“Fuhse262”)(Ex. 1006)

91. Fuhse262 relates to a security element (for example on banknotes) created from an array of optical reflective or refractive elements (such as micromirrors) which create a three-dimensional motif consisting of multiple components which “float at several different floating heights above or below the surface region in order to form a three-dimensional motif.” Fuhse262, ¶0015.

92. An image can also contain multiple two-dimensional images that are “visible from the same or different viewing angles.” Fuhse262, ¶0118. Each image is “only visible in a limited angle range.” Fuhse262, ¶0112.

93. With respect to the optical elements, Fuhse262 recognizes that curved mirrors and lenses may be broken down into arrays of smaller, flat micromirrors, with the advantage of easier fabrication and calculation:

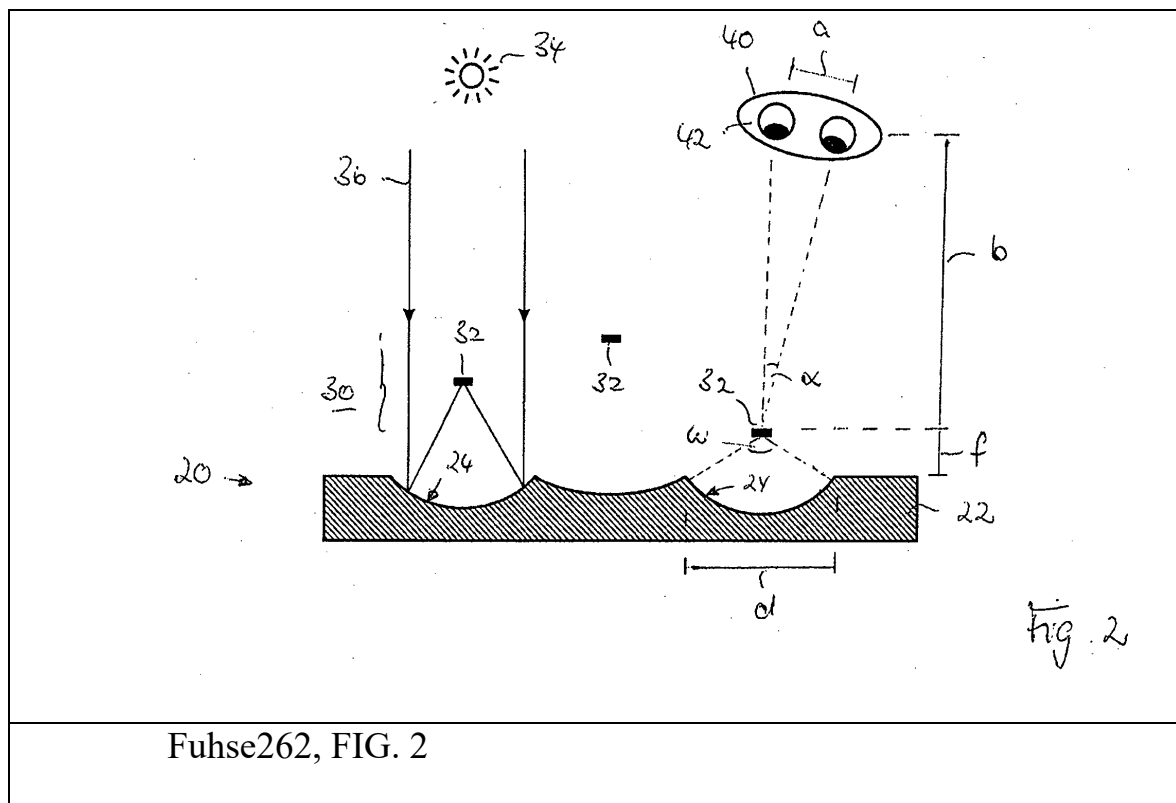
“[0086] In addition, when breaking down a convex mirror or a curved lens into a plurality of micro-optical elements, the surfaces of the micro-optical elements, which in principle are also initially curved, can generally be replaced by flat surfaces because of their small size. This replacement has no adverse effects on the light-spot image produced, particularly if the dimensions of the micro-optical elements are smaller than the resolution of the viewing situation. The advantage is that micro-optic elements with flat surfaces are easier to calculate and produce. From this point of view, it may even be advisable to break down convex mirrors or lenses into small micro-optical elements with flat surfaces if nesting several groups of micro-optical elements is not desired or necessary.”

Fuhse262, ¶0086.

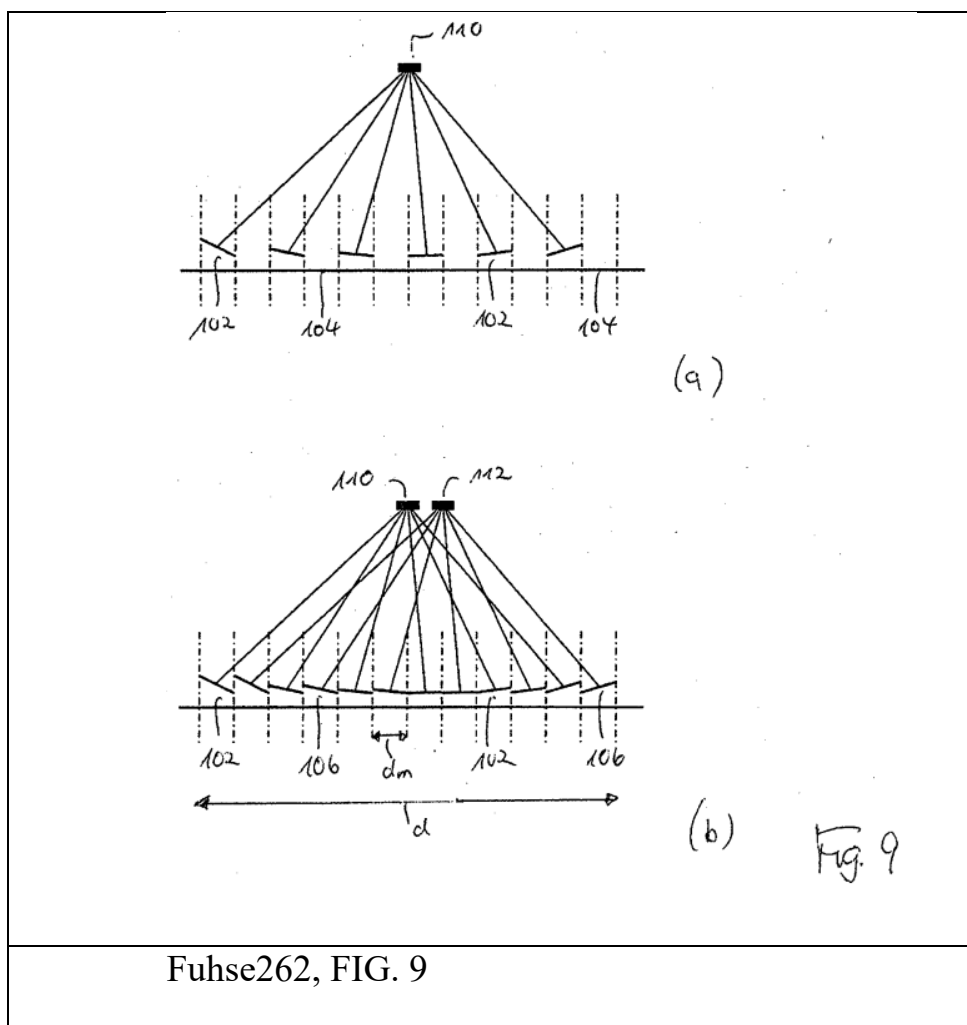
94. Fuhse262 continues that curved mirrors may be replaced by “an arrangement of $n \times n$ micromirrors.” Fuhse262, ¶0087. The micromirrors may, for example, have “a flat mirror surface” with a “dimension of $50 \mu\text{m} \times 50 \mu\text{m}$.” Ex. 1005 (Fuhse262), ¶0087.

95. Figure 2 shows a simplified example with three image points produced by three mirrors, but in practice “a security element 20 will typically have a large

number, for example a few tens, a few hundred or even several thousand, refractive and/or reflective optical elements 24.” Ex. 1005 (Fuhse262), ¶0056.



96. Alternatively, “not only one optical element, but a plurality of optical elements is assigned to every light spot of the light-spot image.” Ex. 1005 (Fuhse262), ¶0019. This is shown in Figure 9:



Fuhse262, FIG. 9

97. Fuhse262 describes an exemplary method for producing its images:

“– a desired three-dimensional motif having image points P_j and height values Z_j above an xy plane is specified, the image points corresponding to the light spots created upon illumination,

– for every image point P_j , a brightness I_j between 0% and 100% is defined,

– there are assigned to the image points P_j aperture cones that have an aperture ratio > 0.2 ,

- for every image point P_j , a sphere of influence E_j is determined by an intersection of the aperture cone originating from the image point with the xy plane,
- the xy plane is divided into a number of coarse fields, and the coarse fields are each divided into a number of fine fields,
- for every image point P_j , based on the defined height value Z_j and the defined brightness value I_j , a number of fine fields to be filled in is determined,
- the fine fields to be filled in determined for the image point P_j are distributed substantially evenly across the coarse fields in the sphere of influence E_j of the image point P_j , and
- the fine fields to be filled in are covered with refractive and/or reflective optical elements that, upon illumination of the depiction element, contribute to producing the light spot that corresponds to image point P_j .”

Fuhse262, ¶0112.

98. This method is described in further detail at ¶¶0125-31. Thus, in the combined teachings of FIG. 2 and FIGs. 8-10, Fuhse262 teaches a substrate and ambient light source (as described in FIG. 2), as well as arrays of micromirrors that include assignments of sets of micromirrors to light spots that form light spot images.

99. Fuhse262 teaches that the orientation of each mirror within the array necessary to form the required images can be calculated as follows:

100. “[0096] For the calculation, (x_0, y_0, z_0) denotes the position of light spot 110 to be produced with $z_0 > 0$, $(x, y, 0)$ denotes the position of the mirror element to be calculated. $\vec{n}$ is the normal vector of the mirror at position $(x, y, 0)$, $\vec{k}$

is the direction vector of the incident light ray and $\vec{p}$ is the direction vector of the reflected light ray.

101. [0097] The position of the mirror surfaces, i.e. the normal vector $\vec{n}$, is to be determined in such a way that the light incident from a specified direction $\vec{k}$ is reflected onto the focal point (x_0, y_0, z_0) for all micromirrors 102 assigned to light spot 110.

102. According to the invention, this is achieved by

$$\vec{n} = \frac{\frac{\vec{p}}{|\vec{p}|} - \frac{\vec{k}}{|\vec{k}|}}{\left| \frac{\vec{p}}{|\vec{p}|} - \frac{\vec{k}}{|\vec{k}|} \right|}, \quad \vec{p} = \begin{pmatrix} x_0 - x \\ y_0 - y \\ z_0 \end{pmatrix}, \quad |\vec{p}| = \sqrt{(x_0 - x)^2 + (y_0 - y)^2 + z_0^2}$$

[0098] If the light source 120 is at the position (x_L, y_L, z_L) , then

$$\frac{\vec{k}}{|\vec{k}|} = \frac{\begin{pmatrix} x_L - x \\ y_L - y \\ z_L \end{pmatrix}}{\sqrt{(x_L - x)^2 + (y_L - y)^2 + z_L^2}}$$

[0099] If the micromirror group 102 is designed for vertical incidence of light, then

$$\frac{\vec{k}}{|\vec{k}|} = \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix},$$

resulting in the normal vector $\vec{n}$

$$\vec{n} = \frac{\frac{\vec{p}_n}{|\vec{p}_n|} - \frac{\vec{k}}{|\vec{k}|}}{\left| \frac{\vec{p}_n}{|\vec{p}_n|} - \frac{\vec{k}}{|\vec{k}|} \right|} = \frac{\begin{pmatrix} x_0 - x \\ y_0 - y \\ z_0 + \sqrt{} \end{pmatrix}}{\sqrt{(x_0 - x)^2 + (y_0 - y)^2 + (z_0 + \sqrt{})^2}} ,$$

wherein the abbreviation

$$\sqrt{} = \sqrt{(x_0 - x)^2 + (y_0 - y)^2 + z_0^2}$$

was used.”

Fuhse262, ¶0096-99.

103. It is possible to create darker areas in the image using “mirrors that are oriented in such a way that spatial regions that do not contain any light sources are reflected.” Ex. 1005 (Fuhse262), ¶ 0108. For this purpose, the mirrors can be directed, for example, at the viewer’s body.

B. U.S. Patent No. 10,639,925 (“Fuhse925”) (Ex. 1008)

104. Fuhse925 relates to an optical security element that shows different images (such as characters, numbers or shapes, referred to as curves in the patent) at different viewing/tilt angles, that “float alternatingly a few millimeters above or below the plane of the security thread.” Fuhse925, Abstract, 6:67-7:1.

105. These images are created using an array of micro mirrors orientated at different inclination angles on a substrate. Fuhse925, Abstract, 6:67-7:1.

C. U.S. Pat. App. Pub. No. 2012/0319395 (“Fuhse395”)(Ex. 1010)

106. Fuhse395 relates to manufacturing techniques of a reflective optical security element, such as would be applied to a banknote. Fuhse, Abstract, ¶¶0087.

107. Manufacturing techniques include using an “an embossing tool” to “emboss[] in thermoplastic foils or into foils coated with radiation-curing lacquers” to form reflective facets. Fuhse, ¶¶59, 148-51.

D. Sauvage-Vincent (Ex. 1033)

108. Like Fuhse395, Sauvage-Vincent relates to manufacturing techniques of a reflective optical security element, such as would be applied to a banknote. EX1033, ¶¶0002, Abstract. Sauvage-Vincent teaches a “die” or “master” that provides a “stamping operation” to produce the microstructure pattern of the desired optical elements. EX1033, ¶¶71, 73, 43, Abstract. The “stamping operation is performed from the die to transfer the microstructure onto a film and structure the layer of dielectric material 101,” such as a film of polymer material. EX1033, ¶¶71, 73, 43, Abstract. This “stamping may be done by hot pressing of the dielectric material (‘hot embossing’) or by molding then cross-linking (‘UV casting’).” *Id.*

E. Morford (Ex. 1024)

109. Morford relates to materials for use in optical components that have properties such as flexibility, high refractivity, and is curable with ultraviolet (UV) light. Morford, Abstract.

X. INVALIDITY ANALYSIS

110. Below I provide a summary of the prior art combinations that I address in more detail below.

- Ground 1: Claims 1 and 6 of the '191 Patent are rendered obvious by Fuhse262 (combination of embodiments).
- Ground 2: Claims 1 and 6 of the '191 Patent are rendered obvious by Fuhse262 in view of Fuhse925.
- Ground 3: Claims 2-4 and 7-11 of the '191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Fuhse395.
- Ground 4: Claims 2-4 and 7-11 of the '191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Sauvage-Vincent.
- Ground 5: Claims 5 and 12 of the '191 Patent are rendered obvious by Fuhse262 (Ground 1) in view of Morford.
- Ground 6: Claims 2-4 and 7-11 of the '191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Fuhse395 (Ground 3).

- Ground 7: Claims 2-4 and 7-11 of the '191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Sauvage-Vincent (Ground 4).
- Ground 8: Claims 5 and 12 of the '191 Patent are rendered obvious by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Morford (Ground 5).

A. Ground 1: Fuhse262 renders obvious claims 1 and 6.

111. It is my opinion, the combined teachings of Fuhse262 renders obvious claims 1, 6 and 12 of the '191 patent.

1. Combined Teachings of Fuhse262

a) Motivation to Combine

112. Fuhse262 describes an invention of “a depiction” element. Fuhse262, ¶¶0001, 0010-11, Abstract. This invention is described by several Figures and accompanying descriptions that are relied on in this declaration, including Figures 1-2, 8(a)-(d), and 9-10.

113. To the extent that these descriptions represent different embodiments for purposes of obviousness, in my opinion, it would have been obvious to combine them.

114. Fuhse262 provides express motivation and direction to combine the features of its embodiments. Figure 2 of Fuhse262 shows various aspects and

elements “[t]o explain the principle of the invention.” Fuhse262, ¶¶0056-60. Figures 8(a)-(d) build on Figure 2 by replacing the “curved concave mirror” of Figure 2 by using micromirrors. Fuhse262 ¶0048 (“Fig. 8 shows in (a) to (d) four exemplary embodiments in which a curved concave mirror is broken down into micro-optical elements with a square base and a flat mirror surface”). Fuhse262 explicitly refers back to the “previous exemplary embodiments” in building on those teachings. Fuhse262, ¶¶0083, 0087. Also, the Figures 8(a)-8(d) show different variations of the same teachings, such as different numbers of groupings of micromirrors.

115. Fuhse262 provides explicit motivation to replace the curved mirrors of Figure 2 with flat micromirrors, including that “higher resolution” is obtained and that “flat surfaces are easier to calculate and produce.” Fuhse262, ¶¶0083, 0087. Further, “[t]his replacement has no adverse effects on the light-spot image produced.” Fuhse262, ¶0086.

116. Likewise, Figure 9 builds on the teachings of Figures 8(a)-8(d) by illustrating them “in a sectional view” and providing further explanation. Fuhse262, ¶¶0091-94, 0049. Finally, Figure 10 builds on the teachings of Figures 8(a)-8(d) and 9 by describing how to calculate the orientation of the surfaces of the micromirrors. Fuhse262, ¶¶0095-101, 0050 (“Fig. 10 illustrates the calculation of the flat mirror surfaces of the micromirrors of Figs. 8 and 9”). Fuhse262 also describes a “further

development of the invention” regarding providing different images to the viewer when viewed at different angles (*see* ¶¶0111-15) and describes a “preferred procedure” to produce the structures of these combined teachings. Fuhse262, ¶¶0125-28, 0036.

b) Reasonable Expectation of Success

117. In my opinion, there would have been a reasonable expectation of success combining the embodiments of Fuhse262.

118. As a POSITA would have recognized, the teachings of Fuhse262 relied on in this Ground (discussed in the Motivation) represent different aspects of the purported invention that all operate on the same principle, and work to disclose different aspects that rely on the same principles. The aspects of the Figure 2 disclosures relied on – such as the substrate and ambient light (*see* Ground 1, elements [1a] and [1b.1] – would operate on the same principles, serve the same purpose, and maintain the same relevant characteristics when applied to the array of micromirrors of Figure 8-10. Fuhse262 teaches to “replace[]” the curved mirrors of Figure 2 with the plurality of flat micromirrors 100 (*see* Fuhse262, ¶¶0083-86), and a POSITA would have reasonably been able to adapt those teachings regarding Figure 2 to flat micromirrors.

119. Likewise, the different specific implementations, such as possible arrays sizes of 100 micromirrors (*see* ¶¶0087) or 288 micromirrors (*see* ¶¶0090-92), would have been routinely and predictably implemented by a POSITA.

120. The art was relatively predictable in the relevant timeframe (2015). *Id.* The predictable nature of the combination is confirmed by evidence showing that the operation of micromirror arrays—and their application to security elements—was well-understood at the time of the alleged priority date. As I have detailed in the Technical Background (see Section V), the various aspects of the technology at issue, including micro-mirror arrays (V.B.2), ray optics (V.B), orientations of mirrors (V.C), and fabrication of optical micro-devices (V.D), were all well-known and known to work well before 2015. As discussed in Section V.A, the technology at issue was mature and known to work. Accordingly, a POSITA would have no difficulty implementing the modifications discussed. Further, given that micromirror arrays of the type contemplated in the '191 Patent were textbook knowledge at the time of the alleged invention, a POSITA would have no difficulty combining embodiments of Fuhse262.

121. Thus, a POSITA would have been able to implement the obviousness modifications in this ground without difficulty and with a reasonable expectation of success. *Id.*

2. Application to the Challenged Claims

122. In my opinion, Fuhse262 teaches the limitations of claims 1, 6, and 12. The mapping below provides my analysis on a limitation-by-limitation basis, with relevant citations to the teachings of Fuhse262.

a) Claim 1

123. In my opinion, Fuhse262 teaches claim 1, as detailed below.

(1) Claim 1, Element [1Pre]: “A method of fabricating a security element useful on paper and coin currency and product labels, comprising:”

124. In my opinion, the preamble simply states what the claim is useful as. In fact, the preamble explicitly purports to describe what the preamble is “useful as.”

125. Also, none of the terms in the preamble are later provided in the claim body, so the preamble does not complete the structure of the claim body.

126. In my opinion, to the extent the preamble is limiting, Fuhse262 teaches the preamble. Fuhse262, ¶¶0008-12, 0037, FIG. 1.

127. Fuhse262’s invention relates to “a depiction element” “[f]or security applications” and with “an attractive visual appearance” (fabricating a security element). Fuhse262, ¶¶0008-12. The depiction element which is a security element is useful as a “data carrier” and “[t]he data carrier can in particular be a value document,” such as a “paper banknote” (paper... currency). Fuhse262, ¶0037, FIG. 1.

128. Coin currency and product labels are also “data carriers” because they carry data related to the currency or product.

129. Based on Fuhse262’s teachings that the depiction element would be useful for data carriers such as currency, a POSITA would have found it obvious to recognize that the depiction element would be useful for coin currency and product labels.

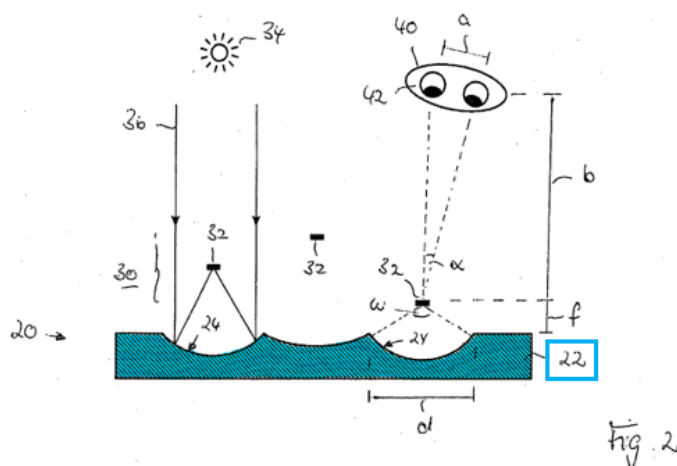
130. As discussed in Grounds 3-4, it was known in the art to apply depiction elements to coin currency and product labels. Jordan, Abstract, ¶¶0013, 0002-04, 0113-14, 0124-25, 0154, 0159, 0174-77.

131. For example, optical depiction elements were included on the surface of Australian coins by 2001. Ex. 1030, p. 6 (citing Exs. 1031-32); Ex. 1031, p. 2; Ex. 1032, p. 1032, pp. 1-2.

(2) Claim 1, Element [1a]: “providing a substrate; and”

132. In my opinion, Fuhse262 teaches element [1a]. Fuhse262, Abstract, ¶¶0001, 0010, 0035, 0056-65, 0110.

133. Fuhse262 provides “a substrate 22” (**providing a substrate**), such as shown annotated in blue in the below reproduction of Figure 2. Fuhse262, Abstract, ¶¶0001, 0010, 0035, 0056-65, 0110.



134. The surface of the substrate defines a “xy plane” or “substrate plane.” Fuhse262, ¶¶0126-27, 0110. In Fuhse262’s coordinate system, this surface corresponds to $z=0$. Fuhse262, ¶¶0110, 0126.

135. Accordingly, Fuhse262 teaches the element [1.a].

(3) Claim 1, Element [1b.1]: “forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and”

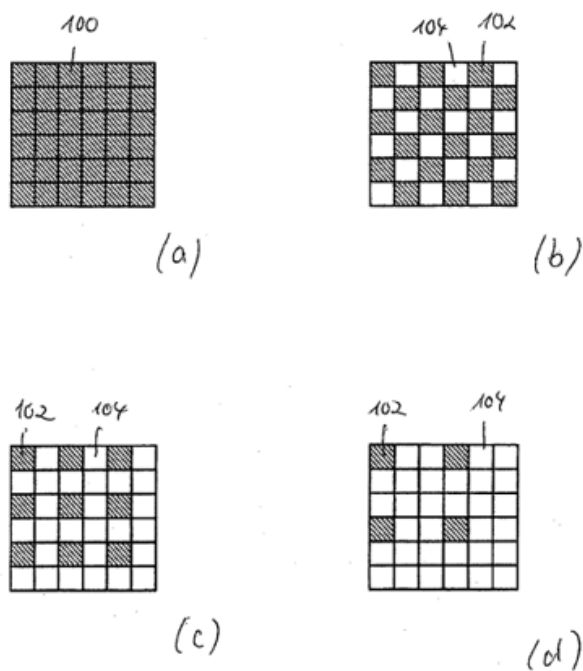
136. In my opinion, Fuhse262 teaches element [1b.1]. Fuhse262, Abstract, 0001, 0010, 0013, 0022, 0029-30, 0035, 0054, 0056-65, 0082-83, 0087-95, 0110, cls. 1, 24.

137. Fuhse262’s arranges on “a surface region” of a substrate (**forming...on a surface of the substrate**) “a plurality of optical elements.” See Fuhse262,

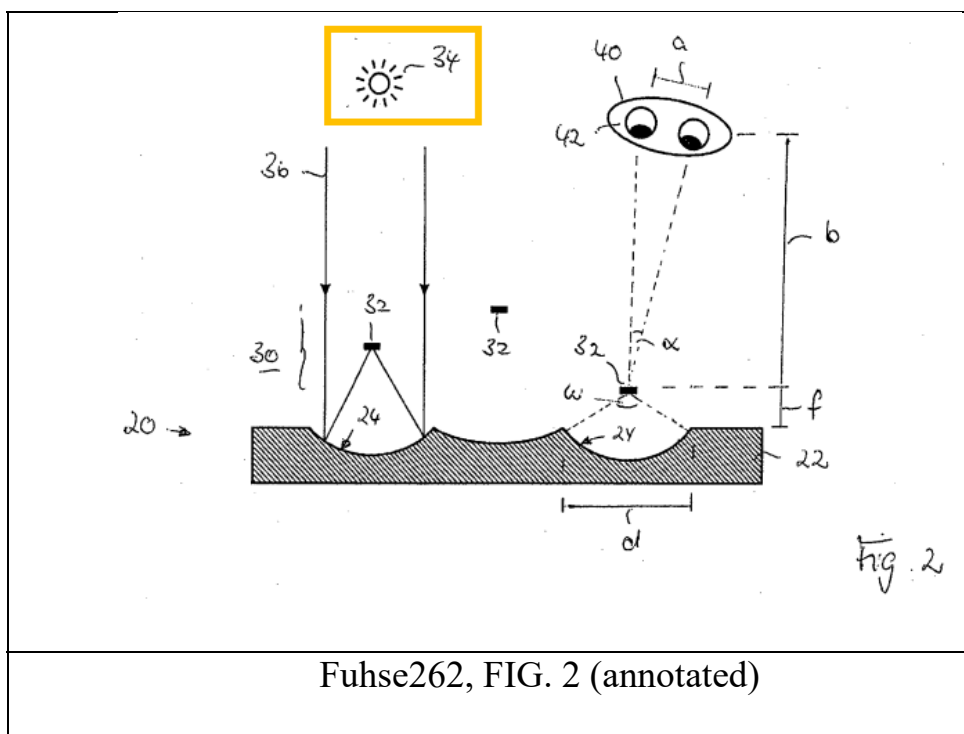
Abstract, ¶¶0010, 0001, 0035, 0056-65, 0110. The optical elements may be “plurality of micromirrors” (**an array of micro mirrors**) “distributed over a certain surface region of substrate 22” (**on a surface of the substrate**). Fuhse262, ¶¶0060, 0013, 0022, 0030, 0083, 0087-95.

138. The surface of the substrate defines a “x-y plane” or “substrate plane.” Fuhse262, ¶¶0126-27, 0110. In Fuhse262’s coordinate system, this surface corresponds to $z=0$. Fuhse262, ¶¶0110, 0126.

139. Figure 8, including Figures 8(a)-8(d), and supporting disclosure provides further detail of the **array of micro mirrors** in the form of “an arrangement of $n \times n$ micromirrors 100, which are arranged next to one another without any distance between them in the surface of the security element.” Fuhse262, ¶¶0060, 0013, 0022, 0030, 0083, 0087-95. Specifically, the curved mirrors of Figure 2 are “replaced by” the plurality of flat micromirrors 100 because they are “easier to calculate and produce.” Fuhse262, ¶¶0083-86.



140. This ordered arrangement of micromirrors 100 is **an array**. The micromirrors shown in Figure 8 **receiv[e] ambient light** because they are “illuminated” in the same manner as the lenses and mirrors described in Fuhse262. Fuhse262, ¶¶0082-83, 0091. Fuhse262 discloses that the illumination is with **ambient light** such as “sunlight or a ceiling lamp.” Fuhse262, ¶0054. For example, Fuhse262 discloses illumination by “distant light source 34,” depicted in Figure 2 as sunlight:



Fuhse262, ¶¶0057-58, 0061, *see also* ¶0029 (distinguishing “normal illumination” “visible to the naked eye” with “directed illumination with laser light”).

141. As I discussed in the Technology Background, sunlight and light from a ceiling lamp are ambient because they are understood to generally illuminate space. *See, supra*, Section V.3. Fuhse262 distinguishes “normal illumination” “visible to the naked eye” (i.e., ambient light) with “directed illumination with laser light.” Fuhse262, ¶0029.

142. Fuhse262 therefore teaches element [1b.1].

(4) Claim 1, Element [1b.2]: “in response, displaying an image in a plane spaced a distance

apart from the surface of the substrate, wherein the image comprises a plurality of pixels,”

143. In my opinion, Fuhse262 teaches element [1b.2]. Fuhse262, ¶¶0010-12, 0015, 0035-36, 0049, 0054-56, 0068, 0083-84, 0091-92, 0126-28. Fuhse262 teaches that in response to illumination, a light-spot image (**displaying an image which comprises a plurality of pixels**) is produced that floats (with all light spots of the light spot image at the “same floating height”, meaning they are in a plane). That image in the plane is above the surface region of the substrate (**a distance apart from the surface of the substrate**).

144. The image is **in a plane**. First, Fuhse262 states that the image may be two-dimensional, and a POSITA would understand that a floating two-dimensional image in space defines that it is in a plane based on Fuhse262’s teaching. Fuhse262 teaches that all the light spots may be at the “same floating height” or “a certain height above or below the substrate surface.” Second, Fuhse262 teaches that arbitrary three-dimensional images may be produced. A POSITA would understand that planed images are within this teaching because a two-dimensional plane is a three-dimensional space with one dimension fixed. For example, when the height (z-dimension) is fixed for an image, the image is defined in the x-y plane at that height z_0 (where z_0 denotes the distance from the plane in the z-direction).

145. Fuhse262 teaches that “upon illumination” (**in response**) “to produce... a light-spot image composed of a plurality of light spots,” (**displaying an image...**

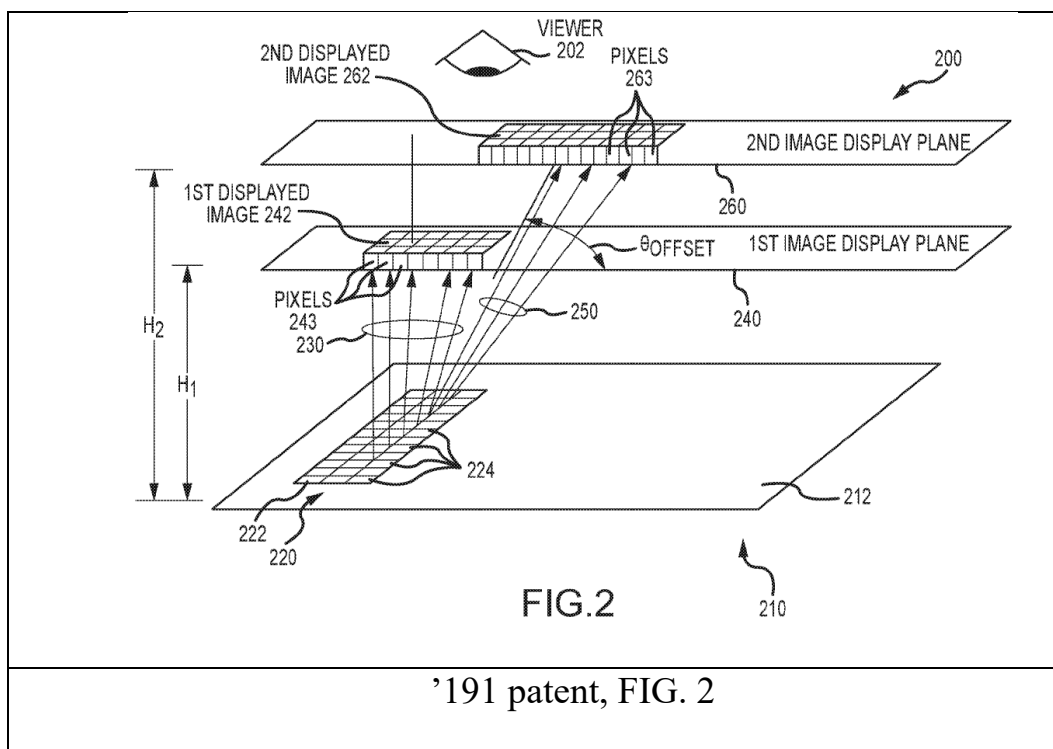
wherein the image comprises a plurality of pixels) “that for a viewer appear floating above or below the surface region” **(in a plane spaced a distance apart from the surface of the substrate)**. Fuhse262, ¶¶0010-12, 0015, 0035-36, 0054-56, 0083-84, 0126-28.

146. The production of a light-spot image composed of a plurality of light spots is **in response** to the illumination. The micromirrors are passive components that produce the light-spot image by reflecting the incident illumination in a pre-determined manner. In other words, the micromirrors produce the light-spot image when there is incident illumination to reflect, and do not produce the light spot image when there is no incident illumination to reflect.

147. The plurality of light spots (**a plurality of pixels**) are the units that form the light-spot image (**the image**). A POSITA would know that overlapping beams reflected by the micromirrors create the light spots. These light spots make up the pixels (picture elements) of the displayed image. This is also how the '191 patent describes “pixels.” For example, with respect to FIG. 2, the '191 patent describes that pixels 243 are what makes up the image 242:

“To this end, a first number of the micro mirrors 224 may be configured to provide sets of pixel-providing micro mirrors that reflect ambient light as shown with arrows 230 to “write” or display **a first displayed image 242 made up of a plurality of pixels 243** (with each of these pixels 243 associated with one of the sets of pixel-providing micro mirrors 224).”

'191 patent, 7:42-48 (emphasis added).



148. Fuhse262 teaches that while “a truly three-dimensional” **image** can be formed by using light spots (**pixels**) of “different floating heights above and/or below the substrate surface,” alternatively, “all light spots [**a plurality of pixels**] in the light-spot image [may] have the same floating height,” (forming **a plane spaced a distance apart from the surface of the substrate**) which provides a two-dimensional image “that floats at a certain height above or below the substrate surface.” Fuhse262, ¶¶0068.

149. Fuhse262 teaches that any arbitrary “desired three-dimensional motif having image points P_j and height values Z_j above an xy plane” may be “specified,” meaning that providing image points P_j of all the same height values Z_j above the

surface of the substrate results in **displaying an image in a plane spaced a distance apart from the surface of the substrate**. Fuhse262, ¶¶0036, 0125-28, cl. 25. Fuhse262 interchangeably refers to image point P_j (**pixel**) and its corresponding light spot as “pixel P_j .” Fuhse262, ¶¶0126, 0128. The “xy plane” is understood to be **the surface of the substrate** because it is the plane that is divided into fields that are “covered with” the optical elements (micromirrors) which are **on a surface of the substrate**, as required by element [1.b1] (*see* element [1.b1]). Fuhse262, ¶¶0036, 0125-28.

150. A two-dimensional image in a plane is simply a three-dimensional image with a small or zero thickness. For example, the surface of the substrate defines a “xy plane” with $z=0$. Fuhse262, ¶¶0126-27, 0110. By teaching any arbitrary three-dimensional image in space (i.e., x, y, z space) can be constructed of light points, it is obvious that a two-dimensional image can be constructed by simply fixing the height (z) values of the pixels, provided the x-y plane is the plane of the surface of the substrate.

151. While providing a two-dimensional image in a plane is obvious based on teaching an arbitrary three-dimensional image, Fuhse262 *explicitly* teaches that a two-dimensional image may be formed by fixing the height (z) values of the pixels:

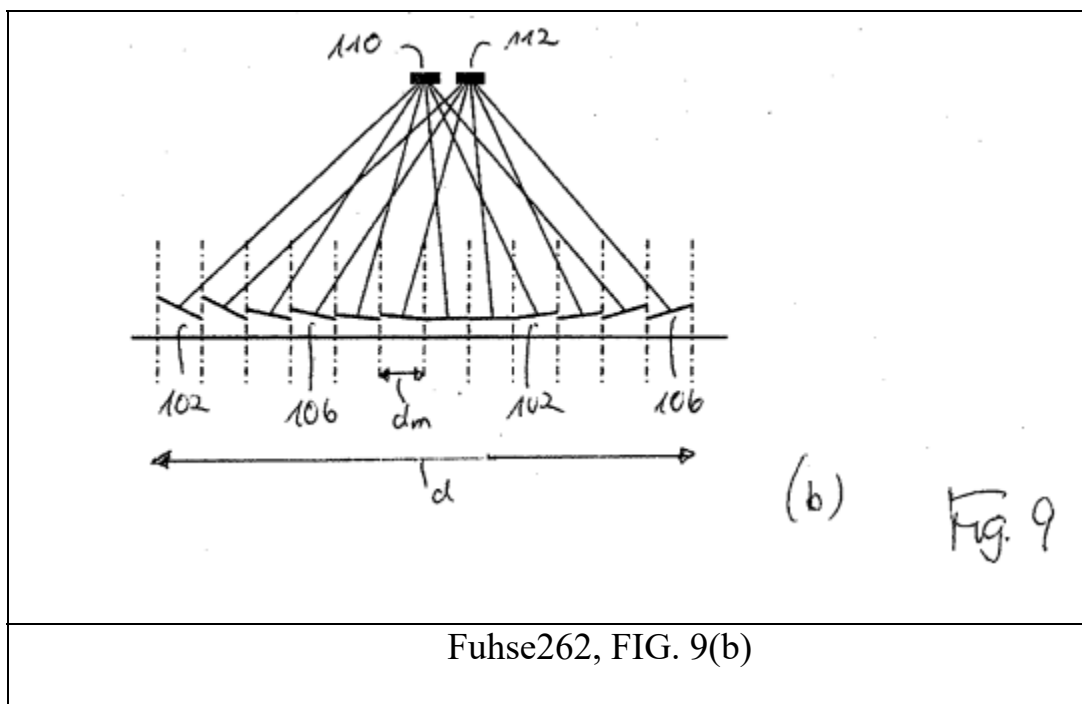
“[0068] If the convex mirrors of a security element have several different focal lengths, i.e. if the light spots of the light-spot image have several different floating heights above and/or below the substrate surface, a truly three-dimensional motif is created. In some

configurations, however, it may also be advisable to design all convex mirrors with the same focal length, so that **all light spots in the light-spot image have the same floating height**. In this way, a backdrop motif is created that floats at a certain height above or below the substrate surface.”

Fuhse262, ¶¶0068, 0015 (emphasis added). In fact, Fuhse262 refers to the resulting image as “a two-dimensional motif,” such as “a font or a logo.” Fuhse262, ¶¶ 0015, 0027, 0117.

152. For the given fixed height of the two-dimensional motif (for example, $z = z_1$), the image is **in a plane** defined by (x, y, z_1) .

153. For example, Figure 9(b) shows “two closely adjacent light spots” 110 and 112 (two pixels) formed at the same height:



Fuhse262, ¶¶0049, 0091-92.

Fuhse262 therefore teaches element [1b.2].

- (5) **Claim 1, Element [1b.3]: “wherein the array of micro mirrors includes for each of the pixels a different set of the micro mirrors each having a reflective surface oriented, in a fixed manner, with a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body, to reflect the ambient light toward a point on the plane corresponding to one of the pixels,”**

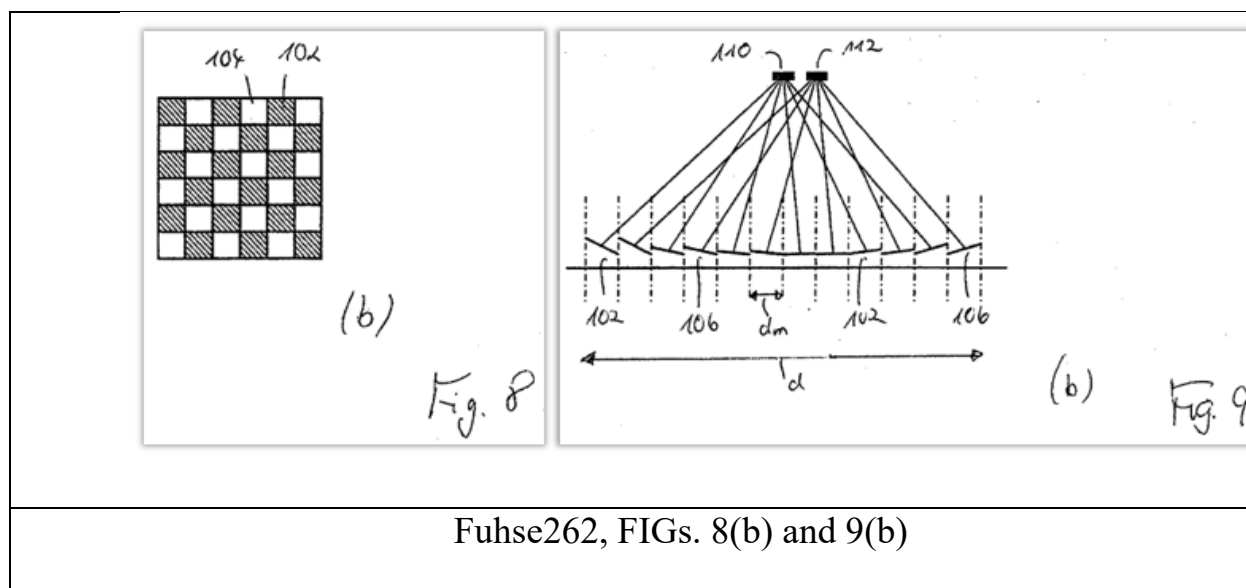
154. In my opinion, Fuhse262 teaches element [1b.3]. Fuhse262, ¶¶0010-11, 0013, 0019-20, 0036, 0060, 0084, 0088, 0091-92, 0095-0101, FIGs. 8b, 9b, and 10. Fuhse262 describes an assignment system to assign micromirrors to light spots (**pixels**) in which each pixel is assigned a “group” of micromirrors, such that each micromirror is assigned to at most one pixel. Figure 10 and its descriptions teach how to properly orient each micromirror to reflect light to its assigned pixel. The micromirrors are fixed in the xy-plane (i.e., **the substrate surface plane**), and each of the x and y axes are rotation axes by which the bodies of the micromirrors are oriented to properly reflect light to the assigned pixel.

155. Fuhse262 discloses that **the array of micro mirrors includes for each of the pixels a different set of the micro mirrors**. Fuhse262, ¶¶0019-20, 0036, 0084, 0088, 0091-92. Fuhse262 explains that “a plurality of optical elements is assigned to every light spot” (**for each of the pixels a different set of the micro mirrors**), such that “groups of optical elements” “are each assigned to different light

spots.” Fuhse262, ¶¶0019-20. Fuhse262 does so by defining “a number of fine fields” “for every image point P_j ,” (**each of the pixels**), and providing that the optical elements in those fine fields (**a different set of the micro mirrors**) “contribute to producing the light spot that corresponds to image point P_j .” Fuhse262, ¶¶0036, 0126-28, cl. 25.

156. In the example of FIG. 8b, (shaded) micromirrors 102 form a set of **micro mirrors**, and (white) “fields 104 [] covered with micromirrors 106” form a second **set of micro mirrors**, and the sets are different because they comprise different micromirrors. Fuhse262, ¶¶0091-92. In other words, each micromirror is assigned to a single light spot. No micromirrors are shared with multiple light spots. Thus, the set of micromirrors for each light spot contains a unique set of micromirrors.

157. As shown in Figure 9(b), “[m]icromirrors 102 form a group of micromirrors, which are all assigned to the same light spot 110 and produce it together when illuminated,” while micromirrors 106 “serve to produce a light spot 112,” meaning a **different set of the micro mirrors is assigned for each of the pixels**. *Id.* Fuhse262 states that in the “[t]he number $n \times n$ of micromirrors is, for example, 10×10 ,” (totaling 100) meaning that in FIG. 8(b), each **set of micro mirrors** would have 50 micromirrors. Fuhse262, ¶0087.



158. Fuhse262 discloses that **the micro mirrors each having a reflective surface oriented... to reflect the ambient light toward a point on the plane corresponding to one of the pixels.** Specifically, Fuhse262 discloses that its micromirrors may be “purely reflective.” Fuhse262, ¶¶0013, 0010-11, 0036, 0060. In particular, Fuhse262 discloses that “the flat mirror surfaces of the micromirrors” “reflect[]” incident light (**the micro mirrors each having a reflective surface**). Fuhse262, ¶¶0095-97. For each of the pixels, the micromirror surfaces reflect incident light (**reflect the ambient light**), such as light source 120, **towards** the point (x_0, y_0, z_0) , which “denotes the position of light spot 110” (**a point on the plane corresponding to one of the pixels**). Fuhse262, ¶¶0095-97.

159. Fuhse262 discloses that such orientation is **in a fixed manner with a body of each of the micro mirrors rotated about at least one of first and second**

rotation axes extending through the body. Fuhse262, ¶¶0095-0101. As an initial matter, Fuhse262's orientation of all its mirrors is **in a fixed manner** because each one has one permanent orientation (normal vector n , as discussed below is fixed). Micromirrors for security elements on, for example, currency, are generally manufactured with a particular orientation to produce a particular image, and generally are not variably controlled.

160. Fuhse262 further teaches that its micromirrors are produced by embossing a lacquer layer and providing a metallized coating on top to increase reflectivity. Fuhse262, ¶¶32-33. The structure of the micromirrors (including the orientation of the mirrored surface) would be **fixed** upon embossing and metallization.

161. Fuhse262 refers to “a display device with a control device” to display different images “very quickly” “depending on the control,” such that “[t]he display device can [] be used as a 3D display for a wide variety of applications.” Fuhse262, ¶38. The “wide variety of applications” are separate, additional applications to provide a 3-D display for electronics, not the applications discussed in this declaration (*e.g.*, micromirror arrays for banknotes, etc.). An electronically controlled display to provide a “continuous sequence of images” would not be suitable for Fuhse262's micromirror arrays for banknotes. *Id.*

162. Fuhse262 discloses how to calculate orientations of its flat micromirror surfaces with respect to Figure 10 and corresponding disclosures. *Id.* In particular, Fuhse262 explains that “[t]he position of the mirror surfaces, i.e. the normal vector $\vec{n}$, is to be determined in such a way that the light incident from a specified direction $\vec{k}$ is reflected onto the focal point (x_0, y_0, z_0) for all micromirrors 102 assigned to light spot 110,” the following equations are used to define the normal vector $\vec{n}$, incident light $\vec{k}$, and reflected light ray $\vec{p}$:

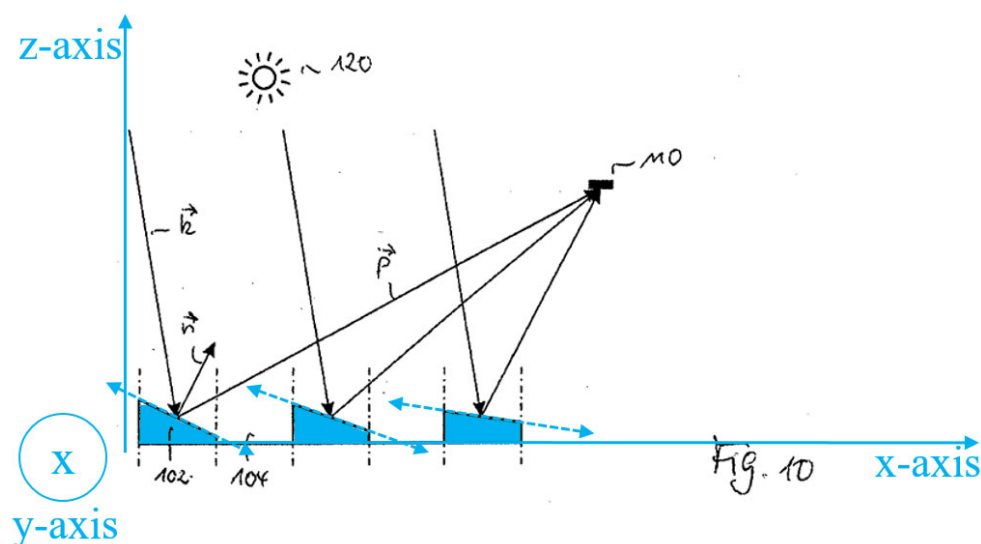
$$\vec{n} = \frac{\frac{\vec{p}}{|\vec{p}|} - \frac{\vec{k}}{|\vec{k}|}}{\left| \frac{\vec{p}}{|\vec{p}|} - \frac{\vec{k}}{|\vec{k}|} \right|}, \quad \vec{p} = \begin{pmatrix} x_0 - x \\ y_0 - y \\ z_0 \end{pmatrix}, \quad |\vec{p}| = \sqrt{(x_0 - x)^2 + (y_0 - y)^2 + z_0^2}$$

Fuhse262, ¶¶0095-97. These vectors are shown in Figure 10.

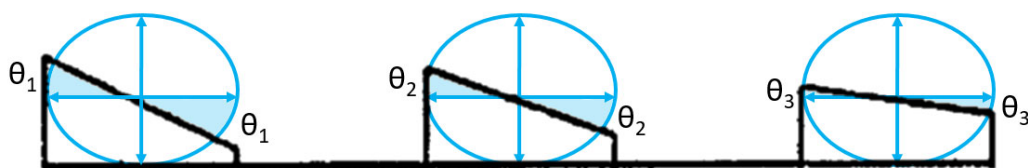
163. The x and y axes are **first and second rotation axes**, such that **a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body** in order to align the normal vector $\vec{n}$ of the micromirrors such that reflected light ray $\vec{p}$ is directed towards the point (x_0, y_0, z_0) corresponding to one of the pixels. In the '191 Patent, the **first and second rotation axes** are likewise the x and y axes. *See* '191 Patent, FIG. 1 (“1ST ROTATION AXIS (Y-AXIS)” and “2ND ROTATION AXIS (X-AXIS)).”

164. As shown in annotated Figure 10 below, **a body of each of the micro mirrors** has been **rotated about at least one of first and second rotation axes**

extending through the body. Assuming the axes shown in annotated Figure 10 below, with the x axis extending along the horizontal, the z axis extending along the vertical, and the y axis extending perpendicular to the page, the below micromirrors have been rotated about **y rotation axis**, which **extend[s]** through the y - length of the micromirror **body**.



165. I have further annotated FIG. 10 below show the rotation of each mirror about the y rotation axis. As can be seen, each mirror has been rotated by a particular angle (i.e., θ_1 , θ_2 , θ_3) in order to reflect light to the coordinates of light spot 110.



166. Fuhse262 therefore renders obvious element [1b.3].

(6) **Claim 1, Element [1b.4]: “wherein each of the different sets concurrently reflect the ambient light to concurrently generate the plurality of pixels,”**

167. In my opinion, Fuhse262 teaches element [1b.4].

168. Fuhse262’s **array of micro mirrors receiving ambient light** is an array of micromirrors arranged on a banknote, for example, that receive the same ambient light that is the same for all micromirrors (*e.g.*, sunlight in FIGs. 2, 10). *See* element [1.b1].

169. Fuhse262 relies on **ambient light** that is incident on all micromirrors, not focused light that is only incident on particular micromirrors at a given time. *See* Section (Technology Background / Ambient Light) V.3. The ’191 patent also discusses that certain mirrors are aimed at the same point in space to create the image pixels (*See* ’191 patent, 2:37-52). In other words, all the micromirrors in Fuhse262’s depiction element receive ambient light **concurrently**.

170. Likewise, Fuhse262’s micromirrors reflect light **concurrently**. Fuhse262’s micromirrors are passive reflectors, such that **each of the different sets concurrently reflect the ambient light to concurrently generate the plurality of pixels** whenever incident light is incident upon them. Fuhse262, ¶¶0095-0101 (describing calculation of orientation of each mirror). Accordingly, the ambient light is incident on the array of micromirrors, and thus **each of the different sets**

will concurrently reflect the ambient light in the manner discussed in element [1.b3]. *See* element [1.b3].

171. Further, each of the different sets **concurrently generate the plurality of pixels** in the manner discussed in element [1.b3]. *See* element [1.b3]. As discussed in element [1.b3], the micromirrors in each set have a **reflective surface oriented, in a fixed manner ... to reflect the ambient light toward a point on the plane corresponding to one of the pixels**. Because the micromirrors concurrently reflect the ambient light, and are properly oriented in a fixed position, the micromirrors concurrently reflect light to their respective pixels to concurrently generate them. Thus, as long as the micromirrors are properly oriented or aimed to generate their respective pixels, the incidence of ambient light will generate concurrent reflections, which will concurrently generate the plurality of pixels.

172. It should be noted that the '191 patent does not use the term “concurrent” (or “simultaneous” or similar terms), and does not even discuss the concept of concurrent operation of sets of micromirrors.

173. In passive micro-optic security elements such as Fuhse262, *concurrent* reflection and generation of pixels is trivially met by any array of passive micromirrors that operate based on reflecting ambient light.

174. Fuhse262 therefore teaches element [1b.4].

(7) **Claim 1, Element [1b.5] “wherein a voxel is created at each of the point on the plane via**

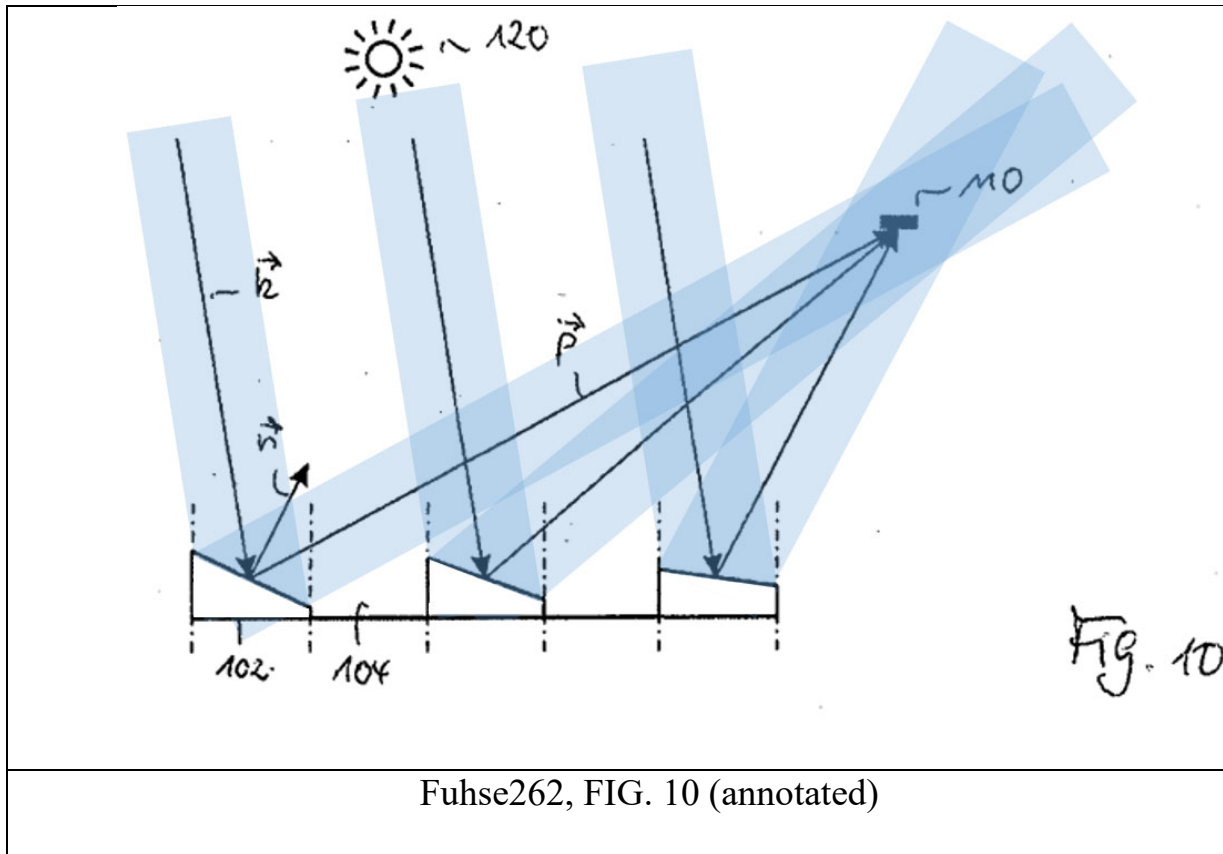
intersection of two or more beams of the reflected ambient light, and”

175. Fuhse262 teaches element [1b.5]. Fuhse262, ¶¶0095-97, FIG. 9-10.

176. While '191 patent does not use the term “voxel,” voxels generally have a volume. This understanding agrees with what Fuhse262 teaches.

177. As discussed with respect to element [1.b3], for each of the pixels, a light spot at point (x_0, y_0, z_0) is a **point on the plane corresponding to one of the pixels**. Fuhse262, ¶¶0095-97. In other words, each light spot is defined in three-dimensional space (i.e., x, y, z coordinates), which is the center-point of **a voxel is created at each of the points on the plane**. *Id.*

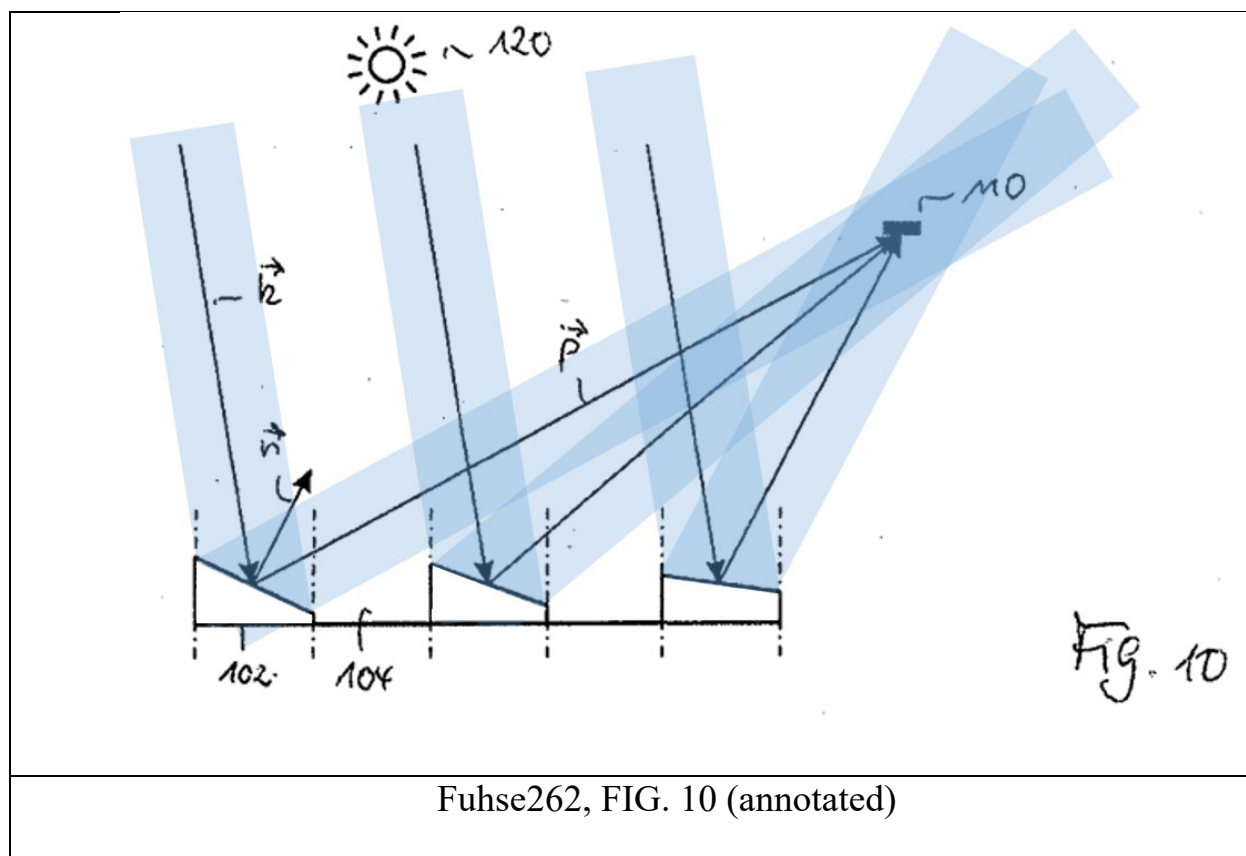
178. For example, with respect to light spot 110 shown in Figure 10, the rays shown are chief rays that depict the center rays of light for each optical element, which is very common in micro-optic design. *See* Section V.2 (describing chief ray). Ambient light reflects from the entire surface of the mirrors and forms reflected beams of light, not just the rays aimed at the center point, as I have depicted below with respect to Figure 10:



179. As can be seen above, the volume of the voxel is set by the superposition of the beams from each micromirror in the set, with the center of the voxel being the coordinates of the point (x_0, y_0, z_0) where all the chief rays intersect. As more micromirrors are added to the set for a given pixel, the pixel becomes brighter and more defined.

180. The beam size reflected from each mirror depends on the size of the mirror, so the size of the voxel ultimately depends on the size of the mirrors and the number of mirrors in the set. See Ex. 1029, p. 359 (discussing the resolution of micromirror based devices is determined by the dimensions of the micromirrors).

181. As shown in Figures 9-10, Fuhse262 creates a voxel via intersection of two or **more beams of the reflected ambient light**. As discussed for element [1.b3], the reflected ambient light for each micromirror is given by “reflected light ray” of direction vector $\vec{p}$, as shown in Figure 10, which is the chief ray for each mirror. The three reflected beams in Figure 10 are reproduced below:



Fuhse262, ¶¶0095-97.

182. Each “reflected light ray” (i.e., the chief ray in each image) represents the center of each **beam[] of the reflected ambient light**. See Section V.2 (describing chief ray). Because each pixel is required to be formed with a “set of

micro mirrors” (as required by [1.b3]), the voxel would include **two or more beams**.

As shown in Figures 9-10, each point (x_0, y_0, z_0) (**a point on the plane corresponding to one of the pixels**) is the center-point of each voxel.

183. Fuhse262 therefore teaches element [1b.5].

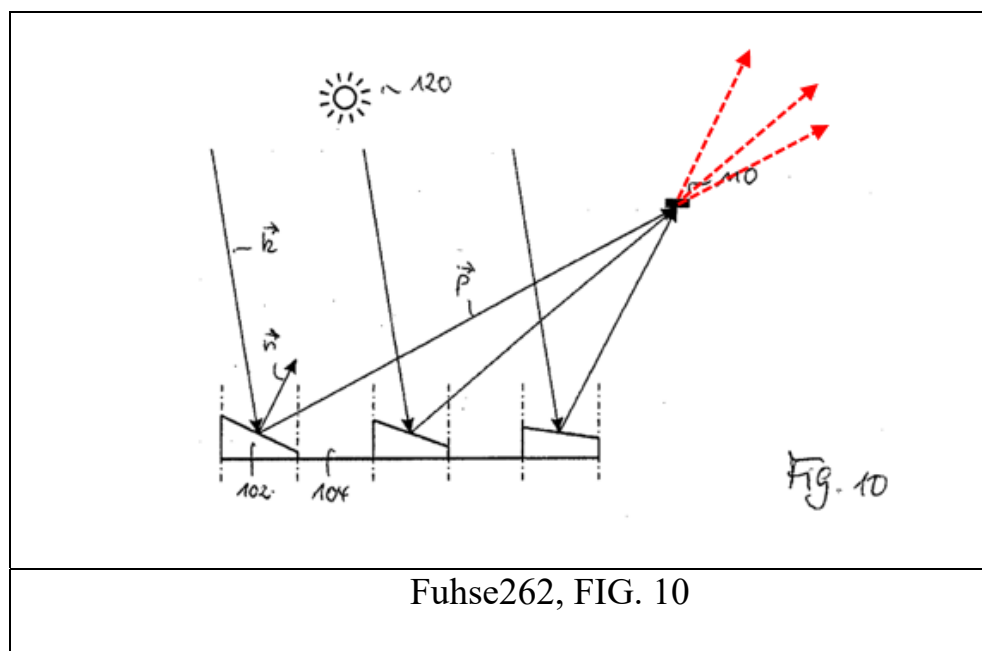
(8) **Claim 1, Element [1b.6]: “wherein each of the created voxels produces an effect of a point source of light floating above the surface of the substrate in the plane.”**

184. In my opinion, Fuhse262 teaches element [1b.6]. Fuhse262, ¶¶0010-11, 0015, 0035-36, 0058-59, 0063-69, 0083, 0089, 0126, cls. 1, 25.

185. Fuhse262 teaches that its “light-spot image composed of a plurality of light spots” (**each of the created voxels**) “for a viewer appear floating above... the surface region” in the form of a specified motif (**produces an effect of a point source of light floating above the surface of the substrate in the plane**). Fuhse262, ¶¶0010-11, 0015, 0035, 0058-59, 0063-69, 0083, 0089, cl. 1. The image in the plane “floats at a certain height above... the substrate surface” because “all light spots in the light-spot image have the same floating height.” Fuhse262, ¶¶0068.

186. Reflected light rays do not terminate at the light spot, but continue unchanged in their ray path, as illustrated below in annotated Figure 10 below. It is a fundamental principle of ray optics that a light ray will continue in its path until it is disturbed. Indeed, the rays must continue in their ray paths to be viewed by the

viewer. As such, the voxel's **effect of a point source** is evident from Fuhse262's Figure 10



187. As discussed in element [1.b5], each voxel is centered at a “point.”

188. Further, the '191 Patent teaches that “the resulting effect is a point source of light” when the “mirrors (which are in the base of the cone) are aimed or targeted (or ‘oriented’) toward the cone apex (image’s pixel).” '191 Patent, 6:7-14. In other words, **voxels produce[] an effect of a point source of light** at least when a cone can be described in which the voxel is the cone’s apex and the micro mirrors are within the base of the cone. Likewise, Fuhse262 teaches a “cone” can be described “originating from the image point” and including all the micromirrors within the base of the cone (*i.e.*, “sphere of influence E_j ”). Fuhse262, ¶¶0036, 0126.

189. Fuhse262 therefore teaches element [1b.6].

b) Claim 6

190. In my opinion, Fuhse262 teaches claim 1, as detailed below.

(1) Claim 6, [6Pre] A method of fabricating a security element useful on paper and coin currency and product labels, comprising:

191. In my opinion, Fuhse262 renders obvious the limitation [6Pre]. *See, supra*, Section X.A.2.a)(1) ([1Pre]).

(2) Claim 6, Element [6a]: providing a substrate; and

192. In my opinion, Fuhse262 renders obvious this limitation. *See, supra*, Section X.A.2.a)(2) ([1a]).

(3) Claim 6, Element [6b.1]: forming an array of micro mirrors on a surface of the substrate, wherein the array of micro mirrors is configured for receiving ambient light and,

193. In my opinion, Fuhse262 renders obvious this limitation. *See, supra*, Section X.A.2.a)(3) ([1b.1]).

(4) Claim 6, Element [6b.2]: in response, displaying a first image and a second image in a plane spaced a distance apart from the surface of the substrate at first and second viewing angles, respectively, wherein the first and second images each comprises a plurality of pixels, and

194. In my opinion, Fuhse262 teaches element [6b.2].

195. Fuhse262 teaches **in response, displaying a first image... in a plane spaced a distance apart from the surface of the substrate... wherein the first... image[] [] comprises a plurality of pixels.** *See, supra*, Section X.A.2.b)(4) ([1b.2]).

196. Fuhse262 also teaches **a second image that comprises a plurality of pixels** and is also **in a plane spaced a distance apart from the surface of the substrate** (*i.e.*, the same plane as the first image). Other than being viewable at a different angle, the claim requires only that the second image has the same requirements of the first image, and is therefore satisfied by the same teachings discussed with respect to element [1b.2].

197. Fuhse262 teaches producing multiple images, including “a light-spot image A” (the **image**) and “a light-spot image B” (**a second image**). Fuhse262, ¶¶0111-20. Both images are produced in the same manner as previously discussed, such as by assigning micromirrors to light spots are described “in connection with Figs. 8 to 10.” Fuhse262, ¶0111.

198. As discussed in element [1b.2], Fuhse262 teaches “two-dimensional” images such as “a font or a logo” (*see* Fuhse262, ¶¶0015, 0027, 0117), and teaches that “several” images may be produced. Fuhse262, ¶¶0116-17.

199. Fuhse262 further teaches that two images may “lie next to each other and/or appear alternately in the same place when the viewing direction changes.” Fuhse262, ¶¶0027, 0118. Whether image A and B “lie next to each other” or are “in

the same place,” they are in the same **plane spaced a distance apart from the surface of the substrate**. For example, when the two images are in the same place, their pixels have the same heights, and therefore are in the same plane. This is accomplished in the same way as discussed in element [1b.2], by selecting all of the image points P_j of the **second image** with the same height values Z_j , the **first image**. *See, supra*, Section X.A.2.b)(4); Fuhse262, ¶¶0036, 0125-28, cl. 25.

200. To the extent it could be argued that Fuhse262 only explicitly discloses a three-dimensional image in the same place or next to a two-dimensional image (*see* ¶¶0027, 0118), it would have been understood to provide two two-dimensional images. As discussed in element [1b.2] (*see, supra*, Section X.A.2.b)(4)X.A.2.a)(4)), by teaching any arbitrary three-dimensional image in space (*i.e.*, x, y, z space) can be constructed of pixels, a POSITA would understand that a two-dimensional image can be constructed by fixing the height (z) values of the pixels. Based on Fuhse262’s teachings that multiple images may be created in the same place or next to each other, and that images may be two-dimensional, it would have been understood to a POSITA to provide two two-dimensional images at the same height (*i.e.*, in the same plane).

201. Fuhse262 also teaches **first and second viewing angles** for the first and second images, respectively. Fuhse262 teaches that “different images become

visible to the viewer from different directions.” Fuhse262, ¶0111, 0024. As

Fuhse262 explains:

“When **tilted to the side**, the security element should show an image change from a light-spot image A to a light-spot image B. First, the required optical elements that produce the light-spot images when illuminated are determined for both light-spot images. As described in connection with Figs. 8 to 10, each light spot is assigned a plurality of optical elements, here a plurality of micromirrors.”

Fuhse262, ¶0111.

202. In other words, light-spot image A (the **image**) is viewable from a certain angle (**a first viewing angle**), and an “image change” to light-spot image B (**the second image**) occurs when “tilted to the side” (**a second viewing**). These teachings are specifically taught to apply to the case where the two images “lie next to each other” or are “in the same place,” such that the images “appear alternately” “when the viewing direction changes.” Fuhse262, ¶¶0027, 0118.

203. Accordingly, Fuhse262 renders obvious element [6b.2].

- (5) **Claim 6, Element [6b.3]: wherein the array of micro mirrors includes for each of the pixels a unique set of the micro mirrors each having a reflective surface rigidly oriented, by rotating a body of each of the micro mirrors about at least one of two rotation axes extending through the body, to reflect the ambient light away from the substrate toward a point on the plane corresponding to one of the pixels,**

204. In my opinion, Fuhse262 teaches element [6b.3], and I opine on the differences below. *See, supra*, Section X.A.2.a)(5) ([1b.3]).

205. The sets of micro mirrors for each pixel are **unique** for the same reasons the sets are **different**. *See, supra*, Section X.A.2.a)(5) ([1b.3]). As discussed, each micromirror is assigned to a single light spot. No micromirrors are shared with multiple light spots. Thus, the set of micromirrors for each light spot contains a **unique** set of micromirrors.

206. The micro mirrors are oriented **rigidly** for the same reasons the micro mirrors are oriented **in a fixed manner**. *See, supra*, Section X.A.2.a)(5) ([1b.3]). In this context the terms rigid and fixed both describe micromirrors that have a permanently fabricated shape (e.g., from embossing) for reflecting light in a single orientation (e.g., to a single pixel).

207. The reflected light is **away from the substrate** for the same reasons it is directed **toward a point on the plane corresponding to one of the pixels** (*see* [1b.3]). Because the array of micromirrors is on the substrate (*see* [1b.1]), reflections from the micromirrors are always **away from the substrate** in accordance with the laws of geometrical optics described above.

(6) **Claim 6, Element [6b.4]: wherein the reflected ambient light from the number of the micro mirrors intersects at the point corresponding to the one of the pixels to create a voxel,**

208. In my opinion, Fuhse262 renders obvious this limitation.

209. Fuhse262 states that the total number of micromirrors may be “for example a few tens, a few hundred or even several thousand.” Fuhse262, ¶0056.

For example, Fuhse262 teaches that “[t]he number $n \times n$ of micromirrors is, for example, 10×10 ,” (totaling 100) (see ¶0087) or may be 288 ($12 \times 12 = 144$ plus $12 \times 12 = 144$) (see ¶¶0090-92). Fuhse262, ¶0087. In Figure 8(c), Fuhse262 teaches that “every fourth field can be covered with micromirrors 102 that are assigned to a specific light spot,” while the other fields “are assigned to up to three other light spots.” Fuhse262, ¶0094. For the 100 micromirror example, if “three other light spots” are utilized, that means the 100 micromirrors would serve four light spots, meaning **each of the sets of the micro mirrors includes** twenty-five micromirrors **(a number of the micro mirrors in the range of 2 to 40)**.

210. This limitation is also satisfied by the description of Figure 8(d), which states that “every ninth field is covered by micromirrors 102 assigned to a specific light spot,” while the remaining “micromirrors [] are assigned to up to eight other light spots.” Fuhse262, ¶0094. If all “eight other light spots” are utilized, the 100 micromirrors would serve nine light spots, meaning **each of the sets of the micro mirrors includes** eleven micromirrors **(a number of the micro mirrors in the range of 2 to 40)**. Similarly, for the 288 micromirror example, **each of the sets** would have 32 (i.e., 288 divided by nine) micromirrors **(a number of the micro mirrors in the range of 2 to 40)**.

- (7) **Claim 6, Element [6b.5]: wherein the reflected ambient light from the number of the micro mirrors intersects at the point corresponding to the one of the pixels to create a voxel,**

211. In my opinion, Fuhse262 renders obvious the limitation. *See, supra*, Section X.A.2.a)(7) ([1b.5]).

(8) Claim 6, Element [6b.6]: whereby the voxel acts like a point light source positioned in the plane at the point corresponding to the one of the pixels.

212. In my opinion, Fuhse262 renders obvious the limitation. *See, supra*, Section X.A.2.a)(8) ([1b.6]).

213. The voxel is created **at the point corresponding to the one of the pixels**. *See also* elements [1b.5], [1b.3]

B. Ground 2: Fuhse262 in view of Fuhse925 renders obvious claims 1 and 6

1. Combined Teachings of Fuhse262 and Fuhse925

a) Motivation to Combine

214. In my opinion, it is obvious to apply the teachings of Fuhse925 to Fuhse262. Fuhse262 and Fuhse925 both relate to security elements for data carriers (e.g., banknotes, etc.) with arrays of optical elements that are arranged to produce, upon illumination, three-dimensional motifs, and thus are in the same field. Fuhse262, Abstract; Fuhse925, Abstract.

215. One reviewing Fuhse262 would have looked to Fuhse925. Fuhse262 describes the proper orientation (i.e., to produce the light spot in the correct location in three-dimensional space) of its micromirrors in the surface plane (i.e., x-y axes) by a normal vector n of its reflective surface. Fuhse262, ¶¶95-99. While it is only

a matter of elementary mathematics to understand how much to rotate the mirror surface in the x and y axes to achieve the normal vector n (as is shown in Fuhse262 (FIGs. 9-10), it is not expressed in explicit detail. Fuhse925, however, *does* provide that explicit detail. Fuhse925 further teaches that the normal surface N can be broken down into two “inclination components” that represent the inclination angle (i.e., how much the mirror surface should be rotated or tilted) of the mirror in each respective axis. Fuhse925, 7:32-65. It would therefore have been obvious to examine how mirror surface orientations are achieved when reviewing Fuhse262.

216. Fuhse925 provides explicit detail for implementing what Fuhse262 teaches, namely a micromirror with a desired surface normal n . As Fuhse925 explains, $N_{\parallel}$ and $N_{\perp}$ are the “mirror slope” in each of the x and y axes (the claimed first and second rotation axes), such that the body of each of the micro mirrors [is] rotated about the x-axis extending through the body by an amount of $N_{\parallel}$, and the body of each of the micro mirrors [is] rotated about the y-axis extending through the body by an amount of $N_{\perp}$ to achieve the proper orientation of the micromirrors. Fuhse925, 7:32-65. Whereas Fuhse262 discloses a desired surface normal for each micromirror and shows the properly angled mirrors (*see* FIGs. 9-10), Fuhse925 provides further explicit detail for how to implement the properly oriented mirrors using “inclination components,” thus, it would have been obvious to combine Fuhse262 and Fuhse925.

217. Additionally, using Fuhse925's teachings regarding inclination components in Fuhse262's system would have involved using a known technique to improve Fuhse262 in a known way, without unpredictable results, and would thus also have been obvious.

b) Reasonable Expectation of Success

218. In my opinion, a POSITA would have had a reasonable expectation of success in implementing the combination of Fuhse262 and Fuhse925. As a POSITA would have recognized, the structures of Fuhse262 and Fuhse925 are similar and compatible.

219. For example, Fuhse262 teaches that its micromirrors may "for example, have a dimension of $50\text{ }\mu\text{m} \times 50\text{ }\mu\text{m}$ and can be formed with a flat mirror surface." Fuhse262, ¶¶95-99. Fuhse925's facets are "micromirrors" with "the dimensions... between $20\text{ }\mu\text{m}$ and $300\text{ }\mu\text{m}$, preferably between $50\text{ }\mu\text{m}$ and $200\text{ }\mu\text{m}$." Fuhse925, 5:28-38, 7:42-48. Fuhse provides almost identical teachings regarding how the micromirrors in Fuhse262 and Fuhse925 should be made, further showing the compatibility in their teachings. *Compare* Fuhse262, ¶0032 ("the optical elements are designed as embossed structures in an embossing lacquer layer... preferably provided with a reflection-increasing coating," "[i]n particular, a full-surface or gridded metallization") *with* Fuhse925, 5:4-8 ("the planar facets are cast in an embossing lacquer layer and preferably provided with a reflection-increasing

coating, especially a metalization”). Thus, the teachings in Fuhse925 regarding proper orientation of micromirrors would have been incorporated into Fuhse262 with no difficulty.

220. As discussed in Ground 1 (*see* X.A.1.b)), the art was relatively predictable in the relevant timeframe (2015). *Id.* Thus, a POSITA would have been able to implement the obviousness modifications in this ground without difficulty. *Id.*

2. Application to the Challenged Claims

221. In my opinion, Fuhse262 in view of Fuhse925 teaches the limitations of claims 1 and 6. *See, supra*, Section X.A(Ground 1). Different elements or additional positions are addressed below.

a) Claims 1, 6

(1) Claims 1, 6, Elements [1Pre]/[6Pre]: A method of fabricating a security element useful on paper and coin currency and product labels, comprising:

222. To the extent not taught by Fuhse262, Fuhse262 in view of Fuhse925 renders this element obvious. Fuhse925, 1:5-14, 5:12-16, 5:39-50, 6:48-62, FIG. 1.

223. Fuhse925 additionally teaches that its invention is **useful as a security element on** not only banknotes, but also on “labels on goods and packaging” (**product labels**). Fuhse925, 6:55-60.

224. In my opinion, one would have been motivated to combine Fuhse262 with Fuhse925 in order to maximize the utility and applications of the invention. While Fuhse262 describes its invention may be applicable to any “data carrier,” it does not explicitly list all of its application. In my opinion, one would have been motivated to look at other references, including Fuhse925, to find additional data carriers for additional applications.

- (2) **Claims 1, 6, Elements [1b.3]/[6.b3]: “wherein the array of micro mirrors includes for each of the pixels a different set of the micro mirrors each having a reflective surface oriented, in a fixed manner, with a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body, to reflect the ambient light toward a point on the plane corresponding to one of the pixels,”**

225. In addition, Fuhse262 in view of Fuhse925 renders obvious element [1b.3] with respect to the term **micro mirrors each having a reflective surface oriented, in a fixed manner with a body of each of the micro mirrors rotated about at least one of first and second rotation axes extending through the body.** Fuhse262, ¶¶0010-11, 0013, 0019-20, 0036, 0060, 0084, 0088, 0091-92, 0095-0101, FIGs. 8b, 9b, and 10; Fuhse925, 6:63-7:18, 7:33-63.

226. Fuhse262 discloses that the micromirrors each have a normal vector n of its reflective surface defined in the x and y axes, and it is a matter of elementary mathematics to understand how to rotate the surface in the x and y axis to achieve

that normal vector n . However, to the extent it would not, Fuhse925's additional teachings would.

227. Like Fuhse262, Fuhse925 teaches a security element (for currency, for example) using arrays of reflective micromirrors to create three-dimensional images appearing to float above the security element. Fuhse925, 6:63-7:18, 7:33-48. Also, like Fuhse262, each micromirror is taught to have a normal vector – “slope N ” – that defines the overall surface orientation of the micromirror. Fuhse925, 7:55-57.

228. Fuhse925 further teaches that the normal surface N can be broken down into two “inclination components” that represent the inclination angle of the mirror in each respective axis. Fuhse925, 7:33-63. Fuhse925 explains:

“As shown in the detailed section **24** in FIG. 3, the depiction region **22** is provided with a plurality of reflective, planar facets **30** that have, for example, a base area of $15\ \mu\text{m} \times 15\ \mu\text{m}$ and a maximum height of a few micrometers. Each of the planar facets **30** is especially characterized by **an inclination angle against the plane** of the areal motif region **20**, which inclination angle has, as **inclination components**, a **parallel component $N_{\parallel}$ parallel to the line 16 (y-direction in FIGS. 2 and 3)** and a **normal component $N_{\perp}$ perpendicular to the line 16 (x-direction in FIGS. 2 and 3)**.

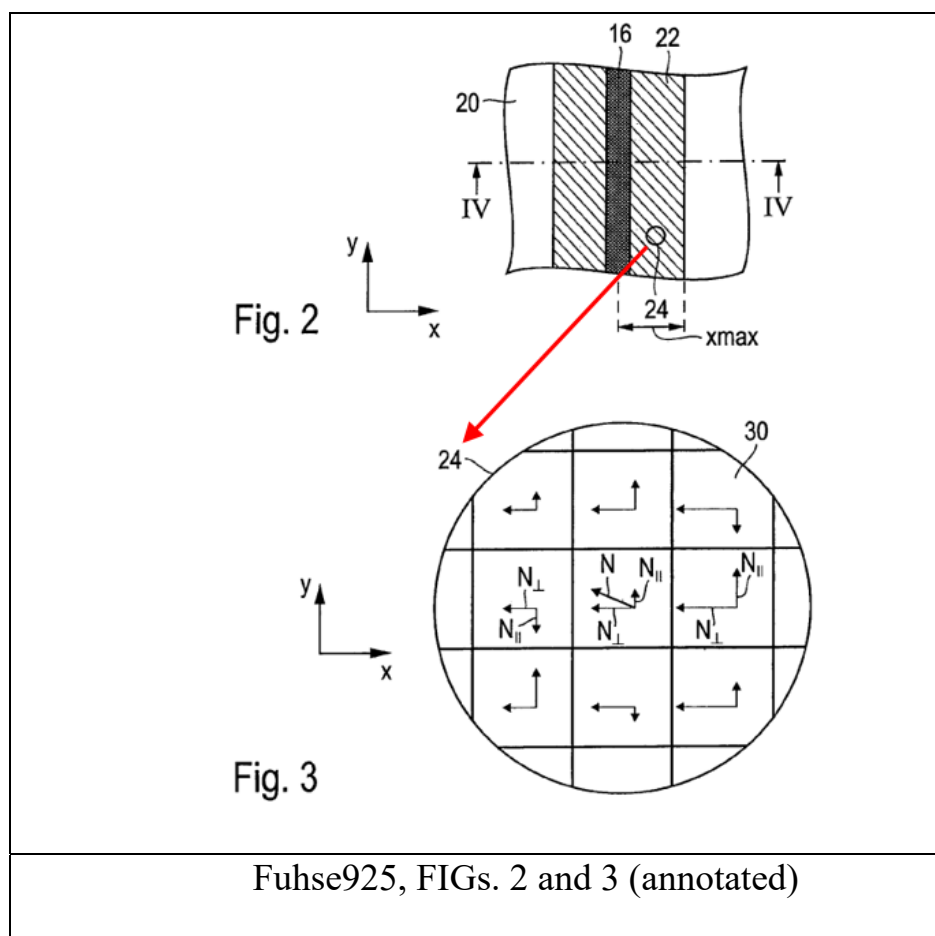
The ray-optically effective reflective facets 30 constitute small inclined micromirrors that direct incident light in a reflection direction given by the condition “angle of incidence equals angle of reflection”. Within the scope of this description, the arrangement of the reflective facets **30** is thus also referred to as a micromirror arrangement.

Particularly the mirror slope or the facet slope in the respective direction can be calculated from the two

inclination components $N_{\parallel}$ and $N_{\perp}$. For illustration, in the top view in FIG. 3, the inclination components of the facets **30** are marked as vectors whose direction indicates the direction of rising mirror level and whose absolute value indicates the slope in the respective direction. The inclination components $N_{\parallel}$ and $N_{\perp}$ yield, as usual, the total slope N of a facet **30**, which is additionally marked for the middle facet in FIG. 3.”

Fuhse925, 7:33-58.

229. Fuhse925 Figures 2 and 3, referenced in the passage above, are reproduced below:



230. Fuhse925, 7:33-58. As Fuhse925 explains, $N_{\parallel}$ and $N_{\perp}$ are the “mirror slope” in each of the x and y axes (**first and second rotation axes**), such that the **body of each of the micro mirrors [is] rotated about the x-axis extending through the body by** an amount of $N_{\parallel}$, and the **body of each of the micro mirrors [is] rotated about the y-axis extending through the body by** an amount of $N_{\perp}$ to achieve the proper orientation of the micromirrors.

231. Fuhse925 also clarifies that that the micromirrors are oriented **in a fixed manner**. Fuhse925 further explains that its reflective planar facets 30 are “characterized by an inclination angle.” Fuhse925, 7:37-42, claim 1. The planar facets 30 are “characterized” by this single “inclination angle” because they are manufactured to provide that angle to achieve a desired reflection.

C. Ground 3: Fuhse262 in view of Fuhse395 renders obvious claims 2-4 and 7-11

232. As explained below, it is my opinion that Fuhse262 in view of Fuhse395 discloses and/or suggests all of the features of claims 2-4 and 7-11 of the '191 patent.

1. Motivation to Combine

233. Fuhse262 and Fuhse395 share the same inventor and assignee (Giesecke & Devrient, Petitioner and a prominent company in the field of the technology at-issue), which I understand weighs strongly in favor of finding a motivation to combine the two references. Further, Fuhse262 and Fuhse395 both

relate to security elements for data carriers (e.g., banknotes, etc.) with arrays of optical elements that are arranged to produce, upon illumination, three-dimensional motifs, and thus are in the same field. Fuhse262, Abstract; Fuhse395, Abstract.

234. It is my opinion that a POSITA would have found it obvious to apply the teachings of Fuhse395 to Fuhse262. Fuhse262 and Fuhse395 both relate to security elements for data carriers (e.g., banknotes, etc.) with arrays of optical elements that are arranged to produce, upon illumination, three-dimensional motifs, and thus are in the same field. Fuhse262, Abstract; Fuhse395, Abstract.

235. It is my opinion that a POSITA would have looked to Fuhse395 when reviewing Fuhse262. Fuhse262 teaches that its “optical elements are designed as embossed structures in an embossing lacquer layer.” Fuhse262, ¶¶32-33, 67. While a POSITA would understand that embossed structures are produced using an embossing tool, it is not expressed in explicit detail how the embossing is performed. Fuhse395 teaches what Fuhse262 does not explicitly disclose, namely, that an “embossing tool” is used for “embossing in thermoplastic foils or into foils coated with radiation-curing lacquers.” Fuhse395, ¶¶59-60, 64-65, 114, 116, 121-24, 129-34, 148-51. It would therefore have been obvious for a POSITA to examine how embossed structures are produced when reviewing Fuhse262.

236. Fuhse395 provides explicit detail for implementing what Fuhse262 teaches, namely a method for producing embossed structures for reflective micromirrors in security elements.

237. As Fuhse395 explains, and as shown in Figures 11 and 16, Fuhse395 teaches that reflective facets 6 (i.e., micromirrors) are formed by embossing “embossing lacquer layer 22” using an “an embossing tool 36” with “an embossing area 37.” Fuhse395, ¶¶147-51. The embossing area 37 has “the inverted form of the surface structure to be embossed,” such that embossing tool 36 produces properly-shaped reflective facets 6 (i.e., micromirrors).

238. Whereas Fuhse262 discloses embossed structures in an embossing lacquer layer, Fuhse395 provides further explicit detail for how to produce the properly oriented embossed micromirrors using an embossing tool, thus, it is my opinion that it would have been obvious for a POSITA to combine Fuhse262 and Fuhse395.

239. Additionally, using Fuhse395’s teachings regarding embossing tools in Fuhse262’s system would have involved using a known technique to improve Fuhse262 in a known way, without unpredictable results, and would thus also have been obvious.

2. Reasonable Expectation of Success

240. It is my opinion that a POSITA would have had a reasonable expectation of success in implementing the combination of Fuhse262 and Fuhse395. Here, the art was relatively predictable in the relevant timeframe (2015). A POSITA would have been able to implement the obviousness modifications in this ground without difficulty.

241. The art related fabrication of OVDs, including techniques such as using “dies” or “masters” for embossing and casting polymer substrates had been highly developed and known to work for decades. As I discussed in Section V.D (Technology Background, Fabrication Methodologies), decades before the relevant date, it was well-known to fabricate arrays of optical elements, including micro mirror arrays, for use in OVDs. These techniques generally relied on the properties of polymers, such as thermoplastics, that has already been developed to a commercially mature stage decades earlier.

242. By the 1980’s there were numerous thermoplastics and fabrication techniques that would be suitable to fabricate the mirco-mirror arrays described in both Fuhse262 and the ’191 Patent. Section V.E. Although prior art to the ’191 Patent, the fabrication techniques discussed in Fuhse262 and Fuhse395 were not new at the time of their filing, and nothing in the structures described by Fuhse262 require

anything more than traditional fabrication techniques for optical micro-structures that were well-known and known to work by the 1980's.

3. Claim 2

- a) The method of claim 1, wherein the forming the array of micro mirrors comprises casting the micro mirrors with a mirror tool in contact with the surface of the substrate,**
- b) wherein the substrate comprises a clear, energy-cured polymer.**

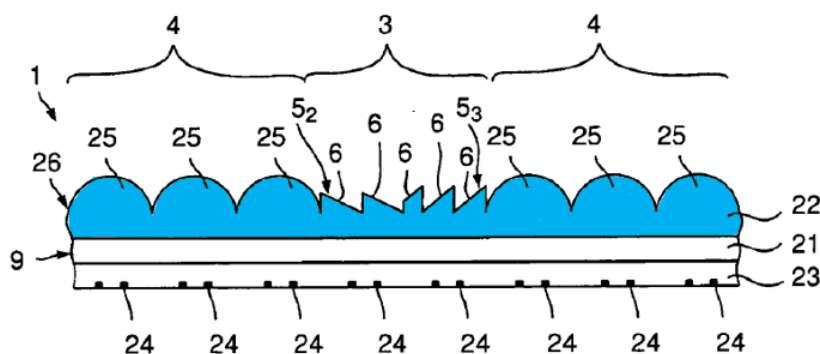
243. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

244. Fuhse262 teaches that its “optical elements are designed [**the forming the array of micro mirrors comprises**] as embossed structures in an embossing lacquer layer.” Fuhse262, ¶¶32-33, 67. Embossing is a well-known fabrication technique that involves using an embossing tool to stamp designs (i.e., “embossed structures” formed from the relief pattern of the stamp) into a substrate (such as “an embossing lacquer layer”). It is my opinion that a POSITA would have understood that in order to form “embossed structures,” an embossing tool must have stamped the embossing lacquer layer (**casting the micro mirrors with a mirror tool in contact with the surface of the substrate**). However, this is not explicitly disclosed in Fuhse262.

245. Fuhse395 teaches what Fuhse262 does not explicitly disclose, namely, that an “embossing tool” (a mirror tool) for “embossing in thermoplastic foils or into

foils coated with radiation-curing lacquers.” Fuhse395, ¶¶59-60, 64-65, 114, 116, 121-24, 129-34, 148-51. For example, as shown in Figures 11 and 13, Fuhse395 teaches that reflective facets 6 (i.e., micromirrors) are formed by embossing “embossing lacquer layer 22” (annotated in blue) that forms part of the substrate (carrier 9) with carrier foil 21. Fuhse395, ¶¶0121, 0148.. Instead of using a foil that is transferred onto a banknote, it is also possible to “carry out a direct printing with subsequent embossing of the security element onto a polymer substrate” (i.e., a plastic banknote). Fuhse395, ¶116.

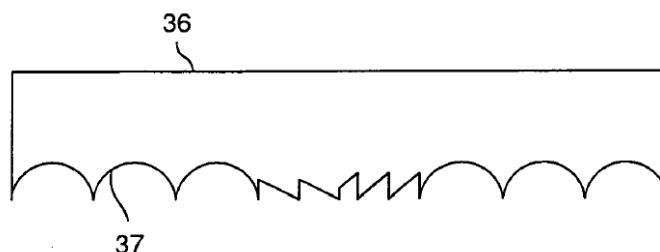
Fig. 11



Fuhse395, ¶¶119-24, 129-34.

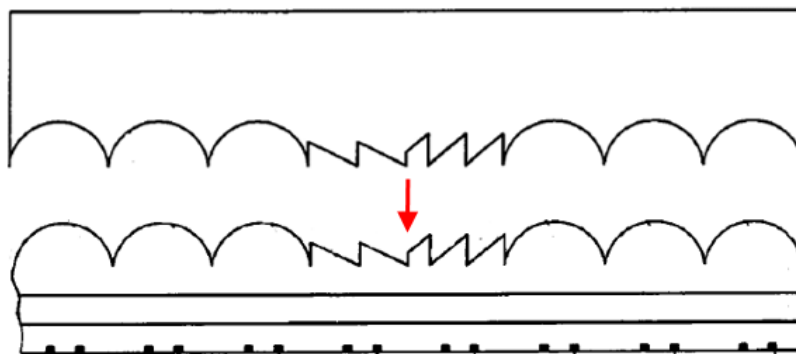
246. As shown in Figure 16, embossing is done using an “an embossing tool 36” with “an embossing area 37.”

Fig. 16



Fuhse395, ¶¶148-51.

247. The embossing area 37 has “the inverted form of the surface structure to be embossed,” such that **casting the micro mirrors with** embossing tool 36 (a **mirror tool**) occurs when the embossing tool 36 is **in contact with the surface of the substrate**, as shown below:

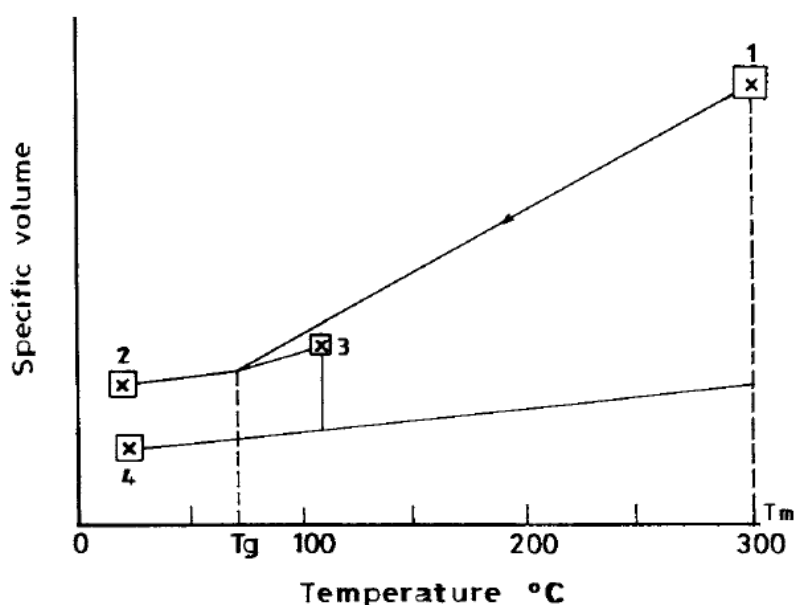


248. Fuhse395 teaches that **the substrate comprises a clear, energy-cured polymer**. The substrate (carrier 9) may be “a radiation-curing plastic (UV resin),” and is thus a **polymer** (*i.e.*, a plastic) and **energy-cured** (*i.e.*, radiation-curing). Fuhse395, ¶¶93, 114, 121, ¶116.

249. Fuhse395 further explains a “polymer substrate” may be used as a substrate, such as a “a plastic foil, e.g. a foil of polyethylene (PE), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyethylene naphthalate (PEN), polypropylene (PP) or polyamide (PA).”

250. It is my opinion that a POSITA would have understood that such resins are clear for security elements on bank notes. For example, polyethylene

terephthalate (PET) was a very common transparent, thermoplastic polymer resin of the polyester family before the relevant date. Amorphous PET, which would result from a hot-embossing process, is fully transparent. As explained in *Polymer Science and Technology*, when “Poly(ethylene terephthalate) is cooled rapidly from 300°C (state 1) to room temperature (state 2). The resulting material is rigid and perfectly transparent.”



See EX1029 (*Polymer Science and Technology*, Ebewe, 1st Edition (2000)), p. 103.

251. Before the relevant time period, PET was known as an effective, **transparent** thermoplastic polymer for use as an embossing layer for optical security devices. For example, U.S. Pat. App. Pub. No. 2014/0285892 (“Sauvage-

Vincent”), Ex. 1033, teaches the following regarding production of a “**transparent layer 101**” (which is “a layer of polymer material intended to be embossed”):

“[0071] The security components as described previously can be produced as follows. The optical structures (undulations) of the different areas are recorded by photolithography or electron beam lithography on a photosensitive support or “photoresist”. A galvanoplasty step is used to transfer these optical structures into a resistant material, for example based on nickel, to produce the die or “master”. A stamping operation is performed from the die to transfer the microstructure onto a film and structure the layer of dielectric material 101 (FIG. 1 A), **typically a stamping lacquer a few microns thick borne by a 12 μ m to 50 μ m film of polymer material, for example of PET (polyethylene terephthalate)**. The stamping may be done by hot pressing of the dielectric material (“hot embossing”) or by molding then cross-linking (“UV casting”). The refractive index of the layer formed by the stamping lacquer is typically 1.58. The duly embossed layer is then metalized. The metallization is done in a vacuum, for example, one of the following metals: silver, aluminum, gold, chrome, copper.”

EX1033, ¶¶71, 73, 43, Abstract.

252. As discussed at the end of the above passage of Sauvage-Vincent, PET embossable layers are compatible with subsequent metallization with metals such as silver, aluminum, and gold.

4. Claim 3

- a) **The method of claim 1, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.**

253. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

254. Fuhse262 teaches that the forming the array of micro mirrors includes providing “the embossed structures ... a reflection-increasing coating[] [and] [i]n particular, **a full-surface or gridded metallization**” (**metallization of surfaces of the micro mirrors**). Fuhse262, ¶¶ 32-34.

255. The “**full-surface or gridded metallization**” is “a reflection-increasing coating” of the micromirrors, meaning it is provided **to form reflective surfaces**. Layers of aluminum, gold, and silver are three of the most common materials to use for highly reflective surfaces of micromirrors, however, it is not explicitly disclosed in Fuhse262. *Id.*

256. Fuhse395 teaches that **the forming facets 6 (the array of micro mirrors) includes** that the “facets 6 [are] metallized in order that they act reflectively” (**metallization of surfaces of the micro mirrors**). Fuhse395, ¶¶ 129, 135, 129-31 (“The facets 6 ... can be formed ... by embossing and mirror-coating.”). Fuhse395 further explains that **the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces**, as Fuhse395 explains:

“In the security element of the invention, **the reflective facets can have a reflection-enhancing, in particular a reflective, coating**. Reflection-enhancing coatings for the purposes of the invention are also coatings that increase the reflectance for example only by about 20% to about 50%, such as e.g. semi-transparent layers, whereas reflective coatings involve a very high reflectance. The reflection-enhancing coating can be a metallic coating, which is vapor-deposited for example. As a coating material there can be employed in particular **aluminum, gold, silver**, copper, palladium, chromium, nickel and/or tungsten as well as alloys thereof. Alternatively, the reflection-

enhancing coating can be formed by a coating with a material with a high refractive index.”

Fuhse395, ¶0024 (emphasis added).

5. Claim 4

- a) The method of claim 3, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors and**
- b) wherein the surface of the substrate includes an embossable coating or layer.**

257. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

258. As discussed under claim 2, it is my opinion that Fuhse262 teaches that in **forming the array of micro mirrors**, its “optical elements are designed as embossed structures in an embossing lacquer layer” (**embossing the surface of the substrate to form the surfaces of the micro mirrors**). Fuhse262, ¶¶32-33, 67. The embossing is of **the surface of the substrate** because the “optical elements [array of micro mirrors] are designed as embossed structures,” and the array of micro mirrors are “on a surface of the substrate” (see element **[1b.1]**). This substrate includes the “embossing lacquer layer” (**an embossable ... layer**). The embossing also creates the structure of the micro mirrors, including its **surfaces**. The embossing is **prior to the metallization of the surfaces of the micro mirrors**

because the metallization is of “the embossed structures,” meaning the embossing occurred before the metallization. Fuhse262, ¶32.

259. As further discussed under claim 2, it is my opinion that Fuhse395 teaches forming **the array of micro mirrors** by “embossing of the embossed layer 22” (**embossing the surface of the substrate**) **to form** “structures for the reflective facets 6” (**the surfaces of the micro mirrors**). Fuhse395, ¶¶129-31.

260. It is my opinion that Fuhse395 teaches an “embossing tool” for “embossing in thermoplastic foils or into foils coated with radiation-curing lacquers.” Fuhse395, ¶¶59-60, 64-65, 114, 116, 121-24, 129-34, 148-51. For example, as shown in Figures 11 and 13, Fuhse395 teaches that reflective facets 6 (*i.e.*, micromirrors) are formed by embossing “embossing lacquer layer 22” that forms part of the **substrate** (carrier 9) with carrier foil 21. As shown in Figure 11, the embossing lacquer layer 22 (which is **an embossable... layer**) is formed on **the surface of the substrate** (carrier 9).

261. It is my opinion that the embossing is performed **prior to the metallization of the surfaces of the micro mirrors** because the “metalliz[ing],” is performed “[s]ubsequently” to the “embossing of the embossed layer 22,” meaning the embossing occurred before the metallization. Fuhse395, ¶0129.

6. Claim 7

- a) The method of claim 6, wherein the forming the array of micro mirrors comprises casting the micro mirrors**

with a mirror tool in contact with the surface of the substrate.

262. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

263. This limitation is similar to the limitation of claim 2(a) above (*see* section X.C.3.a).

7. Claim 8

a) The method of claim 7, wherein the substrate comprises a clear, energy-cured polymer.

264. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

265. This limitation is similar to the limitation of claim 2(b) above (*see* section X.C.3.b).

8. Claim 9

a) The method of claim 6, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.

266. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

267. This limitation is similar to the limitation of claim 3 above (*see* section X.C.4.a).

9. Claim 10

- a) The method of claim 9, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors.**

268. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

269. This limitation is similar to the limitation of claim 4(a) above (*see* section X.C.5.a).

10. Claim 11

- a) The method of claim 10, wherein the surface of the substrate includes an embossable coating or layer.**

270. It is my opinion that Fuhse262 in view of Fuhse395, discloses and/or suggests these limitations.

271. This limitation is similar to the limitation of claim 4(b) above (*see* section X.C.5.b).

272.

D. Ground 4: Fuhse262 in view of Sauvage-Vincent renders obvious claims 2-4 and 7-11

273. As explained below, it is my opinion that Fuhse262 in view of Sauvage-Vincent discloses and/or suggests all of the features of claims 2-4 and 7-11 of the '191 patent.

1. Motivation to Combine

274. It is my opinion that a POSITA would have found it obvious to apply the teachings of Sauvage-Vincent to Fuhse262. Fuhse262 and Sauvage-Vincent both relate to security elements for data carriers (e.g., banknotes, etc.) with arrays of optical elements that are arranged to produce, upon illumination, three-dimensional motifs, and thus are in the same field. Fuhse262, Abstract; Sauvage-Vincent, Abstract.

275. It is also my opinion that a POSITA would have looked to Sauvage-Vincent when reviewing Fuhse262. Fuhse262 teaches that its “optical elements are designed as embossed structures in an embossing lacquer layer.” Fuhse262, ¶¶32-33, 67. While a POSITA would understand that embossed structures are produced using an embossing tool, it is not expressed in explicit detail how the embossing is performed. Sauvage-Vincent teaches what Fuhse262 does not explicitly disclose, namely, that a “die” or “master” may provide a “stamping operation” to produce the microstructure pattern of the desired optical elements. EX1033, ¶¶71, 73, 43, Abstract. It would therefore have been obvious for a POSITA to examine how embossed structures are produced when reviewing Sauvage-Vincent.

276. Sauvage-Vincent provides explicit detail for implementing what Fuhse262 teaches, namely a method for producing embossed structures for reflective micromirrors in security elements.

277. As Sauvage-Vincent explains, a “stamping operation is performed from the die to transfer the microstructure onto a film and structure the layer of dielectric material 101,” such as a film of polymer material. EX1033, ¶¶71, 73, 43, Abstract. This “stamping may be done by hot pressing of the dielectric material (‘hot embossing’) or by molding then cross-linking (‘UV casting’).” *Id.*

278. Whereas Fuhse262 discloses embossed structures in an embossing lacquer layer, Sauvage-Vincent provides further explicit detail for how to produce the properly oriented embossed micromirrors using a die, thus, it would have been obvious for a POSITA to combine Fuhse262 and Sauvage-Vincent.

279. Additionally, using Sauvage-Vincent’s teachings regarding embossing tools in Fuhse262’s system would have involved using a known technique to improve Fuhse262 in a known way, without unpredictable results, and would thus also have been obvious.

2. Reasonable Expectation of Success

280. It is my opinion that a POSITA would have had a reasonable expectation of success in implementing the combination of Fuhse262 and Sauvage-Vincent. Here, the art was relatively predictable in the relevant timeframe (2015). A POSITA would have been able to implement the obviousness modifications in this ground without difficulty.

281. The art related fabrication of OVDs, including techniques such as using “dies” or “masters” for embossing and casting polymer substrates had been highly developed and known to work for decades. As I discussed in Section V.D (Technology Background, Fabrication Methodologies), decades before the relevant date, it was well-known to fabricate arrays of optical elements, including micro mirror arrays, for use in OVDs. These techniques generally relied on the properties of polymers, such as thermoplastics, that has already been developed to a commercially mature stage decades earlier.

282. By the 1980’s there were numerous thermoplastics and fabrication techniques that would be suitable to fabricate the mirco-mirror arrays described in both Fuhse262 and the ’191 Patent. Section V.E. Although prior art to the ’191 Patent, the fabrication techniques discussed in Fuhse262 and Sauvage-Vincent were not new at the time of their filing, and nothing in the structures described by Fuhse262 require anything more than traditional fabrication techniques for optical micro-structures that were well-known and known to work by the 1980’s.

3. Claim 2

- a) The method of claim 1, wherein the forming the array of micro mirrors comprises casting the micro mirrors with a mirror tool in contact with the surface of the substrate,**
- b) wherein the substrate comprises a clear, energy-cured polymer.**

283. It is my opinion that Fuhse262 in view of Sauvage-Vincent discloses and/or suggests these limitations.

284. Fuhse262 teaches that its “optical elements are designed [**the forming the array of micro mirrors comprises**] as embossed structures in an embossing lacquer layer.” Fuhse262, ¶¶32-33, 67. Embossing is a well-known fabrication technique that involves using an embossing tool to stamp designs (i.e., “embossed structures” formed from the relief pattern of the stamp) into a substrate (such as “an embossing lacquer layer”). It is my opinion that a POSITA would have understood that in order to form “embossed structures,” an embossing tool must have stamped the embossing lacquer layer (**casting the micro mirrors with a mirror tool in contact with the surface of the substrate**). However, it is not explicitly disclosed in Fuhse262.

285. Sauvage-Vincent teaches what Fuhse262 does not explicitly disclose, namely, that a nickel “die” or “master” (**a mirror tool**) may to provide an “embossed layer” relief structure of the desired optical elements. EX1033, ¶¶71, 73, 43, Abstract. For example, as shown in Figure 1A, Sauvage-Vincent teaches that its “optical structures” are formed by the stamping operation as applied to dielectric material 101 (FIG. 1A, shown below), “typically a stamping lacquer a few microns thick borne by a 12 μ m to 50 μ m film of polymer material, for example of PET (polyethylene terephthalate)” that forms part of the **substrate**. (*Id.*).

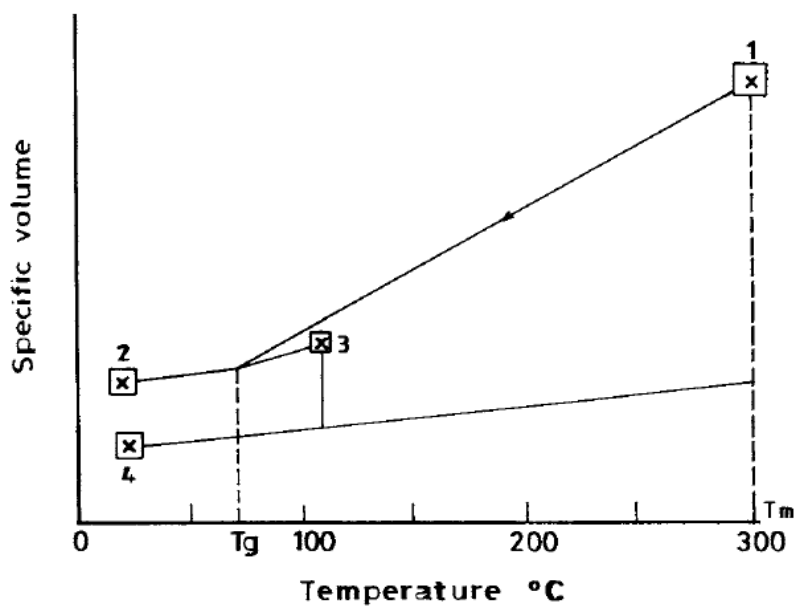
12 μm to 50 μm film of **polymer** material,” (**polymer**) “for example of PET (polyethylene terephthalate),” which is a **clear, energy-cured polymer**. EX1033, ¶¶71, FIG. 1A.

289. Layer 101 is **clear** because it is “transparent in said observation spectral band,” and is also referred to as a “transparent layer 101.” EX1033, Abstract, ¶¶0009, 0030, 0073, FIG. 1A.

290. The dielectric material 101 is an **energy-cured** polymer under two separate examples. First, the transparent dielectric material 101 may be “UV cast[ed]” that is formed when it is molded by the die, meaning that UV **energy cure[s]** the dielectric material. EX1033, ¶71.

291. Second, dielectric material 101 may be stamped by “hot pressing” or “hot embossing,” (i.e., the polymer structures are formed when the die presses against it at elevated temperature) which provides the **energy** for the layer to be **cured**. EX1033, ¶71.

292. Further, polyethylene terephthalate (PET) was a very common transparent, thermoplastic polymer resin of the polyester family before the relevant date. Amorphous PET, which would result from an energy-cured process, is fully transparent. As explained in *Polymer Science and Technology*, when “Poly(ethylene terephthalate) is cooled rapidly from 300°C (state 1) to room temperature (state 2). The resulting material is rigid and perfectly transparent.”



293. See EX1029 (*Polymer Science and Technology*, Ebewe, 1st Edition (2000)), p. 103.

4. Claim 3

- a) The method of claim 1, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.

294. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

295. Fuhse262 teaches that the forming the array of micro mirrors includes providing “the embossed structures ... a reflection-increasing coating[] [and] [i]n particular, a full-surface or gridded metallization” (metallization of surfaces of the micro mirrors). Fuhse262, ¶¶ 32-34.

296. The “full-surface or gridded metallization” is “a reflection-increasing coating” of the micromirrors, meaning it is provided **to form reflective surfaces**. Layers of aluminum, gold, and silver are three of the most common materials to use for highly reflective surfaces of micromirrors, however, it is not explicitly disclosed in Fuhse262.

297. Sauvage-Vincent likewise teaches that the forming desired optical elements includes that a “metallization” (**metallization**). EX1033, ¶71. This “metallization is done in a vacuum, for example, one of the following metals: **silver, aluminum, gold**” (**a layer of aluminum, gold, or silver to form reflective surfaces**). (*Id.*).

5. Claim 4

- a) **The method of claim 3, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors and**
- b) **wherein the surface of the substrate includes an embossable coating or layer.**

298. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

299. Fuhse262 teaches that its “optical elements are designed [**the forming the array of micro mirrors comprises**] as embossed structures in an embossing lacquer layer,” which renders obvious **embossing the surface of the substrate to**

form the surfaces of the micro mirrors and wherein the surface of the substrate includes an embossable coating or layer. Fuhse262, pp. ¶¶29-35. Fuhse847 further teaches that “the embossed structures” are provided with a “metallization,” meaning the embossing must have come **prior to the metallization of the surfaces of the micro mirrors.** Fuhse262, pp. ¶32 (“If the depiction element is at least partially reflective, the embossed structures are preferably provided with a reflection-increasing coating. In particular, a full-surface or gridded metallization, a high-refractive index coating, a thin-film element with a color-shifting effect or a cholesteric liquid crystal layer can be considered as a reflection-increasing coating.”).

300. Sauvage-Vincent further teaches a nickel “die” or “master” may create the microstructures by “hot pressing of the dielectric material (‘hot embossing’)” (**embossing the surface of the substrate to form the surfaces of the micro mirrors**). EX1033, ¶71. This process results in an “embossed layer” (**an embossable... layer**). *Id.* As shown in FIGs. 1A and 7A, the dielectric material 101 is part of the **surface of the substrate**, and **the surface of the substrate includes** the dielectric material 101. EX1033, ¶73 (noting layers 71 and 73 in FIG. 7A are to be removed upon transfer).

301. The embossing is **prior to the metallization of the surfaces of the micro mirrors** because “[t]he duly embossed layer is **then** metalized,” meaning the embossing occurred before the metallization. EX1033, ¶71 (emphasis added).

6. Claim 7

- a) **The method of claim 6, wherein the forming the array of micro mirrors comprises casting the micro mirrors with a mirror tool in contact with the surface of the substrate.**

302. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

303. This limitation is similar to the limitation of claim 2(a) above (*see* section X.D.3.a).

7. Claim 8

- a) **The method of claim 7, wherein the substrate comprises a clear, energy-cured polymer.**

304. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

305. This limitation is similar to the limitation of claim 2(b) above (*see* section X.D.3.b).

8. Claim 9

- a) **The method of claim 6, wherein the forming the array of micro mirrors includes metallization of surfaces of the micro mirrors and wherein the metallization applies a layer of aluminum, gold, or silver to form reflective surfaces.**

306. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

307. This limitation is similar to the limitation of claim 3 above (*see* section X.D.4).

9. Claim 10

- a) The method of claim 9, wherein the forming the array of micro mirrors includes, prior to the metallization of the surfaces of the micro mirrors, embossing the surface of the substrate to form the surfaces of the micro mirrors.**

308. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

309. This limitation is similar to the limitation of claim 4(a) above (*see* section X.D.5.a).

10. Claim 11

- a) The method of claim 10, wherein the surface of the substrate includes an embossable coating or layer.**

310. It is my opinion that Fuhse262 in view of Sauvage-Vincent, discloses and/or suggests these limitations.

311. This limitation is similar to the limitation of claim 4(b) above (*see* section X.D.5.b).

E. Ground 5: Fuhse262 in view of Morford renders obvious claims 5 and 12

312. As explained below, it is my opinion that Fuhse262 in view of Morford discloses and/or suggests all of the features of claims 5 and 12 of the '191 patent.

1. Motivation to Combine

313. It is my opinion that a POSITA would have found it obvious to apply the teachings of Morford to Fuhse262. Fuhse262 relates to micro-optic components, and Morford relates to materials for use in micro-optics components, and thus are in the same field. Fuhse262, Abstract; Morford, Abstract.

314. It is also my opinion that a POSITA would have looked to Morford when reviewing Fuhse262. Fuhse262 teaches that its micromirrors are “embedded in a surrounding material or provided with a protective layer,” but does not specify what material to use for the protective layer. Fuhse262, ¶¶103-04, FIG. 12. However, Morford does.

315. Morford teaches that “a UV-curable high refractive index material” may be used as an optical material. Morford, p. 1. As shown in Figure 2 of Morford, this material has a refractive index of above 1.61 over the entire visible spectrum. Morford, p. 4. As further shown in Figure 4, the UV varnish is highly transparent over the visible range and suitable as a protective layer in Fuhse262. Morford, p. 5.

316. While Fuhse262 teaches that the protective layer usually has “a refractive index of approximately $n = 1.5$ ” (see Fuhse262, ¶104), Morford teaches

that “[i]ncreasing the refractive index of the organic materials and utilizing a UV curing mechanism hold several advantages, including minimal shrinkage during curing, the ability to cure at room temperature, no emission of by-products, and more efficient devices.” Morford, p. 1. A POSITA would have been motivated to select Morford’s “UV-curable high refractive index material” when selecting what material to use for its protective layer.

317. Additionally, using Morford’s teachings regarding UV-curable materials in Fuhse262’s system would have involved using a known technique to improve Fuhse262 in a known way, without unpredictable results, and would thus also have been obvious.

2. Reasonable Expectation of Success

318. It is my opinion that a POSITA would have had a reasonable expectation of success in implementing the combination of Fuhse262 and Morford. Here, the art was relatively predictable in the relevant timeframe (2015). A POSITA would have been able to implement the obviousness modifications in this ground without difficulty.

319. Protective layers are relatively simple, and were well known and well-characterized well before the relevant date. Section V.D.4. It would have been routine to apply the protective later described by Morford to the system of Fuhse262. A POSITA would have been familiar with protective layers and how to implement

them. Fuhse262 is a system that is already adapted to use a protective layer, and little to no medication would be required to accommodate the particular protective layer described by Morford.

320. Protective layers provided by companies like Brewer Science (the provider of the varnish in Morford) are particularly developed for integration into optical micro-device fabrication, and Morford particularly explains the ease with which such materials may be adapted to such products. *See* Morford, p. 1 (“To fully realize the materials’ potential, Brewer Science has been developing processes and machines to provide enabling solutions for device manufacturing.”).

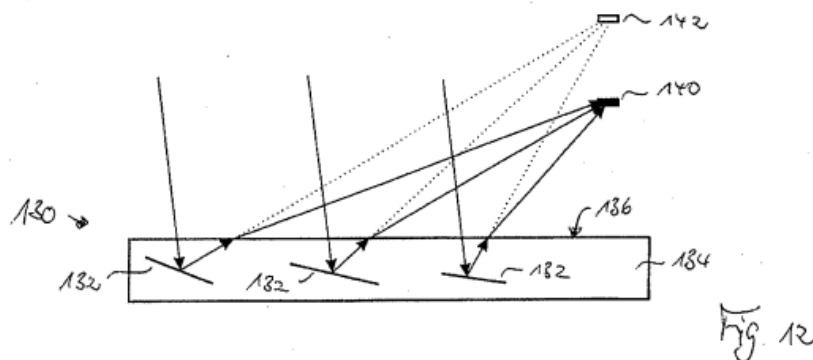
3. Claim 5

- a) **The method of claim 1, wherein the forming the array of micro mirrors comprises filling in recessed surfaces associated with the micro mirrors with a filler comprising at least one of an ultraviolet (UV) varnish, an e-beam solvent, and a water-based varnish and**
- b) **wherein the filler has a refractive index of at least 1.55,**
- c) **whereby at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image.**

321. It is my opinion that Fuhse262 in view of Morford, discloses and/or suggests these limitations.

322. As shown in Figure 12, Fuhse262 teaches that its micromirrors are “embedded in a surrounding material or provided with a protective layer” (**a filler**). Fuhse262, ¶¶103-04. As discussed under claim 2, the micromirrors are “embossed

structures,” and would be understood to include **recessed surfaces** as a result of the embossing. Fuhse262, ¶¶32-33, 67. A POSITA would have understood that by “surrounding” or “embedding” the micromirrors with the protective layer, the **recessed surfaces** would be **fill[ed] in**.



323. Fuhse262 teaches that the protective layer usually has “a refractive index of approximately $n = 1.5$.” Fuhse262, ¶104. A POSITA would have understood that “approximately” 1.5 includes 1.55, so Fuhse262 teaches that **the filler has a refractive index of at least 1.55**.

324. Fuhse262 does not explicitly disclose the material of the protective layer, but the use of **an ultraviolet (UV) varnish** was known in the art, for example, by Morford. Morford teaches that “a UV-curable high refractive index material” may be used as an optical material. Morford, p. 1. As shown in Figure 2 of Morford, this material has a refractive index of above 1.61 over the entire visible spectrum. Morford, p. 4. Morford’s material is a varnish. A varnish is a resin that is applied to a surface to form a hard, typically transparent, film or coating. Morford’s material

is a “resin solution” that is “applied on various substrates using spin coating to create the films,” and is a varnish. Morford, 2-3. As further shown in Figure 4, the UV varnish is highly transparent over the visible range and suitable as a filler in Fuhse262. Morford, p. 5.

325. The '191 Patent's only teaching with respect to **whereby at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image** is that it is a direct result of providing a material with an index of at least 1.55. *See* '191 Patent, 17:11-15. Thus, because Morford provides an index of over 1.55, it would cause **at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image**.

4. Claim 12

- a) (1) The method of claim 6, wherein the forming the array of micro mirrors comprises filling in recessed surfaces associated with the micro mirrors with a filler comprising at least one of an ultraviolet (UV) varnish, an e-beam solvent, and a water-based varnish and wherein the filler has a refractive index of at least 1.55, whereby at least a portion of the received ambient light at extreme angles is reflected to sharpen the displayed image.

326. It is my opinion that Fuhse262 in view of Morford, discloses and/or suggests these limitations.

327. This limitation is similar to the limitation of claim 5 above (*see* section X.E.3.

F. Ground 6: Claims 2-4, 7-11 are rendered obvious under 35 U.S.C. §103 by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Fuhse395 (Ground 3)

328. Ground 6 corresponds to Ground 2 but with the addition of Fuhse395 (Ground 3) applied to Ground 2. Ground 2 addresses the independent claims and Ground 3 addresses certain dependent claims. Accordingly, Fuhse925 (secondary reference for Ground 2) does not affect positions for Ground 3, and Fuhse395 (secondary reference for Ground 3) does not affect positions for Ground 2. The motivation for combination and reasonable expectation of success for Grounds 2 and 3 apply here. Grounds 2 and 3 are re-presented here as Ground 6 with reference to my analysis above. *See, supra*, Sections X.B and X.C (Grounds 2 and 3). It is my opinion that claims 2-4, 7-11 are rendered obvious.

G. Ground 7: Claims 2-4, 7-11 are rendered obvious under 35 U.S.C. §103 by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Sauvage-Vincent (Ground 4)

329. Ground 7 corresponds to Ground 2 but with the addition of Sauvage-Vincent (Ground 4) applied to Ground 2. Ground 2 addresses the independent claims and Ground 4 addresses certain dependent claims. Accordingly, Fuhse925 (secondary reference for Ground 2) does not affect positions for Ground 4, and Sauvage-Vincent (secondary reference for Ground 4) does not affect positions for Ground 2. The motivation for combination and reasonable expectation of success for Grounds 2 and 4 apply here. Grounds 2 and 4 are re-presented here as Ground 7

with reference to my analysis above. *See, supra*, Sections X.B and X.D (Grounds 2 and 4). It is my opinion that claims 2-4, 7-11 are rendered obvious.

H. Ground 8: Claims 5 and 12 are rendered obvious under 35 U.S.C. §103 by Fuhse262 in view of Fuhse925 (Ground 2) and further in view of Morford (Ground 5)

330. Ground 8 corresponds to Ground 2 but with the addition of Morford (Ground 5) applied to Ground 2. Ground 2 addresses the independent claims and Ground 5 addresses certain dependent claims. Accordingly, Fuhse925 (secondary reference for Ground 2) does not affect positions for Ground 5, and Morford (secondary reference for Ground 5) does not affect positions for Ground 2. The motivation for combination and reasonable expectation of success for Grounds 2 and 5 apply here. Grounds 2 and 4 are re-presented here as Ground 8 with reference to my analysis above. *See, supra*, Sections X.B and X.E (Grounds 2 and 5). It is my opinion that claims 5 and 12 are rendered obvious.

XI. SECONDARY CONSIDERATIONS

331. Having reviewed the evidence of record, I am not aware of any secondary considerations that would suggest non-obviousness of the challenged claims. Indeed, as discussed above, the claimed subject matter appears to be well-known micromirror design features that would have been obvious to combine at the time of the alleged invention. To the extent Patent Owner identifies evidence of

secondary considerations at a later point in the proceeding, I reserve the right to offer my opinions to address it at that time.

XII. CONCLUSION

332. For the foregoing reasons, I am of the opinion that claims 1-12 of the '191 patent would have been obvious based on the prior art cited herein.

Declaration of Prof. Lambertus Hesselink, Ph.D.

I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and 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.

Date: _____ May 1 2024 _____ Respectfully Submitted



Prof. Lambertus Hesselink, Ph.D.