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Auyeung et al.

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(54) **LIGHT ASSEMBLY FOR PROVIDING SUBSTANTIALLY UNIFORM ILLUMINATION**

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(58) **Field of Classification Search**
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(56) **References Cited**

U.S. PATENT DOCUMENTS

2,254,961 A 9/1941 Lawrence et al.
4,235,285 A 11/1980 Johnson et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2615706 A1 9/2006
CN 201925854 U 8/2011
(Continued)

OTHER PUBLICATIONS

Kim, Yu-Sin, et al., "Development of a Numerical Model for the Luminous Intensity Distribution of a Planar Prism LED Luminaire for Applying an Optimization Algorithm," Leukos, vol. 9, No. 1, Jul. 2012, pp. 57-72 (published online: Sep. 16, 2013).
(Continued)

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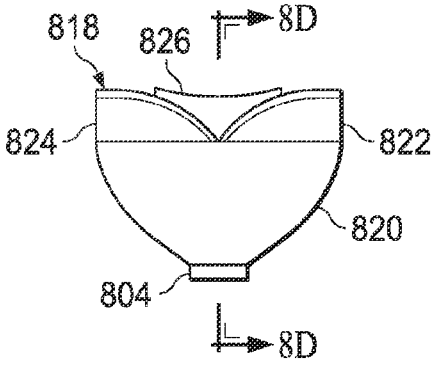
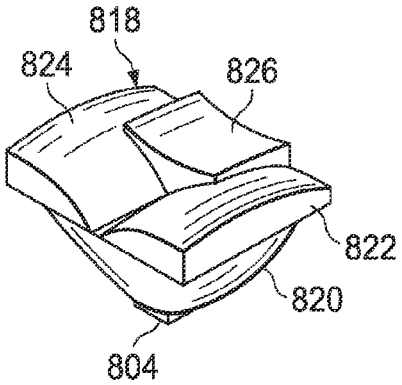
(57) **ABSTRACT**

A lighting assembly can be used for illuminating a predetermined area. The assembly includes a number of LEDs directed toward the predetermined area and a number of lenses. Each lens is disposed over only one associated LED and is configured to direct light from that LED toward the predetermined area, such that the light from each lens is directed across the entire predetermined area. The light intensity from each lens is substantially uniform across the entire predetermined area.

26 Claims, 13 Drawing Sheets





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G09F 13/02	(2006.01)
G09F 15/00	(2006.01)
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USPC 362/522, 309, 334, 335, 336, 337, 338, 362/340, 332, 311, 331, 333; 257/98, 257/100

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,679,118	A	7/1987	Johnson et al.	
5,036,248	A	7/1991	McEwan et al.	
5,083,194	A	1/1992	Bartilson	
5,329,426	A	7/1994	Villani	
5,384,940	A	1/1995	Soule et al.	
5,803,579	A	9/1998	Turnbull et al.	
5,818,640	A	10/1998	Watanabe et al.	
5,857,767	A	1/1999	Hochstein	
5,896,093	A	4/1999	Sjobom	
5,924,788	A	7/1999	Parkyn, Jr.	
5,926,320	A	7/1999	Parkyn, Jr. et al.	
6,045,240	A	4/2000	Hochstein	
6,274,924	B1	8/2001	Carey et al.	
6,364,507	B1	4/2002	Yang	
6,428,189	B1	8/2002	Hochstein	
6,517,218	B2	2/2003	Hochstein	
6,536,923	B1	3/2003	Merz	
6,547,423	B2	4/2003	Marshall et al.	
6,582,103	B1 *	6/2003	Popovich	F21S 4/008 361/224
6,607,286	B2	8/2003	West et al.	
6,674,096	B2	1/2004	Sommers	
6,741,351	B2	5/2004	Marshall et al.	
6,783,269	B2	8/2004	Pashley et al.	
6,784,603	B2	8/2004	Pelka et al.	
6,799,864	B2	10/2004	Bohler et al.	
6,837,605	B2	1/2005	Reill	
6,864,513	B2	3/2005	Lin et al.	
6,896,381	B2	5/2005	Benitez et al.	
6,918,684	B2	7/2005	Harvey	
6,948,838	B2	9/2005	Kunstler	
7,006,306	B2	2/2006	Falicoff et al.	
7,009,213	B2	3/2006	Camras et al.	
7,048,400	B2	5/2006	Murasko et al.	
7,118,236	B2	10/2006	Hahm et al.	
7,144,135	B2	12/2006	Martin et al.	
7,153,002	B2	12/2006	Kim et al.	
7,159,997	B2	1/2007	Reo et al.	
7,246,931	B2	7/2007	Hsieh et al.	
7,336,195	B2	2/2008	van de Ven	
7,339,202	B2 *	3/2008	Chiu	G02B 6/0025 257/100
7,374,306	B2	5/2008	Liu	
7,374,316	B2	5/2008	Kuo et al.	
7,375,381	B2	5/2008	Shimizu et al.	
7,390,117	B2	6/2008	Leatherdale et al.	
7,396,146	B2	7/2008	Wang	
7,410,275	B2 *	8/2008	Sommers	F21V 5/04 362/257
7,434,964	B1	10/2008	Zheng et al.	
7,458,706	B1	12/2008	Liu et al.	
7,478,915	B1	1/2009	Pedersen	
7,513,639	B2	4/2009	Wang	
7,513,653	B1	4/2009	Liu et al.	
7,549,777	B2	6/2009	Huang	
7,572,654	B2	8/2009	Chang	
7,618,162	B1	11/2009	Parkyn et al.	
7,618,163	B2	11/2009	Wilcox	
7,654,684	B1	2/2010	Wight et al.	
7,665,862	B2	2/2010	Villard	
7,674,019	B2	3/2010	Parkyn et al.	
7,686,469	B2	3/2010	Ruud et al.	
7,736,019	B2	6/2010	Shimada et al.	
7,748,863	B1	7/2010	Holman et al.	
7,753,561	B2	7/2010	Chaves et al.	
7,753,564	B2	7/2010	Cheng et al.	
7,841,750	B2	11/2010	Wilcox et al.	
7,857,483	B2	12/2010	Storch et al.	
7,866,851	B2	1/2011	Chang	
7,896,522	B2	3/2011	Heller et al.	
7,905,634	B2	3/2011	Agurok et al.	
7,942,559	B2	5/2011	Holder et al.	
7,952,262	B2	5/2011	Wilcox et al.	
7,959,326	B2	6/2011	Laporte	
7,980,733	B2	7/2011	Shih et al.	
7,997,761	B2	8/2011	Peck et al.	
8,002,435	B2	8/2011	Laporte	
8,035,119	B2	10/2011	Ng et al.	
8,052,303	B2	11/2011	Lo et al.	
8,056,614	B2	11/2011	Chen et al.	
8,092,049	B2	1/2012	Kinnune et al.	
8,101,434	B2	1/2012	Guillien et al.	
8,192,048	B2	6/2012	Kristoffersen et al.	
8,201,970	B2	6/2012	Wang et al.	
8,210,723	B2	7/2012	Peck et al.	
8,215,814	B2	7/2012	Marcoux	
8,235,553	B2	8/2012	Minami et al.	
8,246,219	B2	8/2012	Teng et al.	
8,262,252	B2	9/2012	Bergman et al.	
8,267,551	B2	9/2012	Lin	
8,273,158	B2	9/2012	Jarrier et al.	
8,308,331	B2	11/2012	Loh	
8,310,158	B2	11/2012	Coplin et al.	
8,330,387	B2	12/2012	York et al.	
8,338,841	B2	12/2012	Lerman et al.	
8,348,461	B2	1/2013	Wilcox et al.	
8,360,613	B2	1/2013	Little, Jr.	
8,376,585	B2	2/2013	Noeth	
8,408,737	B2	4/2013	Wright et al.	
8,454,194	B2	6/2013	Liu	
8,454,215	B2	6/2013	Bollmann	

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,465,178	B2	6/2013	Wilcox et al.	
8,469,552	B2	6/2013	Moeller	
8,476,650	B2	7/2013	Liao	
8,547,023	B2	10/2013	Chang et al.	
8,567,987	B2	10/2013	Wronski	
8,573,815	B2	11/2013	Mallory et al.	
8,577,434	B2	11/2013	Merchant et al.	
8,585,253	B2	11/2013	Duong et al.	
8,602,599	B2	12/2013	Zimmer et al.	
8,610,357	B2	12/2013	Stoll et al.	
8,622,574	B2	1/2014	Liu	
8,628,217	B2	1/2014	Moshtagh	
8,632,225	B2	1/2014	Koo et al.	
8,651,693	B2	2/2014	Josefowicz et al.	
8,662,704	B2	3/2014	Carraher et al.	
8,733,981	B2	5/2014	Jiang et al.	
8,789,967	B2	7/2014	Gordin et al.	
8,801,221	B2	8/2014	Lin et al.	
8,824,125	B1	9/2014	Cox et al.	
8,835,958	B2	9/2014	Hsieh	
8,858,024	B2	10/2014	Wu et al.	
8,864,344	B2	10/2014	Jiang et al.	
8,870,410	B2	10/2014	Auyeung	
8,870,413	B2	10/2014	Auyeung	
8,876,325	B2	11/2014	Lu et al.	
8,922,734	B2	12/2014	Lin	
8,931,934	B2	1/2015	Lin	
9,046,293	B2	6/2015	Pelka et al.	
9,182,101	B2	11/2015	Nakamura et al.	
2003/0099105	A1	5/2003	Watson	
2004/0004827	A1	1/2004	Guest	
2005/0018428	A1	1/2005	Harvey	
2005/0047170	A1	3/2005	Hilburger et al.	
2005/0151141	A1	7/2005	Grotsch et al.	
2006/0076568	A1*	4/2006	Keller	G02B 6/4214 257/98
2006/0081863	A1*	4/2006	Kim	H01L 33/54 257/98
2006/0146531	A1	7/2006	Reo et al.	
2006/0245083	A1*	11/2006	Chou	G02B 19/0061 359/726
2007/0201225	A1	8/2007	Holder et al.	
2007/0257270	A1	11/2007	Lu et al.	
2007/0279904	A1	12/2007	Tasch et al.	
2008/0073663	A1*	3/2008	Chang	H01L 33/58 257/99
2008/0080179	A1	4/2008	Giorgi	
2008/0084693	A1	4/2008	Shimada et al.	
2008/0084701	A1	4/2008	Van De Ven et al.	
2008/0180014	A1	7/2008	Tzeng et al.	
2008/0212319	A1	9/2008	Klipstein	
2008/0247173	A1	10/2008	Danek et al.	
2008/0273327	A1	11/2008	Wilcox et al.	
2009/0097265	A1	4/2009	Sun et al.	
2009/0154158	A1	6/2009	Cheng et al.	
2009/0180281	A1	7/2009	Ahland, III et al.	
2009/0256459	A1	10/2009	Liu	
2009/0262532	A1*	10/2009	Wilcox	F21V 5/04 362/248
2009/0267474	A1	10/2009	Zhou et al.	
2009/0273933	A1*	11/2009	Woodward	F21V 7/0091 362/297
2009/0290338	A1	11/2009	Heller et al.	
2009/0296407	A1	12/2009	Bailey	
2009/0303711	A1	12/2009	Remus et al.	
2010/0002727	A1	1/2010	Svelmoe	
2010/0008094	A1	1/2010	Shuai et al.	
2010/0014289	A1	1/2010	Thomas et al.	
2010/0014290	A1	1/2010	Wilcox	
2010/0027271	A1*	2/2010	Wilcox	F21S 8/081 362/311.02
2010/0039810	A1	2/2010	Holder et al.	
2010/0046225	A1	2/2010	Zheng	
2010/0085774	A1	4/2010	Park	
2010/0118531	A1	5/2010	Montagne	
2010/0128488	A1	5/2010	Marcoux	
2010/0149801	A1*	6/2010	Lo	F21V 5/04 362/235
2010/0172135	A1	7/2010	Holder et al.	
2010/0195330	A1	8/2010	Schaefer et al.	
2010/0232155	A1	9/2010	Wang	
2010/0296267	A1	11/2010	Yu et al.	
2010/0296283	A1	11/2010	Taskar et al.	
2010/0302785	A1	12/2010	Zhou	
2010/0302786	A1	12/2010	Wilcox et al.	
2011/0002120	A1	1/2011	Song et al.	
2011/0031887	A1	2/2011	Stoll et al.	
2011/0038151	A1	2/2011	Carraher et al.	
2011/0063857	A1	3/2011	Ll et al.	
2011/0068708	A1	3/2011	Coplin et al.	
2011/0075409	A1	3/2011	Zheng	
2011/0149548	A1	6/2011	Yang et al.	
2011/0170283	A1	7/2011	Chan	
2011/0205744	A1*	8/2011	Kim	F21V 5/04 362/296.01
2011/0219650	A1	9/2011	Wright et al.	
2011/0242807	A1	10/2011	Little, Jr. et al.	
2011/0242816	A1	10/2011	Chowdhury et al.	
2011/0278633	A1	11/2011	Clifford	
2011/0280003	A1	11/2011	Hsu et al.	
2012/0014115	A1	1/2012	Park et al.	
2012/0043560	A1	2/2012	Wu et al.	
2012/0080699	A1	4/2012	Chowdhury et al.	
2012/0087125	A1	4/2012	Liu	
2012/0163005	A1	6/2012	Liu	
2012/0201022	A1	8/2012	Van de Ven et al.	
2012/0250321	A1	10/2012	Blincoe et al.	
2012/0307495	A1	12/2012	Shih	
2013/0010468	A1	1/2013	Stoll et al.	
2013/0057861	A1	3/2013	Ishii et al.	
2013/0063970	A1	3/2013	Oh	
2013/0135861	A1	5/2013	Chen et al.	
2013/0193850	A1	8/2013	Demuynck et al.	
2013/0270585	A1	10/2013	Mei et al.	
2013/0291414	A1	11/2013	Cegnar	
2013/0335979	A1	12/2013	Lauret et al.	
2014/0016326	A1	1/2014	Dieker et al.	
2014/0029253	A1	1/2014	Auyeung	
2014/0029259	A1	1/2014	Auyeung	
2014/0029274	A1	1/2014	Auyeung	
2014/0085905	A1	3/2014	Broughton	
2014/0104851	A1	4/2014	Auyeung	
2014/0112007	A1	4/2014	Auyeung	
2014/0168963	A1	6/2014	Stone et al.	
2014/0168998	A1	6/2014	Tang et al.	
2014/0268761	A1	9/2014	Raleigh et al.	
2014/0373348	A1	12/2014	Li	

FOREIGN PATENT DOCUMENTS

CN	202629916	U	12/2012
CN	102889549	A	1/2013
DE	202005016441	U1	2/2007
EP	1078301	A1	2/2001
EP	1528603	A2	5/2005
EP	1988576	A1	11/2008
EP	2039985	A2	3/2009
EP	2092859	A1	8/2009
EP	2172696	A1	4/2010
EP	2378337	A2	10/2011
EP	2416062	A2	2/2012
EP	2448021	A2	5/2012
EP	2553331	A1	2/2013
EP	2622267	A1	8/2013
GB	2421584	A	6/2006
JP	2003195790	A	7/2003
JP	2005024706	A	1/2005
JP	2005217094	A	8/2005
JP	2005327820	A	11/2005
JP	2007035951	A	2/2007
JP	2007281260	A	10/2007
JP	2011060575	A	3/2011
JP	2012054115	A	3/2012

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	2012113276	A	6/2012
WO	2004051223	A2	6/2004
WO	2006033770	A2	3/2006
WO	2006126123	A1	11/2006
WO	2008047335	A1	4/2008
WO	2008122941	A1	10/2008
WO	2009064607	A1	5/2009
WO	2010010494	A1	1/2010
WO	2010033545	A2	3/2010
WO	2010130732	A1	11/2010
WO	2011041813	A1	4/2011
WO	2011042837	A1	4/2011
WO	2011123267	A1	10/2011
WO	2012021718	A1	2/2012
WO	2012095242	A1	7/2012
WO	2012121718	A1	9/2012

OTHER PUBLICATIONS

Lee, Hsiao-Wen, et al., "Improvement of Illumination Uniformity for LED Flat Panel Light by Using Micro-Secondary Lens Array," Optics Express, vol. 20, No. S6, Nov. 5, 2012, 11 pages.

Liu, Peng, et al., "Optimized Design of LED Freeform Lens for Uniform Circular Illumination," Journal of Zhejiang University—Science C (Computers & Electronics), Dec. 9, 2012, pp. 929-936.

Parkyn, William A., "Segmented Illumination Lenses for Steplighting and Wall-Washing," SPIE Conference on Current Developments in Optical Design and Optical Engineering VIII, Denver, Colorado, Jul. 1999, SPIE vol. 3779, pp. 363-370.

Tracepro, "LED Reflector and Lens Simulation Using TracePro® Illumination Design and Analysis Software," White Paper, Oct. 2013, 11 pages.

Whang, A., et al., "Designing Uniform Illumination Systems by Surface-Tailored Lens and Configurations of LED Arrays," IEEE 2009, Journal of Display Technology, vol. 5, No. 3, Mar. 2009, pp. 94-103.

Steigerwald, D., et al., "Illumination with Solid State Lighting Technology," IEEE Journal on Selected Topics in Quantum Electronics, vol. 8, No. 2, Mar./Apr. 2002, pp. 310-320.

Cheng, L., et al., "The Research of LED Arrays for Uniform Illumination," Advances in Information Sciences and Service Sciences (AISS), vol. 4, No. 10, Jun. 2012, pp. 174-182.

Arik, M., "Thermal Management of LEDs: Package to System," Third International Conference on Solid State Lighting, Proc. of SPIE, vol. 5187, Jan. 21, 2012, pp. 64-75.

Dieker, et al., U.S. Appl. No. 61/659,828, filed Jun. 14, 2012, "Asymmetric Area Lighting Lens with Improved Uniformity," 14 pages.

Defendant Irvin International, Inc.'s Answer, Affirmative Defenses, and Counterclaims to Plaintiff's Complaint, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, filed Jun. 6, 2016, pp. 1-41 (see p. 39).

Lamar's First Amended Answer and Counterclaims to Plaintiff's Complaint, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, filed Jun. 8, 2016, pp. 1-61 (see p. 53).

Defendant American Lighting Technologies, Inc. D/B/A Lighting Technologies' Amended Answer, Affirmative Defenses and Counterclaims to Plaintiff's Complaint, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, filed Jun. 27, 2016, pp. 1-43 (see p. 38).

Defendant American Lighting Technologies, Inc. D/B/A Lighting Technologies' Answer and Affirmative Defenses to Plaintiff's Complaint, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, filed Jun. 6, 2016, pp. 1-37.

Adaptive Micro Systems, LLC, "Signs—Sealed and Delivered! Adaptive's Approach to Heat Management," Mar. 2008, 2 pages.

"Advanced Lighting Guidelines," 2001 Edition, New Buildings Institute, Inc., Jul. 20, 2001, 394 pages.

Barco, "DB-x20 Digital Billboard Out-of-Home Media LED Screen," Apr. 2009, 6 pages.

Batinsey, J., "Outdoor Lighting Ordinance Guide," Jun. 2006, 17 pages.

Chang, R. et al., "LED Backlight Module by Lightguide-Diffusive Component," Journal of Display Technology, vol. 8, No. 2, Feb. 2012, pp. 79-86.

Chen, C. et al., "P-72: Inclined LED Array for Large-Sized Backlight System," Society for Information Display, International Symposium, Digest of Technical Papers, SID 05 Digest, May 2005, pp. 558-561.

"Unified Development Code," Chapter 10 of the Tyler Code of Ordinances, City of Tyler, Apr. 23, 2008, 378 pages.

Defendants Invalidity Contentions, Appendix A, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-19.

Defendants Invalidity Contentions, ExhibitA01, *Ultravision Technologies* v. *Lamar et al.*, Ed. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-80.

Defendants Invalidity Contentions, ExhibitA02, *Ultravision Technologies* v. *Lamar et al.*, Ed. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-74.

Defendants Invalidity Contentions, ExhibitA03, *Ultravision Technologies* v. *Lamar et al.*, Ed. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-52.

Defendants Invalidity Contentions, ExhibitA04, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-53.

Defendants Invalidity Contentions, ExhibitB01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-34.

Defendants Invalidity Contentions, ExhibitB02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-36.

Defendants Invalidity Contentions, ExhibitB03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-21.

Defendants Invalidity Contentions, ExhibitB04, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-27.

Defendants Invalidity Contentions, ExhibitC01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-52.

Defendants Invalidity Contentions, ExhibitC02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-67.

Defendants Invalidity Contentions, ExhibitC03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-35.

Defendants Invalidity Contentions, ExhibitC04, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-87.

Defendants Invalidity Contentions, ExhibitC05, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-51.

Defendants Invalidity Contentions, ExhibitC06, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-79.

Defendants Invalidity Contentions, ExhibitD01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-109.

Defendants Invalidity Contentions, ExhibitD02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-186.

Defendants Invalidity Contentions, ExhibitD03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-133.

Defendants Invalidity Contentions, ExhibitD04, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-111.

Defendants Invalidity Contentions, ExhibitD05, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-133.

(56) **References Cited**

OTHER PUBLICATIONS

Defendants Invalidity Contentions, ExhibitD06, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-135.
Defendants Invalidity Contentions, ExhibitE01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-169.
Defendants Invalidity Contentions, ExhibitE02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-192.
Defendants Invalidity Contentions, ExhibitE03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-443.
Defendants Invalidity Contentions, ExhibitE04, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-171.
Defendants Invalidity Contentions, ExhibitF01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-34.
Defendants Invalidity Contentions, ExhibitF02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-13.
Defendants Invalidity Contentions, ExhibitF03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-100.
Defendants Invalidity Contentions, ExhibitG01, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-30.
Defendants Invalidity Contentions, ExhibitG02, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-11.
Defendants Invalidity Contentions, ExhibitG03, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-94.
Defendants Invalidity Contentions, ExhibitH01 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-60.
Defendants Invalidity Contentions, ExhibitH02 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-26.
Defendants Invalidity Contentions, ExhibitH03 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-71.
Defendants Invalidity Contentions, ExhibitH04 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-151.
Defendants Invalidity Contentions, ExhibitH05 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-181.
Defendants Invalidity Contentions, Exhibit101 (redacted), *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case. No. 2:16-cv-374, Sep. 9, 2016, pp. 1-168.
Deepa, R. et al., "Modeling and Simulation of Multielement LED Source," The Illuminating Engineering Institute of Japan, Journal of Light & Visual Environment, vol. 35, No. 1, Jun. 21, 2011, pp. 34-41.
Design & Engineering Services, "Advanced Lighting Systems for Externally Lit Billboards," ET 08.12 Report, Southern California Edison, Jan. 4, 2010, 58 pages.
Ding, Y., "Freeform LED lens for uniform illumination," Optics Express, vol. 16, No. 17, Aug. 18, 2008, 9 pages.
Lee, S., "How to Select a Heat Sink," http:www.electronics-cooling.com/1995/06/how-to-select-a-heat-sink/, Jun. 1, 1995, pp. 1-10.
Huang, K. et al., "Free-form lens design for LED indoor illumination," Proc. of SPIE, vol. 7852, Nov. 15, 2010, pp. 78521 D-1-78521 D-8.
"The Lighting Handbook," 12-18, IES 10th Edition, Dec. 6, 2011, 1 page.
"The Lighting Handbook," 8-17, IES 10th Edition, Dec. 6, 2011, 2 pages.
Jeon, H. et al., Illuminance Distribution and Photosynthetic Photon Flux Density Characteristics of LED Lighting with Periodic Lattice Arrangements, Transactions on Electrical and Electronic Materials, vol. 13, No. 1, Feb. 25, 2012, pp. 16-18.
Jiang, J., "Optical design of a freeform TIR lens for LED streetlight," Optik—International Journal for Light and Electron Optics, vol. 121, Issue 19, Oct. 2010, pp. 1761-1765.
Defendants Corrected Joint Invalidity Contentions, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, Sep. 9, 2016, pp. 1-108.
Keller, A., "Signs of the Times," Floridatrend.com, Dec. 2011, pp. 50-53.
Lakkio, O., "Winning the Optical Challenges in LED Street Lighting," Digi-Key, May 27, 2011, 5 pages.
"Billie—The Bright Answer for Billboard Lighting," Ledil Product Release, Dec. 8, 2013, 2 pages.
"LEDIL Standard Optics for Osram LEDs," Ledil, Jan. 2011, 60 pages.
"Strada 6in1 Module for Streeting Lighting," Ledil, 2010, 1 page, <<http://ledil.fi/sites/default/files/Documents/Technical/Articles/Article_2.pdf>>.
LEDIL, "Who is LEDIL?," www.ledil.com, Mar. 22, 2011, 17 pages.
LEDIL, "Who is LEDIL?," www.ledil.com, May 22, 2011, 68 pages.
Lee, S. et al., "Driving Performance and Digital Billboards Final Report," Virginia Tech Transportation Institute, Center for Automotive Safety Research, Mar. 22, 2007, 90 pages.
Lighting Solutions Techzone Magazine, "Look Inside Today's Lighting Technology," Digi-Key Corporation, TZL112.US, Jun. 7, 2011, 76 pages.
Lo, Y. et al., "Optical Design of a Butterfly Lens for a Street Light Based on a Double-Cluster LED," Microelectronics Reliability, vol. 52, May 2011, pp. 889-893.
LED Professional Review, Issue 17, Jan./Feb. 2010, 52 pages.
LED Professional Review, Issue 18, Mar./Apr. 2010, 64 pages.
LED Professional Review, Issue 19, May/Jun. 2010, 64 pages.
LED Professional Review, Issue 20, Jul./Aug. 2010, 48 pages.
LED Professional Review, Issue 21, Sep./Oct. 2010, 64 pages.
LED Professional Review, Issue 22, Nov./Dec. 2010, 60 pages.
Luminautics, "LED Display Primer," 2011, pp. 1-21.
Luo, X. et al., "Automated Optimization of an Aspheric Light-Emitting Diode Lens for Uniform Illumination," Applied Optics, vol. 50, No. 20, Jul. 2011, pp. 3412-3418.
Moreno, I., "Configuration of LED Arrays for Uniform Illumination," Proc. of SPIE, vol. 5622, Oct. 2004, pp. 713-718.
"LED Ad-Poster Billboard Luminaire," Neptun, Jan. 2012, 1 page.
"LED Ad-Poster Billboard Luminaire," Neptun, May 25, 2011, 1 page.
Office Action Summary received in U.S. Appl. No. 14/630,500, dated Dec. 31, 2015, 65 pages.
"Street Lighting with LED Lights Sources Application Note," OSRAM Opto Semiconductors, Jan. 2009, pp. 1-10.
Qin, Z. et al., "Analysis of Condition for Uniform Lighting Generated by Array of Light Emitting Diodes with Large View Angle," Optics Express, vol. 18, No. 16, Aug. 2010, pp. 17460-17476.
Deepa, R. et al., "Automated Test Jig for Uniformity Evaluation of Luminaries," IJAET, vol. 3, No. 1, Mar. 2012, pp. 41-47.
Deepa, R. et al., Optimization of multi-element LED source for uniform illumination of plane surface, Optical Society of America, Optics Express, vol. 19, No. S4, Jul. 4, 2011, pp. A639-A648.
"Starbeam," Thorlux Lighting, Brochure, Aug. 2012, 8 pages.
"Starbeam," Thorlux Lighting, Brochure, Jul. 2015, 4 pages.
"Starbeam," Thorlux Lighting, Brochure, Mar. 2014, 16 pages.
"Starbeam," Thorlux Lighting, Technical Information, Mar. 2014, 10 pages.
"Starflood," Thorlux Lighting, Brochure, Mar. 2016, 16 pages.
"Starflood; High performance mini LED floodlights," Thorlux Lighting, Retreived Jul. 21, 2016, 16 pages, <<http://www.thorlux.com/luminaires/starflood>>.
"General Catalog—2012," Thorlux Lighting, Dec. 2012, 164 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Tsai, J. et al., "LED Backlight Module by a Lightguide-Diffusive Component With Tetrahedron Reflector Array," J. Display Tech., vol. 8, No. 6, Jun. 2012, pp. 321-328.
Hubbell Lighting, "Universal Lighting Technologies Invention Disclosure," Jun. 14, 2012, 15 pages.
Wang, K. et al., "Freeform LED Lens for Rectangularly Prescribed Illumination," J. Opt. A: Pure Appl. Opt., No. 11, Aug. 2009, 105501, 10 pages.
Wang, K. et al., "New reversing design method for LED uniform illumination," Optics Express, vol. 19, Issue S4, Jul. 4, 2011, pp. A830-A840.
West, R.S. et al., "43.4: High Brightness Direct LED Backlight for LCD-TV," SID 03 Digest, May 2003, 4 pages.
Wu, D. et al., "Freeform Lens Design for Uniform Illumination with Extended Source," 2011 In▼ I Conf. Elecs. Packaging Tech. & High Density Packaging, Aug. 2011, pp. 1085-1089.
Wu, R. et al., "Optimization Design of Irradiance Array for LED Uniform Rectangular Illumination," Applied Optics, vol. 1, No. 13, May 2012, pp. 2257-2263.
Zhenrong, Z. et al., "Freeform Surface Lens for LED Uniform Illumination," Applied Optics, vol. 48, No. 35, Dec. 2009, pp. 6627-6634.
Zhu, Z. et al., "Uniform Illumination Design by Configuration of LED Array and Diffuse Reflection Surface for Color Vision Application," J. Display tech, vol. 7, No. 2, Feb. 2011, pp. 84-89.
P.R. 4-3 Joint Claim Construction and Prehearing Statement, *Ultravision Technologies* v. *Lamar et al.*, E.D. Texas, Case No. 2:16-cv-374, filed Jan. 27, 2017, pp. 1-20.

* cited by examiner

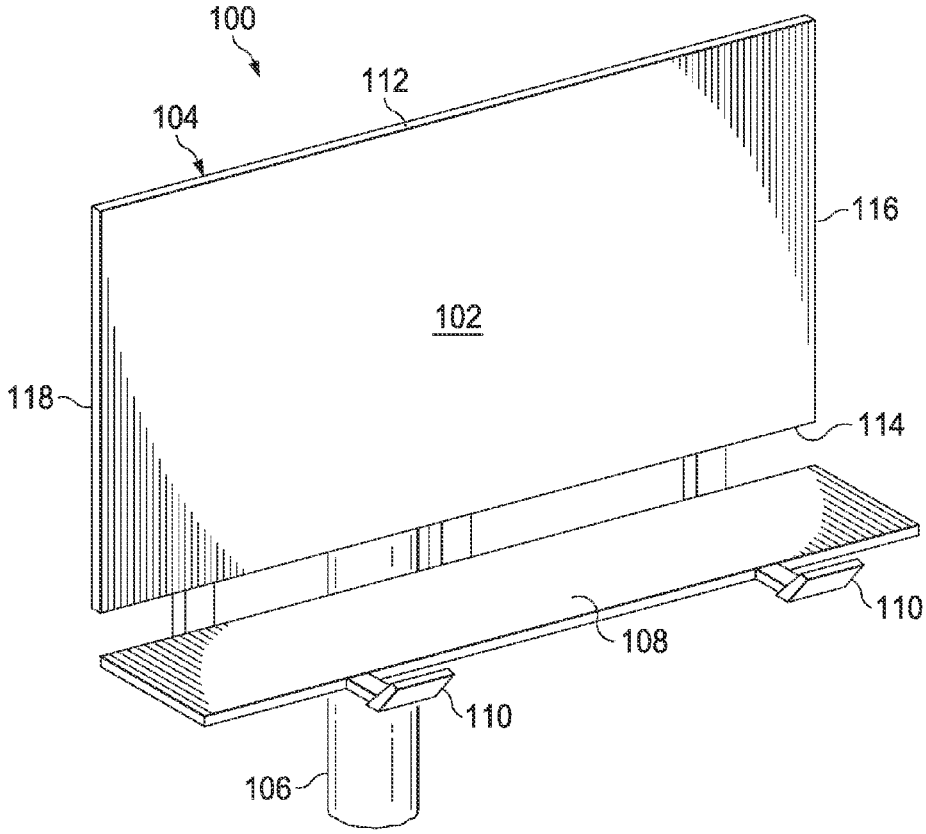

FIG. 1A

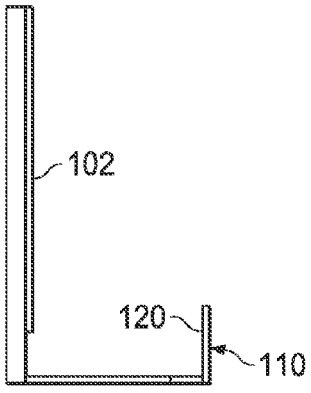

FIG. 1B

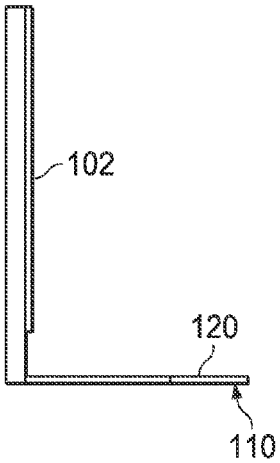

FIG. 1C

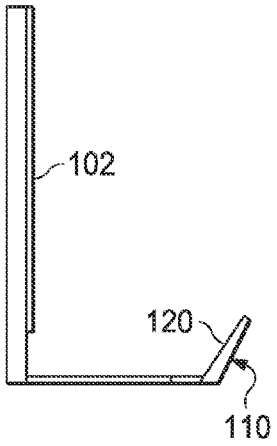

FIG. 1D

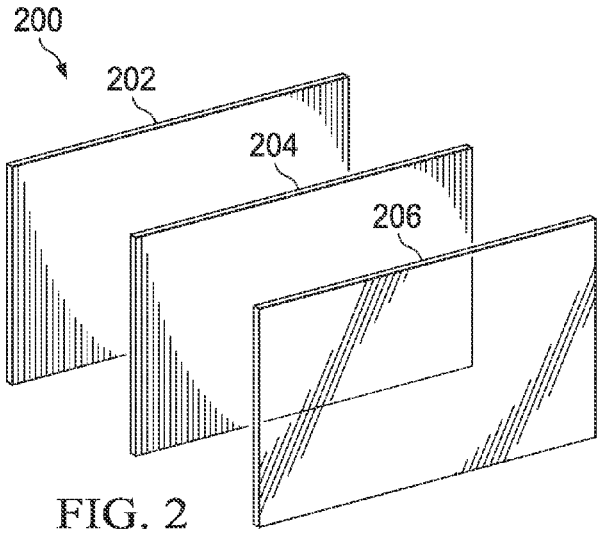

FIG. 2

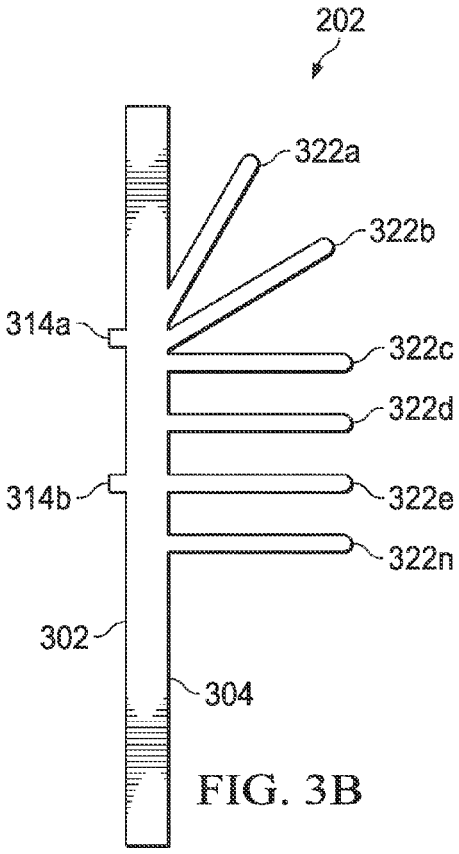

FIG. 3B

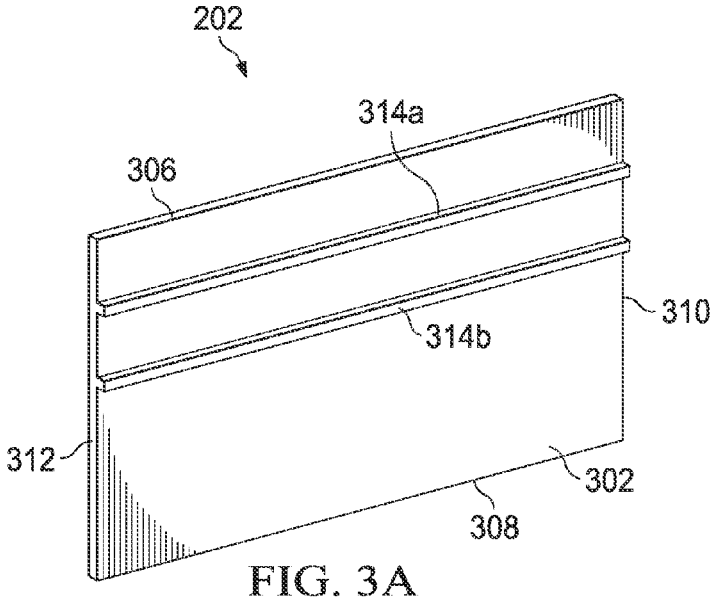

FIG. 3A

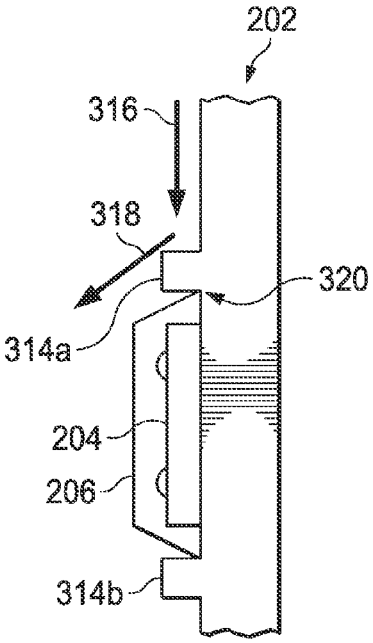

FIG. 3C

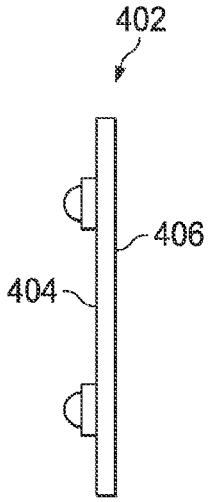

FIG. 4B

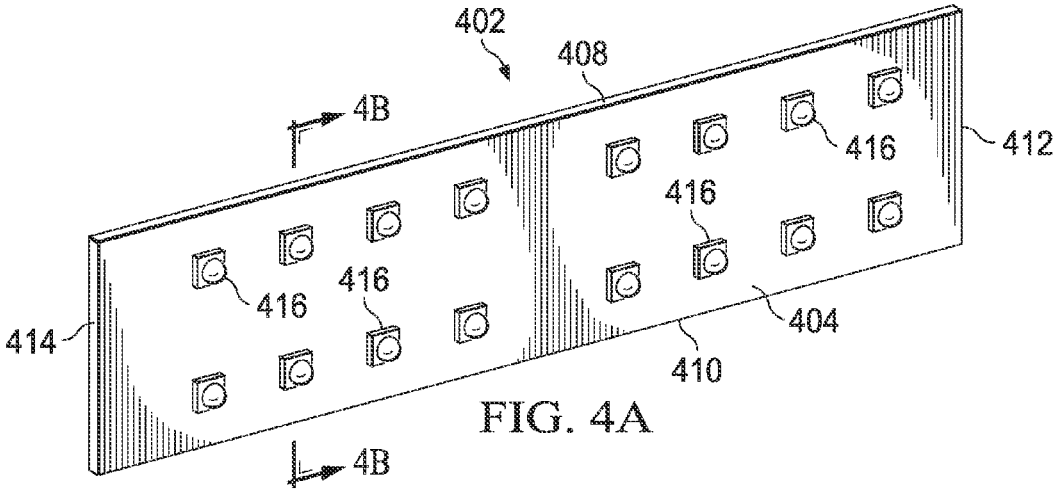

FIG. 4A

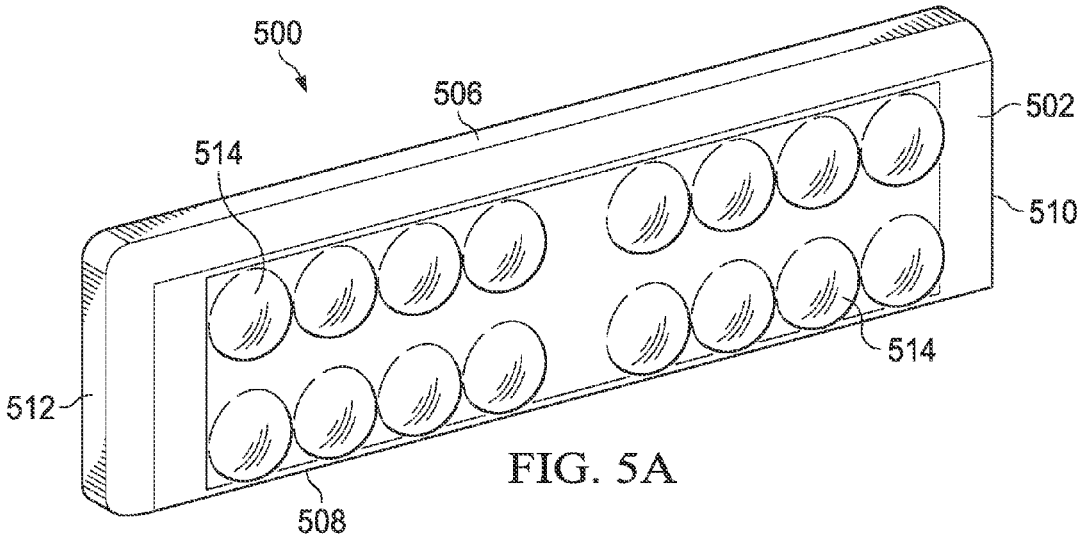

FIG. 5A

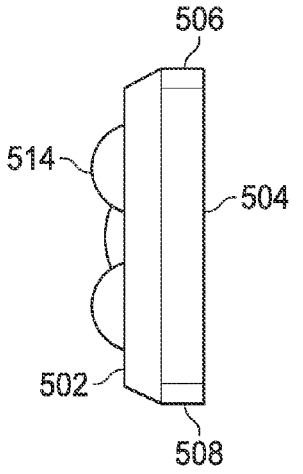

FIG. 5B

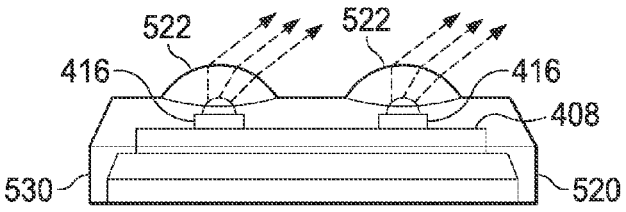

FIG. 5C

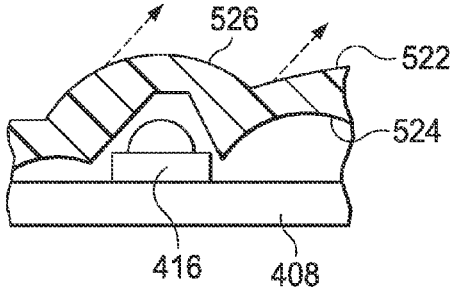

FIG. 5D

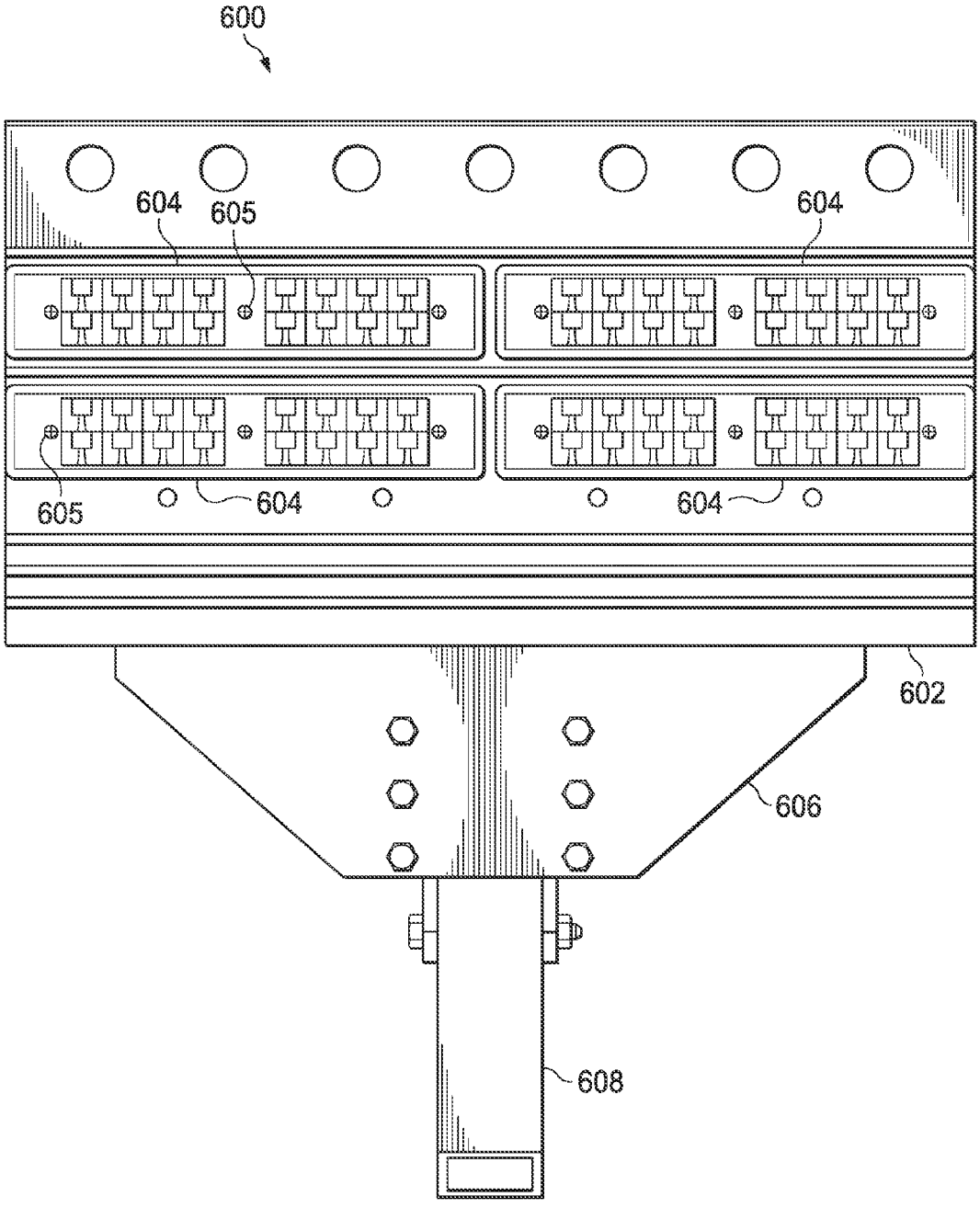

FIG. 6A

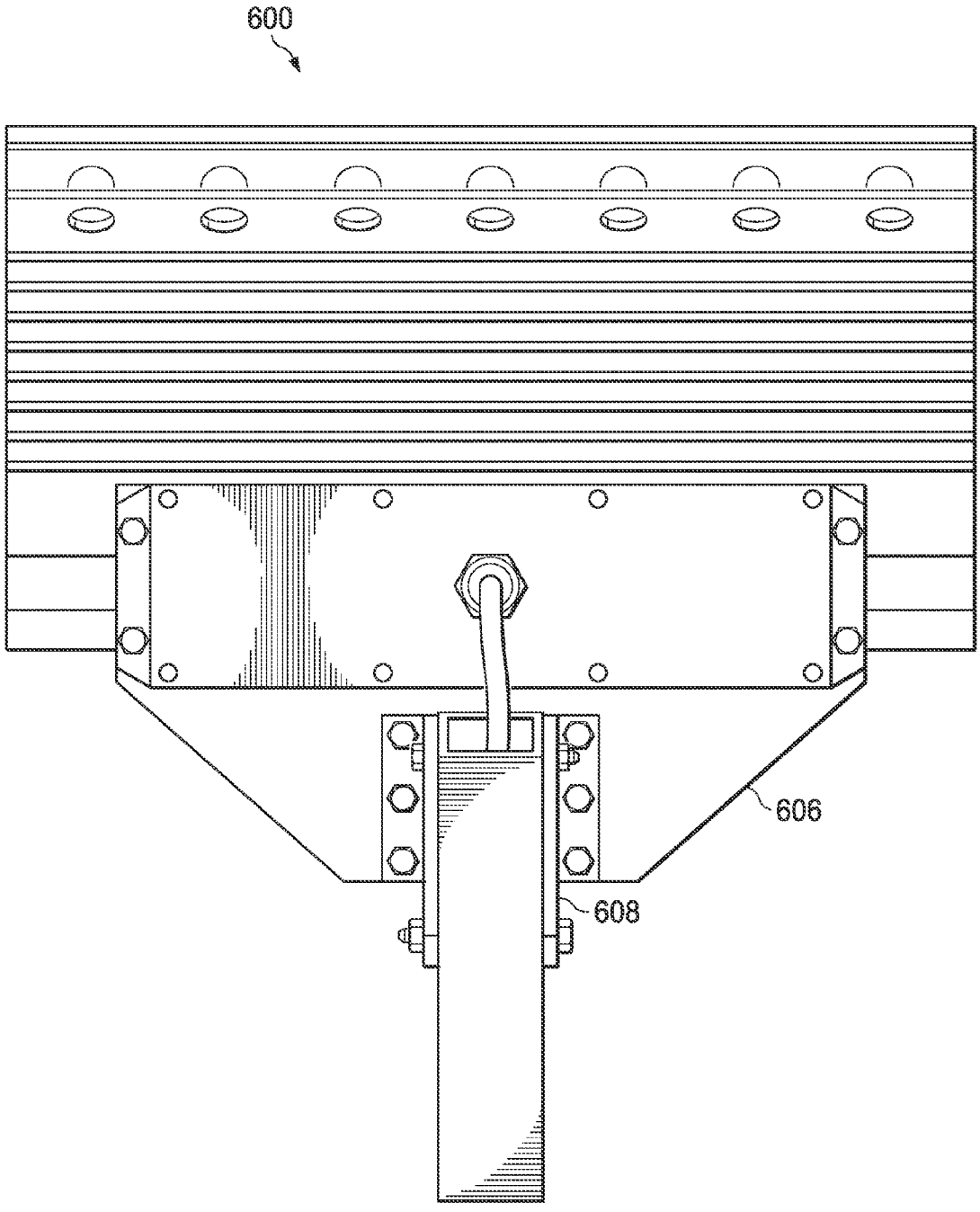

FIG. 6B

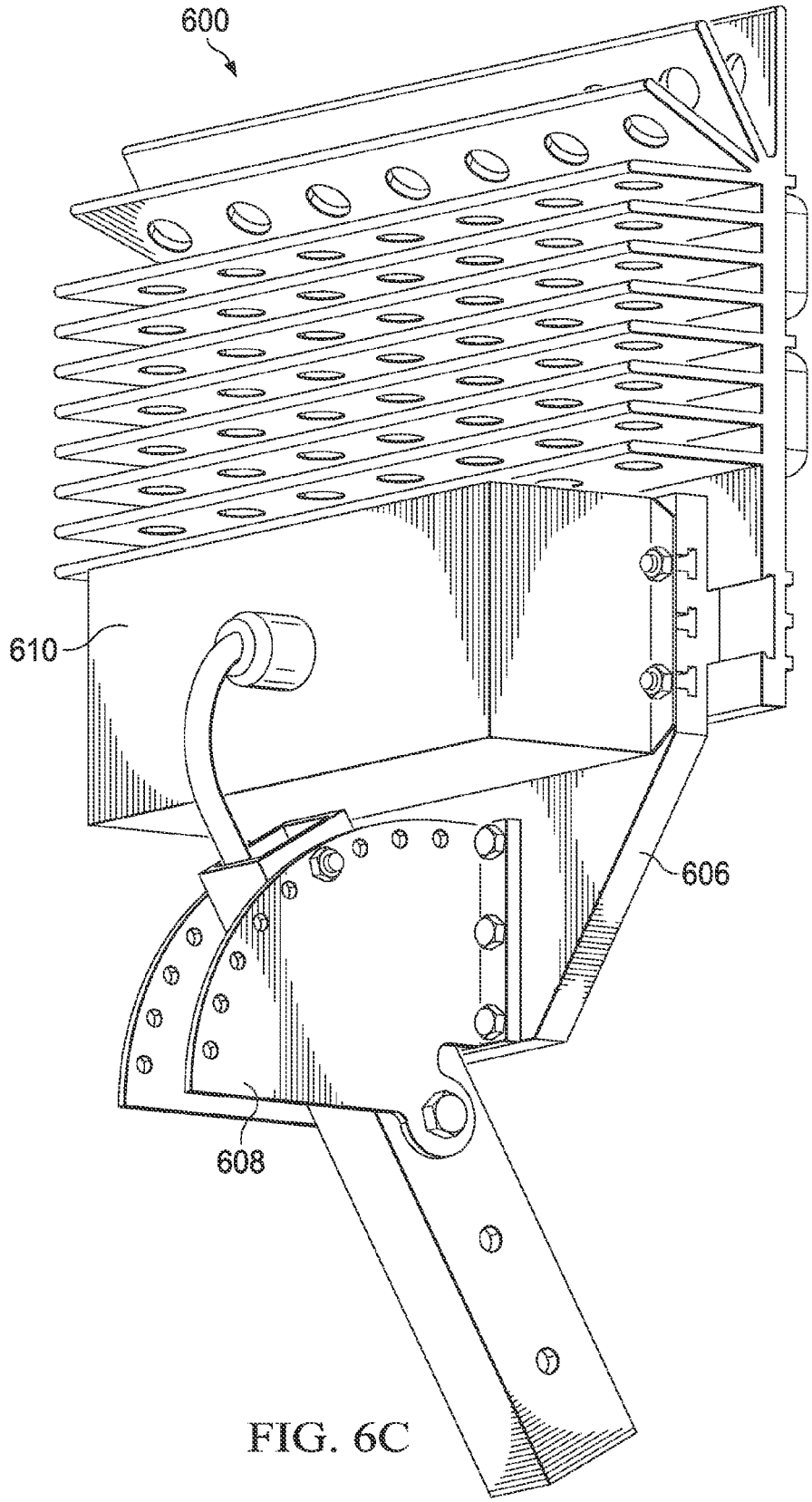

FIG. 6C

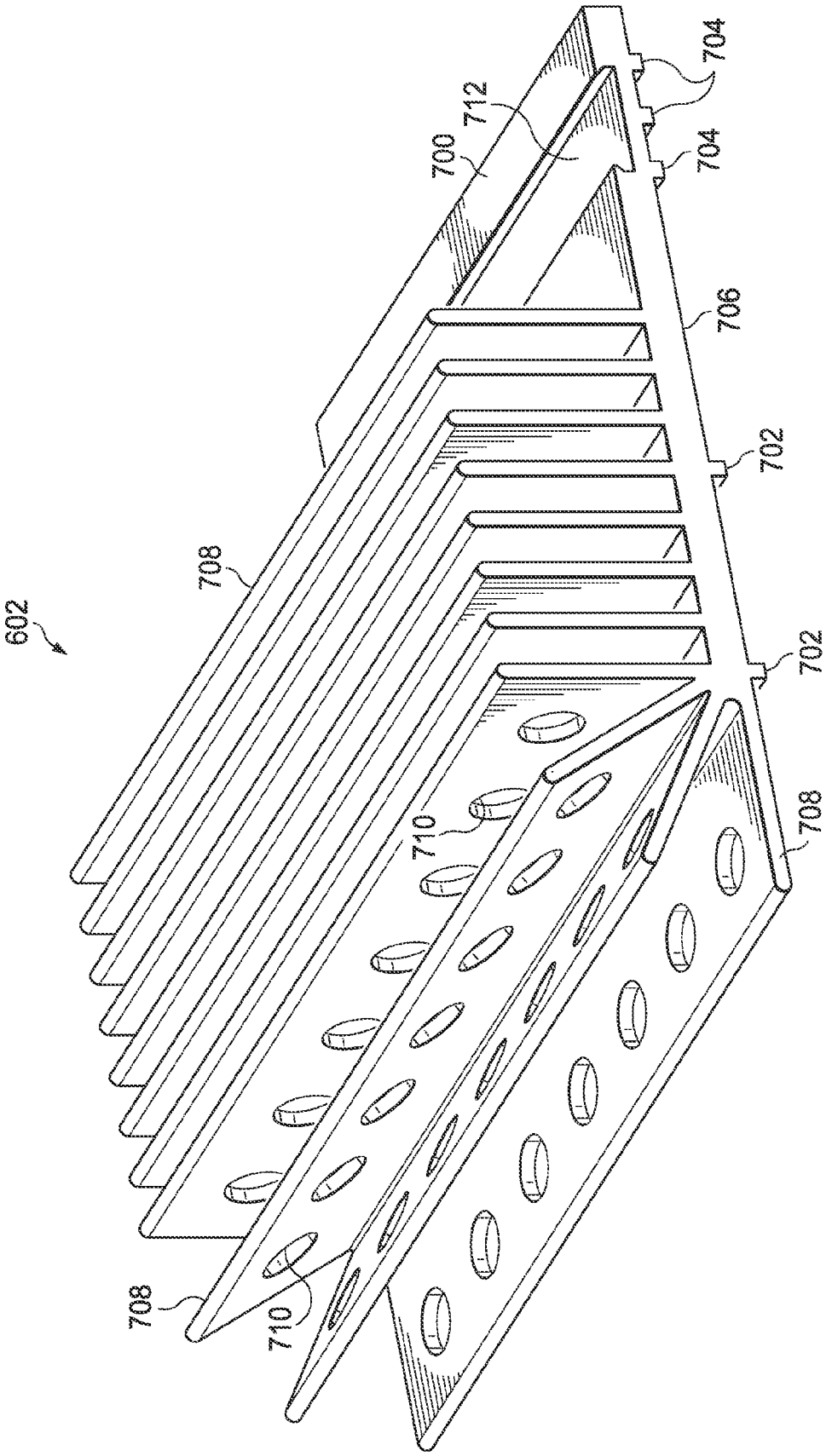

FIG. 7A

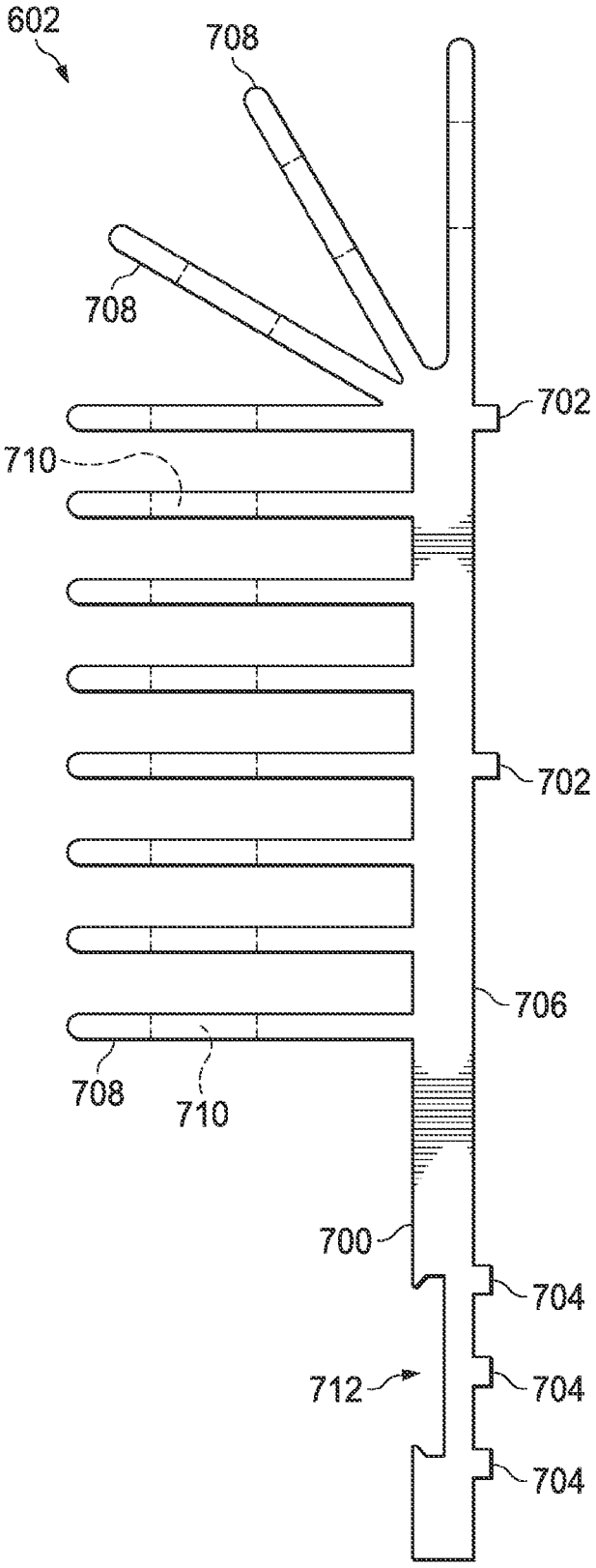

FIG. 7B

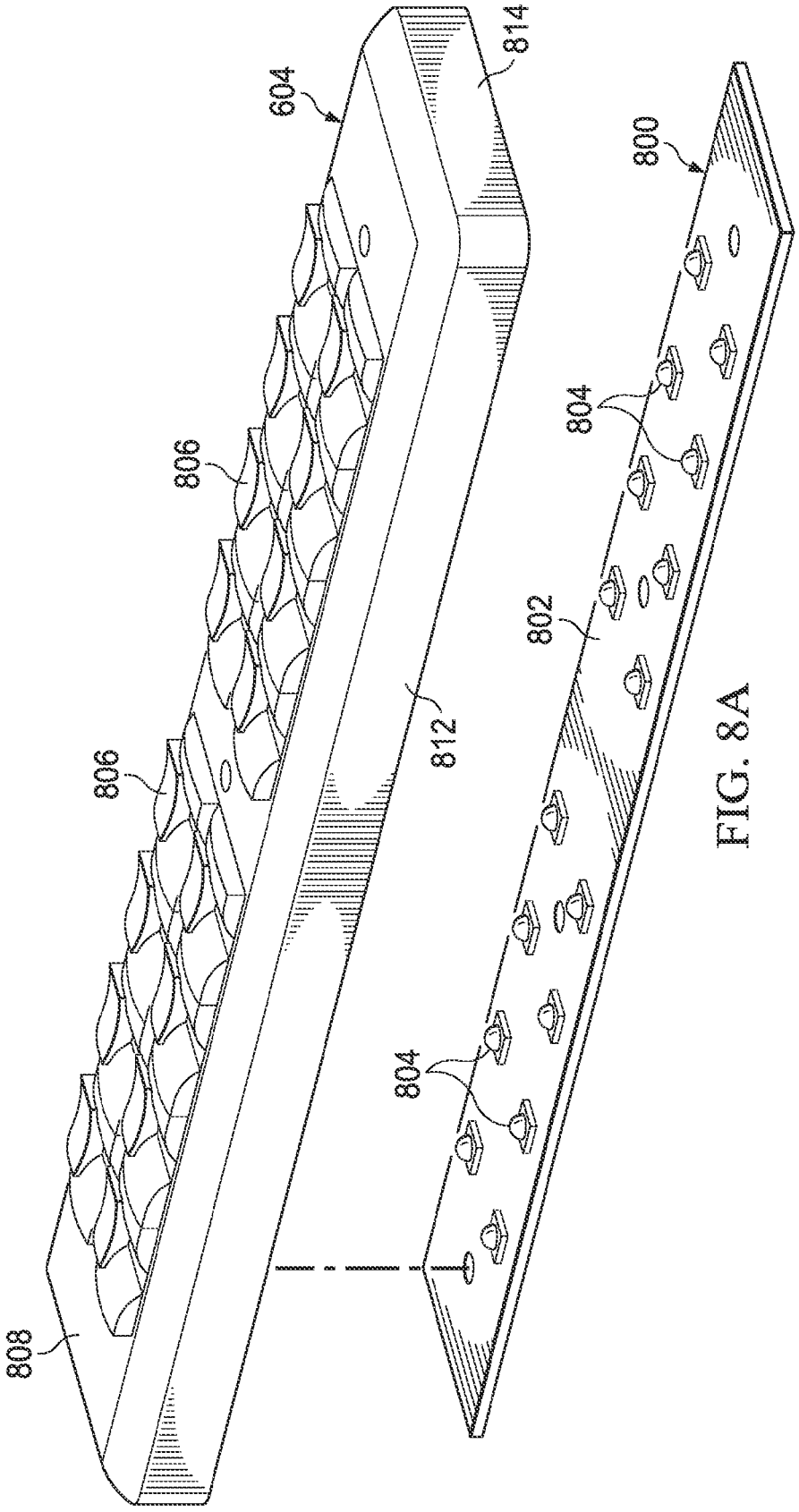

FIG. 8A

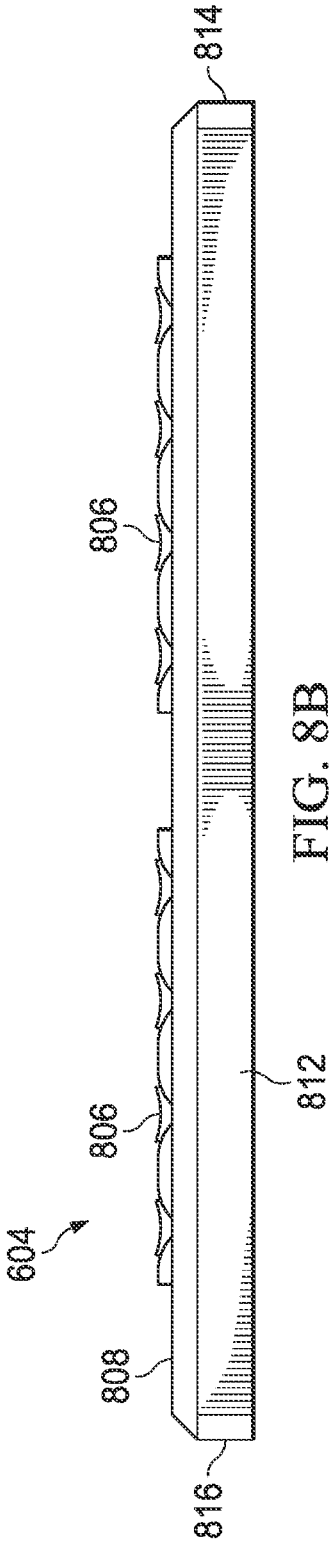

FIG. 8B

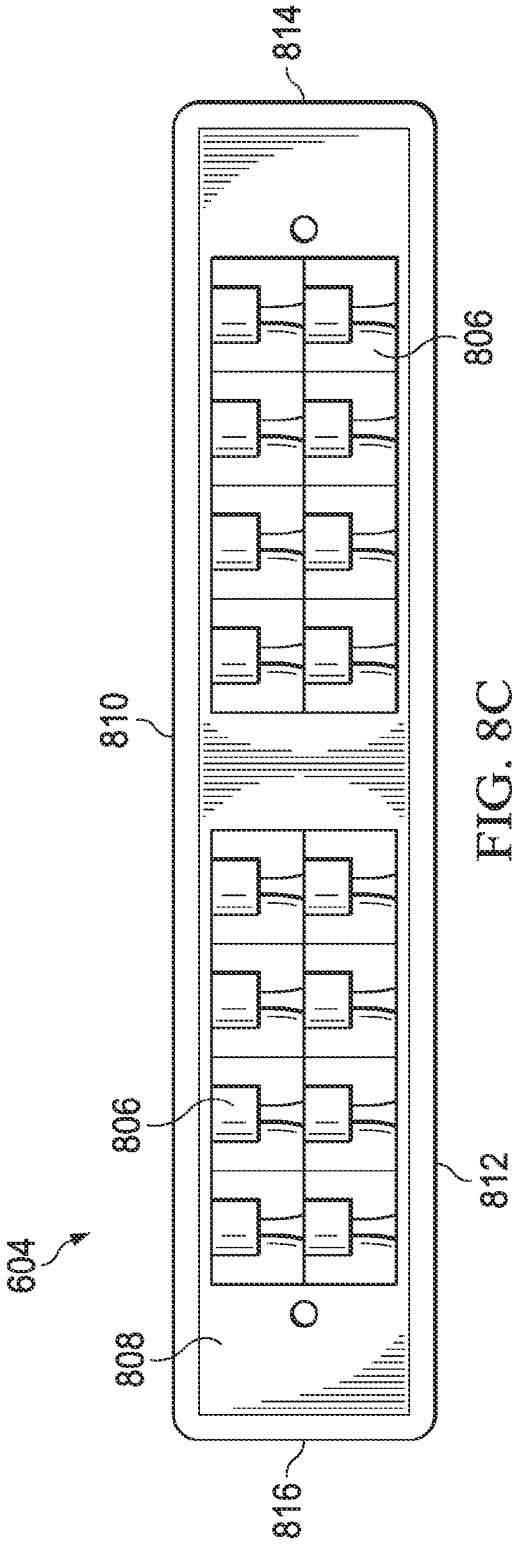

FIG. 8C

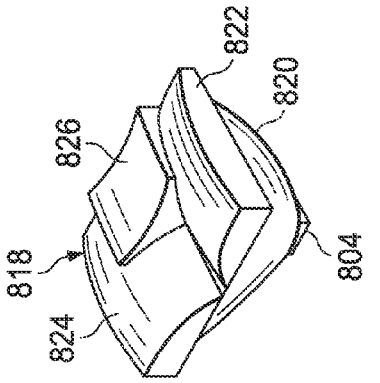

FIG. 8G

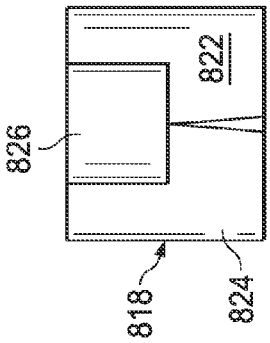

FIG. 8F

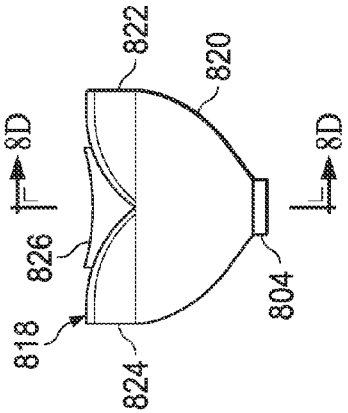

FIG. 8E

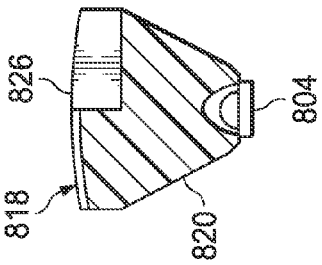

FIG. 8D

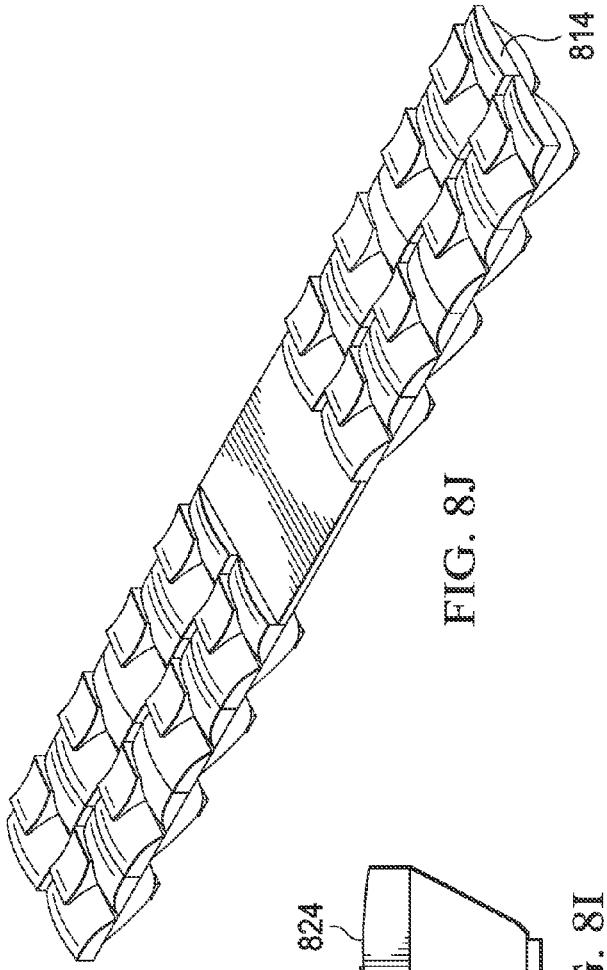

FIG. 8J

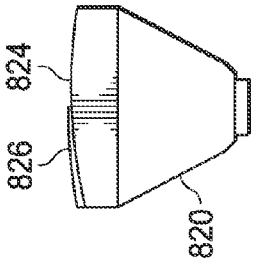

FIG. 8I

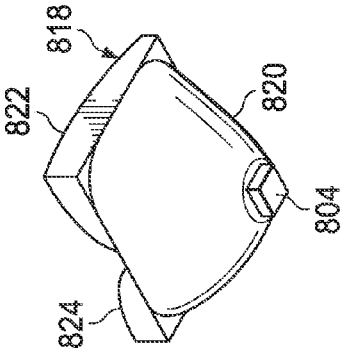

FIG. 8H

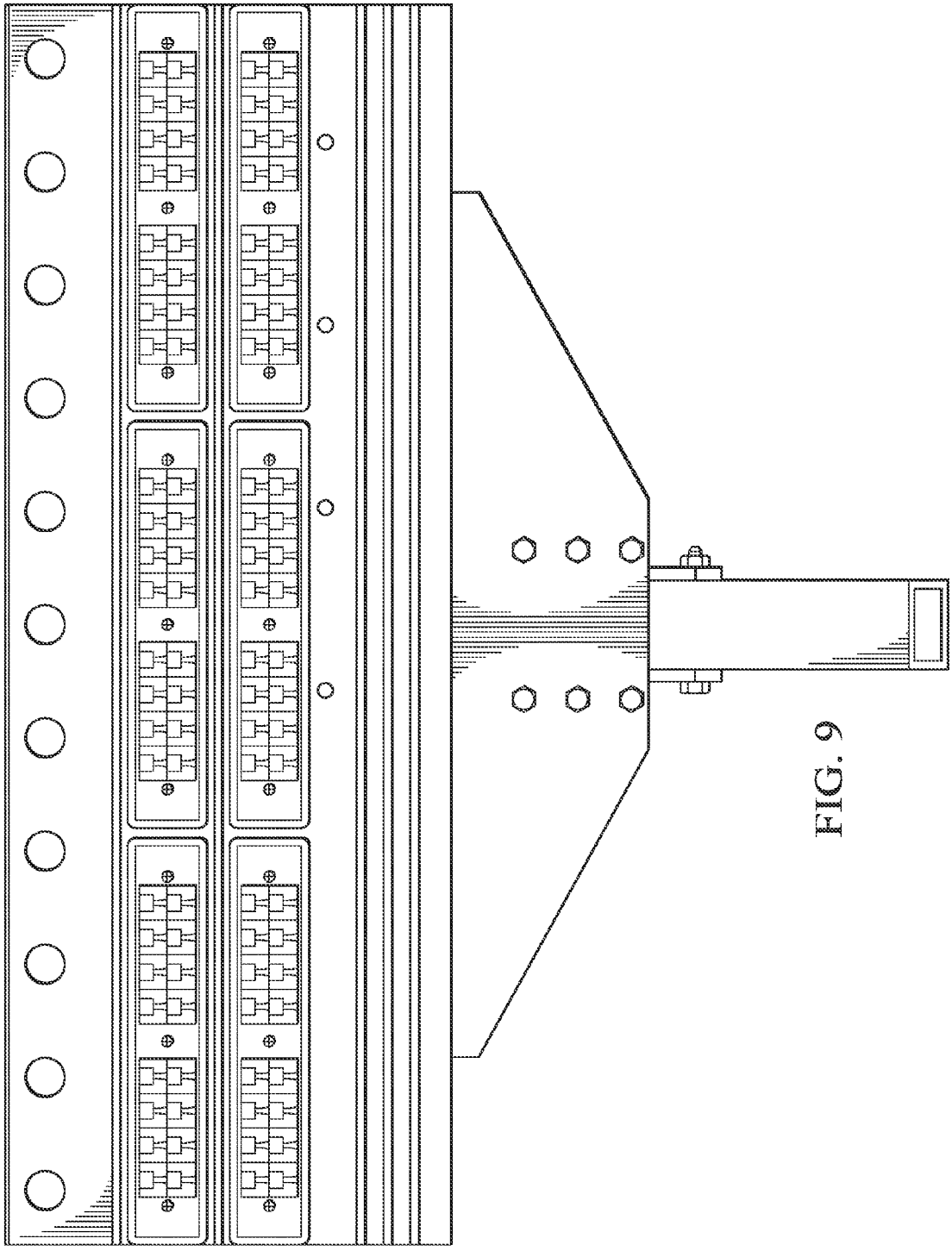

FIG. 9

LIGHT ASSEMBLY FOR PROVIDING SUBSTANTIALLY UNIFORM ILLUMINATION

This application is a continuation of U.S. patent application Ser. No. 13/836,517, filed Mar. 15, 2013 (now U.S. Pat. No. 8,974,077, issued Mar. 10, 2015), which claims the benefit of U.S. Provisional Application No. 61/677,346, filed on Jul. 30, 2012, which applications are hereby incorporated herein by reference.

This application is related to U.S. patent application No. 61/677,340, filed Jul. 20, 2012, U.S. patent application Ser. No. 13/836,612, filed Mar. 15, 2013 (now U.S. Pat. No. 8,870,410) and U.S. patent application Ser. No. 14/137,343, filed Dec. 20, 2013 (now U.S. Pat. No. 8,870,413). This application is also related to U.S. patent application no. 14/xxx,xxx, filed concurrently herewith.

TECHNICAL FIELD

The following disclosure relates to lighting systems and, more particularly, to lighting systems using light emitting diodes to externally illuminate signs.

SUMMARY

The present invention, in one aspect thereof, comprises a back panel for use in a light emitting diode (LED) lighting assembly. An extruded substrate formed of a thermally conductive material is provided, the substrate having a plurality of fins extending from a first side of the substrate, each of the fins having a substantially rectangular shape oriented so that a longitudinal axis of the fin is substantially parallel to a longitudinal axis of the substrate. At least some of the fins include a hole formed through the fin to enable heated air to rise through the fins. A plurality of LEDs are mounted on a second side of the substrate, and oriented in a longitudinal orientation with the fins oriented parallel to the bottom edge of a surface to be illuminated, such that heat rises perpendicular to the surface of the fin.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

FIG. **1**A illustrates one embodiment of a billboard that may be externally lighted by one or more lighting assemblies;

FIGS. **1**B-**1**D illustrate embodiments of angular positions of the lighting assembly of FIG. **1** relative to the billboard;

FIG. **2** illustrates one embodiment of a lighting assembly that may be used to light the billboard of FIG. **1**;

FIGS. **3**A and **3**B illustrate one embodiment of a back panel that may be used in the lighting assembly of FIG. **2**;

FIG. **3**C illustrates one embodiment of the back panel of FIGS. **3**A and **3**B with a light panel and an optics panel that may also be used in the lighting assembly of FIG. **2**;

FIGS. **4**A and **4**B illustrate one embodiment of a light panel that may be used with the lighting assembly of FIG. **2**;

FIGS. **5**A, **5**B, **5**C and **5**D illustrate one embodiment of an optics panel that may be used with the lighting assembly of FIG. **2**;

FIGS. **6**A-**6**C illustrate a more detailed embodiment of the lighting assembly of FIG. **2**;

FIGS. **7**A and **7**B illustrate an embodiment of a back panel that may be used with the lighting assembly of FIGS. **6**A-**6**C;

FIG. **8**A illustrates an embodiment of an LED assembly and an optics panel that may be used with the lighting assembly of FIG. **6**;

FIGS. **8**B-**8**J illustrates embodiments of the optics panel of FIG. **8**A and optical elements that may be used to form part of the optics panel; and

FIG. **9** illustrates a more detailed embodiment of the lighting assembly of FIG. **2**.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Billboards, such as those commonly used for advertising in cities and along roads, often have a picture and/or text that must be externally illuminated to be visible in low-light conditions. As technology has advanced and introduced new lighting devices such as the light emitting diode (LED), such advances have been applied to billboards. However, current lighting designs have limitations and improvements are needed. Although billboards are used herein for purposes of example, it is understood that the present disclosure may be applied to lighting for any type of sign that is externally illuminated.

Referring to FIG. **1**A, one embodiment of a billboard **100** is illustrated. The billboard **100** includes a surface **102** onto which a picture and/or text may be painted, mounted, or otherwise affixed. The surface **102** may be any size, such as a commonly used size having a width of forty-eight feet wide and a height of fourteen feet. The surface **102** may be provided by placing a backing material on a frame **104** made of steel and/or other materials. The frame **104** may be mounted on one or more support poles **106**, which may be considered part of the frame **104** or separate from the frame **104**. The billboard **100** may include a walkway or other support structure **108** that enables the surface **102** to be more easily accessed.

One or more lighting assemblies **110** may be coupled to the walkway **108** (e.g., to a safety rail or to the walkway itself) and/or to another structural member of the billboard **100** to illuminate some or all of the surface **102** in low light conditions. The lighting assembly **110** may be mounted at or near a top edge **112** of the billboard **100**, a bottom edge **114** of the billboard **100**, a right edge **116** of the billboard **100**, and/or a bottom edge **118** of the billboard **100**. The lighting assembly **110** may be centered (e.g., located in approximately the center of the billboard **100**) or off center as illustrated in FIG. **1**A.

With additional reference to FIGS. **1**B-**1**D, a surface **120** of the lighting assembly **110** may be parallel with respect to the surface **102** of the billboard **100** (FIG. **1**B), may be perpendicular with respect to the surface **102** (FIG. **1**C), or may be angled with respect to the surface **102** (FIG. **1**D). It is understood that the lighting assembly **110** may be placed in many different orientations and locations relative to the billboard **100** and to one another, and the illustrated positions are only for purposes of example. Furthermore, it is understood that references to "top," "bottom," "left," and "right" are used in the present disclosure for purposes of description and do not necessarily denote a fixed position. For example, the billboard **100** may be turned on end, and the referenced "top," "bottom," "left," and "right" edges may still be readily identifiable although the "top" edge would be the "left" edge or the "right" edge.

One problem with current lighting technology is that it can be difficult to direct light only onto the surface **102** and even more difficult to do so evenly. This may be due partly to the placement of the lighting assembly **110**, as shown in FIGS. **1**B-**1**D. As the lighting assembly **110** is off center relative to the surface **102**, light emitted from the lighting assembly **110** may not evenly strike the surface **102**. One problem with uneven illumination is that certain parts of the surface **102** may be more brightly illuminated than other parts. This creates "hot spots" that may be undesirable. Attempting to evenly illuminate the surface **102** may cause light to be directed past the edges **112**, **114**, **116**, and **118** as attempts are made to balance out hot spots in particular areas. However, light that does not strike the surface **102** is wasted and may create problems (e.g., light pollution), as well as waste illumination that could be used for the surface **102**.

In addition to the difficulties of evenly illuminating the surface **102**, the use of LEDs in an exterior lighting environment involves issues such as heat dissipation and protecting the LEDs against environmental conditions such as moisture. The presence of moving mechanical features such as fans that may be used to provide increased airflow for cooling may create additional reliability problems. Due to the difficulty and expense of replacing and/or repairing the lighting assembly **110** in combination with the desire to provide consistent lighting while minimizing downtime, such issues should be addressed in a manner that enhances reliability and uptime.

Referring to FIG. **2**, one embodiment of a lighting assembly **200** is illustrated. The lighting assembly **200** provides a more detailed embodiment of the lighting assembly **110** of FIG. **1**. The lighting assembly **200** includes a back panel **202**, a light panel **204** (e.g., a printed circuit board (PCB)) having a plurality of LEDs (not shown) mounted thereon, and an optics panel **206**. As will be described below in more detailed examples, light from the LEDs of the light panel **204** may be directed by the optics panel **206** to illuminate the surface **102** of the billboard **100** of FIG. **1**. The back panel **202** may be configured to serve as a supporting substrate for the light panel **204** and optics panel **206**, as well as to dissipate heat produced by the LEDs.

It is understood that any of the back panel **202**, light panel **204**, and optics panel **206** may actually be two or more physical substrates rather than a single panel as illustrated in FIG. **2**. Furthermore, it is understood that there may be additional panels positioned behind the back panel **202**, in front of the optics panel **206**, and/or between the back panel **202** and light panel **204** and/or between the light panel **204** and optics panel **206**.

Referring to FIGS. **3**A-**3**C, one embodiment of the back panel **202** is illustrated with a front surface **302** and a back surface **304**. The back panel **202** includes a top edge **306**, a bottom edge **308**, a right edge **310**, and a left edge **312**. The panel **202** may be formed of one or more thermally conductive materials (e.g., aluminum) and/or other materials.

The front surface **302** provides a mounting surface for the light panel **204**. In some embodiments, the front surface **302** of the panel **202** may include one or more protrusions **314***a* and **314***b* that are substantially parallel to the top edge **306**. The protrusions **314***a* and **314***b* may be configured to protect the light panel **204** from moisture. Although only two protrusions **314***a* and **314***b* are illustrated, it is understood that a single protrusion may be provided or three or more protrusions may be provided. Furthermore, such protrusions may vary in length, shape (e.g., may have angled or curved surfaces), orientation, and/or location on the front surface **302**.

Referring specifically to FIG. **3**C, a light panel **204** and an optical panel **206** may be mounted under the protrusion **314***a* (FIG. **3**C). Moisture running down the front surface **302** in the direction of arrow **316** may strike the protrusion **314***a* and be directed away from the light panel **204** and optical panel **206** as shown by arrow **318**. Although not shown, moisture may also be directed length down the protrusion **314***a*. Accordingly, protrusion **314***a* may serve as a gutter and aid in directing moisture away from a joint **320** where the optical panel **206** abuts the front surface **302**. This may be beneficial even when a moisture resistant compound is used to seal the joint **320**. In embodiments where there are multiple light panels **204** arranged vertically on the front surface **302**, there may be a protrusion positioned above each light panel **204**. For example, the protrusion **314***a* may be positioned directly above one light panel **204** and the protrusion **314***b* may be positioned directly above another light panel **204**.

Referring specifically to FIG. **3**B, the back surface **304** may be configured to increase heat dissipation. For example, the back surface **304** may be configured with a heat sink provided by fins **322***a*-**322**N, where N denotes a total number of fins. The fins **322***a*-**322**N increase the surface area of the back surface **304**, thereby providing for additional heat dissipation to the surrounding air. The fins **322***a*-**322**N may be formed as part of the panel **202** or may be otherwise coupled to the panel **202** (e.g., may be part of a discrete heat sink that is coupled to the back surface **304**). Some or all of the fins **322***a*-**322**N may be angled, as shown by fins **322***a* and **322***b*. In some embodiments, holes (not shown) may be provided in some or all of the fins **322***a*-**322**N to aid in air circulation. In such embodiments, the holes may cause a chimney effect in which heated air rises through the holes and is replaced by cooler air. This may be particularly effective in environments where natural air movement is limited.

Referring to FIGS. **4**A and **4**B, one embodiment of a single PCB **402** of the light panel **204** is illustrated. In the present example, the light panel **204** may include multiple PCBs **402**, although it is understood that any number of PCBs may be used based on design issues such as the amount of illumination needed, the amount of illumination provided by a single PCB **402**, the size of the surface **102** of the billboard **100**, and/or other factors. As shown in the present embodiment with a substantially rectangular cross-section, the PCB **402** includes a front surface **404**, a back surface **406**, a top edge **408**, a bottom edge **410**, a right edge **412**, and a left edge **414**.

The PCB **402** may include one or more strings of LEDs **416**, with multiple LEDs **416** in a string. For example, a string may include eight LEDs **416** and each PCB **402** may include two strings for a total of sixteen LEDs **416**. In this configuration, a light panel **204** having eight PCBs **402** would include ninety-six LEDs **416**. It is understood that although the PCBs **402** are shown as being substantially identical, they may be different in terms of size, shape, and other factors for a single light panel **204**.

In the present example, the LEDs **416** are surface mounted, but it is understood that the LEDs **416** may be coupled to the panel **204** using through hole or another coupling process. The surface mounted configuration may ensure that a maximum surface area of each LED **416** is in contact with the PCB **402**, which is in turn in contact with the back panel **202** responsible for heat dissipation. Each

string of LEDs may receive a constant current with the current divided evenly among the LEDs **416**.

Referring to FIGS. **5**A, **5**B, **5**C and **5**D, one embodiment of a single lens panel **500** of the optics panel **206** is illustrated. In the present example, the optics panel **206** may include multiple lens panels **500**, although it is understood that any number of lens panels may be used based on design issues such as the number, arrangement, and orientation of the LEDs **416**, the size of the surface **102**, and/or other factors. As shown in the present embodiment with a substantially rectangular cross-section that is configured for use with the PCB **402** of FIG. **4**, a single lens panel **500** includes a front surface **502**, a back surface **504**, a top side **506**, a bottom side **508**, a right side **510**, and a left side **512**. The sides **506**, **508**, **510**, and **512** may form a cavity into which the PCB **402** may fit, thereby providing protection for the PCB **402** from environmental conditions such as moisture.

The lens panel **500** may include a beveled or angled top side **506** and/or bottom side **508** as illustrated in FIG. **5**B. The beveling/angling may aid in preventing moisture from reaching the PCB **402** under the lens panel **500**, as water will more readily flow from the area of the joint **320** (FIG. **3**C) due to the angled surface than if the top side **506** was relatively flat.

The lens panel **500** may include multiple optical elements **514**. A single optical element **514** may be provided for each LED **416**, a single optical element **514** may be provided for multiple LEDs **416**, and/or multiple optical elements **514** may be provided for a single LED **416**. In some embodiments, the optical elements **514** may be provided by a single multi-layer optical element system provided by the lens panel **500**.

In the present example, the optical elements **514** are configured so that the light emitted from each LED **416** is projected onto the entire surface **102** of the billboard **100**. In other words, if all other LEDs **416** were switched off except for a single LED **416**, the entire surface **102** would be illuminated at the level of illumination provided by the single LED **416**. In one embodiment, the rectangular target area of the surface **102** would be evenly illuminated by the LED **416**, while areas beyond the edges **112**, **114**, **116**, and **118** would receive no illumination at all or at least a minimal amount of illumination from the LED **416**. What is meant by "evenly" is that the illumination with a uniformity that achieves a 3:1 ratio of the average illumination to the minimum. Thus, by designing the lens in such a manner, when all LEDs are operating, the light form the collective thereof will illuminate the surface at the 3:1 ratio. When one or more LEDs fail, the overall illumination decreases, but the uniformity maintains the same uniformity. Also, as described hereinabove, the "surface" refers to the surface that is associated with a particular LED panel. It may be that an overall illuminated surface is segmented and multiple panels are provided, each associated with a particular segment.

FIG. **5**C illustrates a detail of the lens assembly. Each of the diodes **416** is mounted on the board **408** at a minimum distance. Overlying the board and LEDs **416** is transparent lens substrate **520**. This substrate **520** has a plurality of lens structures **522**, each associated with one of the LEDs **416**, such that each of the LEDs **416** has the light emitted therefrom directed outward towards the surface, each lens structure being substantially the same. The minimum distance is designed such that overlapping light from adjacent LEDs does not create interference patterns and result in dead spots on the surface. The lens structure **522** is designed to create the 3:1 uniformity and also, the lens structure is designed to "direct" the light from an edge of the surface to cover the entire surface. This is shown by the angle of the light rays in FIG. **5**C. Also, the beveled edge **530** will basically surround the PCB **402**, thus protecting it from moisture. The lens substrate **520** is secured with screws (not shown).

FIG. **5**D illustrates a detail of the lens structure **522**. This structure includes an interior surface **524** and an exterior surface **526** that shapes and directs the light in the correct pattern. This is an acrylic material. With such a design, the lighting assembly can be disposed at an edge of the surface to illuminate the entire surface.

In some embodiments, as shown in FIG. **1**, two lighting assemblies **110** may be used. Each lighting assembly may be powered by a separate power supply (not shown), and may be configured to illuminate the entire surface **102**. In such an embodiment, if one power supply fails, the remaining lighting assembly **110** will still illuminate the entire surface **102**, although at a lesser intensity than when both lighting assemblies **110** are functioning. This provides evenly distributed illumination when both lighting assemblies **110** are functioning correctly, and continues to provide evenly distributed illumination when one lighting assembly **110** malfunctions. Accordingly, the entire surface **102** of the billboard **100** may be illuminated even when an entire lighting assembly **110** has malfunctioned and is providing no illumination at all due to the redundancy provided by configuration of the lighting assemblies **110**.

Furthermore, in some embodiments as described above, each LED **416** of a single lighting assembly **110** may be configured via the optical elements **514** to illuminate the entire surface **102**. In such embodiments, if one or more LEDs **416** or strings of LEDs fails, the remaining LEDs **416** will still illuminate the entire surface **102**, although at a lesser intensity than when the failed LEDs **416** are functioning. This provides evenly distributed illumination when all LEDs **416** are functioning correctly, and continues to provide evenly distributed illumination when one or more LEDs are malfunctioning. Accordingly, the billboard **100** may be illuminated even when multiple LEDs **416** have malfunctioned and are providing no illumination at all due to the redundancy provided by configuration of the lighting assemblies **110**.

It is understood that some embodiments may direct substantially all illumination from a lighting assembly **110** evenly across the surface **102** while some illumination is not evenly distributed. For example, substantially all LEDs **416** may be directed to each evenly illuminate the surface **102** with the exception of a relatively small number of LEDs **416**. In such cases, the illumination provided by the remaining LED or LEDs **416** may be directed to one or more portions of the surface **102**. If done properly, this may be accomplished while minimizing any noticeable unevenness in the overall illumination, even if one of the remaining LEDs **416** malfunctions. For example, the lighting assembly **110** may be configured to direct the illumination provided by one LED **416** to only the left half of the surface **102**, while directing the illumination from another LED **416** to only the right half of the surface **102**. The loss of one of these two LEDs may not noticeably impact the illumination of the surface **102**. It is understood that such variations are within the scope of this disclosure.

In embodiments where the illumination is evenly distributed across the surface **102**, it is understood that the optics panel **206** may be configured specifically for the light panel **204** and the surface **102**. For example, assuming the surface **102** is forty-eight feet wide and sixteen feet high, the lens

panel **500** of FIG. **5** may be specifically designed for use with the PCB **402** of FIG. **4**. This design may be based on the particular layout of the PCB **402** (e.g., the number and arrangement of the LEDs **416**), the amount of illumination provided by the LEDs **416**, the size of the surface **102**, the distance between the lens panel **500** and the surface **102**, the angle at which the lens panel **500** is mounted relative to the surface **102** (e.g., FIGS. **1**B-**1**D), and/or other factors. Accordingly, changes in any of these factors may entail a change in the design of the lens panel **500** in order to again evenly distribute the illumination provided by each LED **416** across the entire surface **102**. It is understood that various standard configurations of the lighting assembly **110** may be developed for various billboard and/or other externally illuminated signs so that a particular configuration may be provided based on the parameters associated with a particular billboard and/or externally illuminated sign.

Referring to FIGS. **6**A-**6**C, one embodiment of a lighting assembly **600** is illustrated that provides a more detailed embodiment of the lighting assembly **200** of FIG. **2**. The lighting assembly **600** includes a back panel **602**, a light panel formed by multiple LED assemblies (denoted by reference number **800** in FIG. **8**A), and an optics panel formed by multiple lens panels **604**. Accordingly, as described previously, the light panel **204** in the current example is represented by multiple LED assemblies **800** and the optics panel **206** is represented by multiple lens panels **604**. In the present embodiment, the lighting assembly **600** includes four LED assemblies **800** and four lens panels **604**.

Although various attachment mechanisms (e.g., threaded screws, bolts, and/or other fasteners) may be used to coupled the lens panels and LED assemblies to the back panel **602**, the present embodiment uses multiple threaded fasteners **605** (e.g., screws) that extend through the lens panels and the LED assemblies and engage threaded holes in the back panel **602**.

The lighting assembly **600** is also illustrated with a mounting plate **606** that couples to the back panel **602** and to an adjustable mounting bracket **608**. The adjustable mounting bracket **608** may be used to couple the lighting assembly **600** to a portion of the billboard **100** (FIG. **1**) and/or to another support member. A power supply enclosure **610** may be coupled to the mounting plate **606** and configured contain a power supply (not shown) capable of supplying power to LEDs of the LED assemblies **800**. It is noted that separating the power supply from the back panel **602** may aid in heat dissipation by the back panel **602** as it does not have to dissipate heat from the power supply to the same extent as if the power supply was mounted directly to the back panel **602**.

The location of the power supply may also be beneficial as snow not melted by the heat produced by the LED may be melted by heat produced by the power supply. This may aid in reducing snow buildup on the LEDs.

With additional reference to FIGS. **7**A and **7**B, one embodiment of the back panel of FIG. **602** is illustrated. A front surface **700** includes multiple protrusions **702** that may be configured to protect the light panels (not shown) against moisture as previously described. The front surface **700** may include additional protrusions **704**.

A back surface **706** includes multiple fins **708** that form a heat sink to aid in the dissipation of heat from the back panel **602**. In the present example, the fins **708** are substantially rectangular in shape. In the present example, the back panel **602** is extruded and the fins **708** run parallel to the top edge with a longitudinal axis of each fin **708** being substantially parallel to a longitudinal axis of the back panel **602**. Forming the fins **708** in a vertical manner is possible, but may increase the cost of the back panel **602** due to the extrusion process. As shown, the fins **708** may be substantially perpendicular to the back surface **706**, and/or may be angled. In the present example, the fins **708** are angled such that near the top of the back panel **702**, the fins **708** are angled towards the top.

Because the fins **708** are parallel to the top edge, heat may be trapped due to its inability to rise vertically. Accordingly, holes **710** may be present in some or all of the fins **708** (marked but not actually visible in the side view of FIG. **7**B) to provide paths for the heat to rise vertically in spite of the orientation of the fins **708**. The holes **710** may create a chimney effect that increases air flow across the fins **708** and aids in the cooling process. In some embodiments, some or all of the fins **708** may be angled such that heat is not trapped.

The back surface **706** may also include a groove **712** that is configured to receive a tongue of the mounting plate **606** in a tongue-in-groove manner.

With additional reference to FIGS. **8**A-**8**J, embodiments of a single LED assembly **800** and a single lens panel **604** that may be used with the lighting assembly **600** are illustrated. As shown, the single LED assembly **800** and the single optics panel **604** may be configured for use together.

Referring specifically to FIG. **8**A, the LED assembly **800** includes a substrate **802** (e.g., a PCB) onto which are mounted multiple LEDs **804**. In the present example, the LED assembly **800** includes two strings of eight LEDs **804** each for a total of sixteen LEDs **804**. It is understood that this is merely an example, and there may be more or fewer LEDs **804** on the light panel **800**, and the LEDs **804** may be arranged in many different ways on the substrate **802**.

Referring also to FIGS. **8**B-**8**J, the optics panel **604** may include optical elements **806** arranged on an upper surface **808** of the optics panel **604**. The optics panel **604** may further include sides **810**, **812**, **814**, and **816** that are configured to fit around the edge of the substrate **802** of the light panel **800**. The bottom edge of each side **810**, **812**, **814**, and **816** abuts the front surface **700** of the back panel **602** and may be sealed to the front surface **700** using a moisture resistant sealant.

As shown in FIGS. **8**D-**8**H, a single optical element **806** may include multiple lens elements designed to distribute the illumination provided by a single LED **804** across a surface such as the surface **102** of FIG. **1**. A first lens element **820** may be positioned proximate to the LED **804**, and additional lens elements **822**, **824**, and **826** may be positioned above the lens element **820**. Multiple optical elements **806** may be combined and formed as a single optics panel **604** that is configured to operate with the LED assembly **800**.

Referring to FIG. **9**, another embodiment of a lighting assembly **900** is illustrated that provides a more detailed embodiment of the lighting assembly **200** of FIG. **2**. The lighting assembly **900** is similar to the lighting assembly **600** of FIG. **6**, but includes six LED assemblies rather than the four six LED assemblies of the lighting assembly **600**. It is understood that the lighting assembly **900** may require a larger power supply than the lighting assembly **600** (e.g., a one hundred and fifty watt power supply instead of a one hundred and twenty watt power supply).

Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A method of illuminating visual media content on a billboard display surface using a first lighting unit and a second lighting unit that each include a circuit board, a plurality of LEDs arranged on the circuit board, and a plurality of optical elements, wherein each optical element of the plurality of optical elements of the first and second lighting units overlies a respective one of the LEDs of the first and second lighting units, and wherein each optical element of the plurality of optical elements of the first and second lighting units is configured to redirect light from the respective one of the LEDs, the method comprising the steps of:

directing light from the first lighting unit toward a portion of the billboard display surface that extends from an edge of the billboard display surface, wherein the light from the first lighting unit is directed across the entire portion of the billboard display surface and wherein if one or more LEDs of the plurality of LEDs of the first lighting unit fails, remaining LEDs of the plurality of LEDs of the first lighting unit still illuminate the entire portion of the billboard so that all of the visual media content on the portion of the billboard display surface is visible without any additional light; and

at the same time, directing light from the second lighting unit toward the portion of the billboard display surface such that the light from the second lighting unit is directed across the entire portion of the billboard display surface, wherein if one or more LEDs of the plurality of LEDs of the second lighting unit fails, remaining LEDs of the plurality of LEDs of the second lighting unit still illuminate the entire portion of the billboard so that all of the visual media content on the portion of the billboard display surface is visible without any additional light;

wherein each optical element of the plurality of optical elements comprises:

a first outer boundary, a second outer boundary opposite the first outer boundary, a third outer boundary connecting the first outer boundary and the second outer boundary, a fourth outer boundary opposite the third outer boundary, and a central region halfway between the first outer boundary and the second outer boundary;

a first element with a convex outer surface extending from the first outer boundary toward the central region and having a peak located between the central region and the first outer boundary, the peak being spaced from the central region, the peak of the first element being vertically spaced from the circuit board on which the respective LED is arranged by a first distance;

a second element with a convex outer surface extending from the second outer boundary toward the central region and having a peak located between the central region and the second outer boundary, the peak being spaced from the central region, the peak of the second element being vertically spaced from the circuit board on which the respective LED is arranged by a second distance, wherein a portion of the convex outer surface of the first element intersects with a portion of the convex outer surface of the second element at an angle in a region between the first element and the second element;

a third element disposed between the third outer boundary and a region halfway between the third outer boundary and the fourth outer boundary, wherein the third element has a peak that is vertically spaced from the circuit board on which the respective LED is arranged by a third distance that is greater than the first distance and is greater than the second distance; and

a fourth element positioned proximate the respective LED, wherein the first, second and third elements are positioned above the fourth element, the fourth element having a first boundary enclosing a first surface adjacent the respective LED and a second boundary enclosing a second surface adjacent the first, second and third elements, the first boundary being smaller than the second boundary.

2. The method of claim 1, wherein the portion of the billboard display surface extends from a left edge of the billboard display surface to a right edge of the billboard display surface so that all of the billboard display surface is illuminated by only the first and second lighting units without any additional lighting unit.

3. The method of claim 1, wherein the method further comprises the steps of illuminating the billboard display surface using a third lighting unit and a fourth lighting unit that each include a circuit board, a plurality of LEDs arranged on the circuit board of the third and fourth lighting units, and a plurality of optical elements, each optical element of the plurality of optical elements of the third and fourth lighting units overlying a respective one of the LEDs of the third and fourth lighting units, wherein each optical element comprises a first element, a second element and a third element that are configured to redirect light from the respective one of the LEDs, the method further comprising the steps of:

at the same time as directing the light from the first and second lighting units, directing light from the third lighting unit toward a second portion of the billboard display surface such that the light from the third lighting unit is directed across the entire second portion of the billboard display surface; and

at the same time, directing light from the fourth lighting unit toward the second portion of the billboard display surface such that the light from the fourth lighting unit is directed across the entire second portion of the billboard display surface, wherein visual media content on the second portion of the display surface is visible without any additional light.

4. The method of claim 3, wherein the portion of the billboard display surface and the second portion of the billboard display surface extend from a left edge of the billboard display surface to a right edge of the billboard display surface so that all of the billboard display surface is illuminated using only light from the first, second, third and fourth lighting units.

5. The method of claim 1, wherein the method further comprises the steps of illuminating the billboard display surface using a third lighting unit, a fourth lighting unit, a fifth lighting unit, and a sixth lighting unit, each of the third, fourth, fifth and sixth lighting units including a circuit board, a plurality of LEDs arranged on the circuit board of the third, fourth, fifth and sixth lighting units, and a plurality of optical elements, each optical element of the plurality of optical elements of the third, fourth, fifth and sixth lighting units overlying a respective one of the LEDs of the third, fourth, fifth and sixth lighting units, wherein each optical element comprises a first element, a second element and a third element that are configured to redirect light from the respective one of the LEDs, the method comprising:

at the same time as directing the light from the first and second lighting units, directing light from the third lighting unit toward the billboard display surface;

at the same time, directing light from the fourth lighting unit toward the billboard display surface;

at the same time, directing light from the fifth lighting unit toward the billboard display surface; and

at the same time, directing light from the sixth lighting unit toward the billboard display surface; and

wherein all of the billboard display surface is illuminated only from the light from the first, second, third, fourth, fifth and sixth lighting units.

6. The method of claim **1**, wherein the method further comprises the steps of illuminating the billboard display surface using a third lighting unit that includes a circuit board, a plurality of LEDs arranged on the circuit board of the third lighting unit, and a plurality of optical elements, each optical element of the plurality of optical elements of the third lighting unit overlying a respective one of the LEDs of the third lighting unit, wherein each optical element comprises a first element, a second element and a third element that are configured to redirect light from the respective one of the LEDs, the method further comprising:

at the same time as directing the light from the first and second lighting units, directing light from the third lighting unit toward the portion of the billboard display surface such that the light from the third lighting unit is directed across the entire portion of the billboard display surface.

7. The method of claim **6**, wherein the method further comprises the steps of illuminating the billboard display surface using a fourth lighting unit, a fifth lighting unit, and a sixth lighting unit, each of the fourth, fifth, and sixth lighting units including a circuit board, a plurality of LEDs arranged on the circuit board of the fourth, fifth, and sixth lighting units, and a plurality of optical elements, each optical element of the plurality of optical elements of the fourth, fifth, and sixth lighting units overlying respective one of the LEDs of the fourth, fifth, and sixth lighting units, wherein each optical element comprises a first element, a second element and a third element that are configured to redirect light from the respective one of the LEDs, the method comprising the steps of:

at the same time as directing the light from the first and second lighting units, directing light from the fourth lighting unit toward a second portion of the billboard display surface such that the light from the fourth lighting unit is directed across the entire second portion of the billboard display surface;

at the same time, directing light from the fifth lighting unit toward the second portion of the billboard display surface such that the light from the fifth lighting unit is directed across the entire second portion of the billboard display surface; and

at the same time, directing light from the sixth lighting unit toward the second portion of the billboard display surface such that the light from the fifth lighting unit is directed across the entire second portion of the billboard display surface, wherein the portion of the billboard display surface and the second portion of the billboard display surface are illuminated with only the first, second, third, fourth, fifth, and sixth lighting units.

8. The method of claim **7**, wherein the portion of the billboard display surface and the second portion of the billboard display surface extend from a left edge of the billboard display surface to a right edge of the billboard display surface and from a top edge to a bottom edge of the billboard display surface so that all of the billboard display surface is illuminated.

9. The method of claim **8**, wherein a distance along the top edge of the billboard display surface from the left edge to the right edge is 48 feet and wherein a distance along the right edge of the billboard display surface from the top edge to the bottom edge is 14 feet.

10. The method of claim **1**, wherein each of the plurality of optical elements of the first lighting unit and of the second lighting unit are substantially the same.

11. The method of claim **1**, wherein the entire portion of the billboard is evenly illuminated even when multiple LEDs of the first lighting unit or the second lighting unit provide no illumination.

12. The method of claim **1**, wherein the LEDs are arranged in a plurality of rows, the LEDs being arranged such that overlapping light from adjacent LEDs does not create interference patterns that result in dead spots on the billboard display surface.

13. The method of claim **1**, wherein each of the plurality of optical elements of the first lighting unit and of the second lighting unit further comprises a fourth element disposed between the respective circuit board and the first, second and third elements, wherein the first, second and third elements join the fourth element at an interface, wherein the fourth element has a curved surface above the LED.

14. The method of claim **1**, wherein the first lighting unit and the second lighting unit each further comprise a heat sink and wherein, for each of the first and second lighting units:

the circuit board is substantially planar;

the plurality LEDs are arranged in a plurality of rows on a first surface of the circuit board, the rows extending along a longitudinal axis of the circuit board;

the heat sink is arranged on a second surface of the circuit board so that each LED is spaced from the heat sink by the circuit board;

the heat sink comprises a first section substantially parallel to the second surface of the circuit board and a plurality of fins extending away from the first section and substantially perpendicular thereto, a longitudinal axis of each fin being substantially perpendicular to the longitudinal axis of the circuit board; and

wherein the method further comprises extracting heat generated while illuminating the visual content, the heat being extracted from the plurality LEDs using the heat sink.

15. A method of illuminating a billboard display surface using a first lighting assembly and a second lighting assembly that each include a plurality of LEDs and a plurality of optical elements, each optical element overlying a respective one of the LEDs, the billboard display surface being divided into only a first portion and a non-overlapping second portion, the method comprising the steps of:

directing light from the first lighting assembly toward the first portion of the billboard display surface such that the light from the first lighting assembly is directed across the entire first portion of the billboard display surface; and

at the same time, directing light from the second lighting assembly toward the second portion of the billboard display surface such that the light from the second lighting assembly is directed across the entire second portion of the billboard display surface;

wherein when all LEDs of the first lighting assembly are operating, the entire first portion of the billboard dis-

play surface is illuminated with an illumination level and a uniformity, and wherein failure of one or more LEDs of the first lighting assembly will cause the illumination level of light impinging the first portion of the billboard display surface to decrease while the uniformity of light impinging the first portion of the billboard display surface remains substantially the same; and

wherein when all LEDs of the second lighting assembly are operating, the entire second portion of the billboard display surface is illuminated with an illumination level and a uniformity, and wherein failure of one or more LEDs of the second lighting assembly will cause the illumination level of light impinging the second portion of the billboard display surface to decrease while the uniformity of light impinging the second portion of the billboard display surface remains substantially the same

wherein each optical element of the plurality of optical elements comprises:

a first outer boundary, a second outer boundary opposite the first outer boundary, a third outer boundary connecting the first outer boundary and the second outer boundary, a fourth outer boundary opposite the third outer boundary, and a central region halfway between the first outer boundary and the second outer boundary;

a first element with a convex outer surface extending from the first outer boundary toward the central region and having a peak located between the central region and the first outer boundary, the peak being spaced from the central region, the peak of the first element being vertically spaced from a circuit board on which the respective LED is arranged by a first distance;

a second element with a convex outer surface extending from the second outer boundary toward the central region and having a peak located between the central region and the second outer boundary, the peak being spaced from the central region, the peak of the second element being vertically spaced from the circuit board on which the respective LED is arranged by a second distance, wherein a portion of the convex outer surface of the first element intersects with a portion of the convex outer surface of the second element at an angle in a region between the first element and the second element;

a third element disposed between the third outer boundary and a region halfway between the third outer boundary and the fourth outer boundary, wherein the third element has a peak that is vertically spaced from the circuit board on which the respective LED is arranged by a third distance that is greater than the first distance and is greater than the second distance; and

a fourth element positioned proximate the respective LED, wherein the first, second and third elements are positioned above the fourth element, the fourth element having a first boundary enclosing a first surface adjacent the respective LED and a second boundary enclosing a second surface adjacent the first, second and third elements, the first boundary being smaller than the second boundary.

16. The method of claim **15**, wherein the first lighting assembly comprises a first lighting unit and wherein the second lighting assembly comprises a second lighting unit;

wherein the first lighting unit comprises a first group of the plurality of LEDs arranged on a first circuit board; and

wherein the second lighting unit comprises a second group of the plurality of LEDs arranged on a second circuit board.

17. The method of claim **15**, wherein the first lighting assembly comprises a first lighting unit and a second lighting unit, and wherein the second lighting assembly comprises a third lighting unit and a fourth lighting unit;

wherein the first lighting unit comprises a first group of the plurality of LEDs arranged on a first circuit board;

wherein the second lighting unit comprises a second group of the plurality of LEDs arranged on a second circuit board;

wherein the third lighting unit comprises a third group of the plurality of LEDs arranged on a third circuit board; and

wherein the fourth lighting unit comprises a fourth group of the plurality of LEDs arranged on a fourth circuit board.

18. The method of claim **15**, wherein the first lighting assembly comprises a first lighting unit, a second lighting unit, and a third lighting unit and wherein the second lighting assembly comprises a fourth lighting unit, a fifth lighting unit and a sixth lighting unit;

wherein the first lighting unit comprises a first group of the plurality of LEDs arranged on a first circuit board;

wherein the second lighting unit comprises a second group of the plurality of LEDs arranged on a second circuit board;

wherein the third lighting unit comprises a third group of the plurality of LEDs arranged on a third circuit board;

wherein the fourth lighting unit comprises a fourth group of the plurality of LEDs arranged on a fourth circuit board;

wherein the fifth lighting unit comprises a fifth group of the plurality of LEDs arranged on a fifth circuit board; and

wherein the sixth lighting unit comprises a sixth group of the plurality of LEDs arranged on a sixth circuit board.

19. The method of claim **15**, wherein the optical elements of the first lighting assembly and of the second lighting assembly are substantially the same.

20. The method of claim **15**, wherein the LEDs are arranged in a plurality of rows, the LEDs being arranged such that overlapping light from adjacent LEDs does not create interference patterns that result in dead spots on the billboard display surface.

21. The method of claim **15**, wherein the first lighting assembly further comprises a heat sink;

wherein the circuit board is substantially planar;

wherein the plurality LEDs are arranged in a plurality of rows on a first surface of the circuit board, the rows extending along a longitudinal axis of the circuit board;

wherein the heat sink is arranged on a second surface of the circuit board so that each LED is spaced from the heat sink by the circuit board;

wherein the heat sink comprises a first section substantially parallel to the second surface of the circuit board and a plurality of fins extending away from the first section and substantially perpendicular thereto, a longitudinal axis of each fin being substantially perpendicular to the longitudinal axis of the circuit board; and

wherein the method further comprises extracting heat generated while illuminating the billboard display surface, the heat being extracted from the plurality LEDs using the heat sink.

22. A method of illuminating a billboard, the method comprising the steps of:

illuminating a first portion of a display surface of the billboard using a first lighting assembly, the display surface having a width of forty-eight feet, the first lighting assembly including a plurality of LEDs and a plurality of optical elements proximate the plurality of LEDs so as to direct light across the first portion of the display surface; and

illuminating a second portion of the display surface of the billboard using a second lighting assembly, the second lighting assembly including a second plurality of LEDs and a second plurality of optical elements proximate the second plurality of LEDs so as to direct light across the second portion of the display surface;

wherein the first portion and the second portion comprise all of the display surface of the billboard;

wherein the first lighting assembly and the second lighting assembly are laterally spaced along a single edge of the display surface;

wherein all of the display surface is illuminated using only the first lighting assembly and the second lighting assembly without any additional lighting assembly;

wherein when all LEDs of the first lighting assembly are operating, the entire first portion of the billboard display surface is illuminated with an illumination level and a uniformity, and wherein failure of one or more LEDs of the first lighting assembly will cause the illumination level of light impinging the first portion of the billboard display surface to decrease while the uniformity of light impinging the first portion of the billboard display surface remains substantially the same; and

wherein when all LEDs of the second lighting assembly are operating, the entire second portion of the billboard display surface is illuminated with an illumination level and a uniformity, and wherein failure of one or more LEDs of the second lighting assembly will cause the illumination level of light impinging the second portion of the billboard display surface to decrease while the uniformity of light impinging the second portion of the billboard display surface remains substantially the same

wherein each optical element of the plurality of optical elements comprises:

a first outer boundary, a second outer boundary opposite the first outer boundary, a third outer boundary connecting the first outer boundary and the second outer boundary, a fourth outer boundary opposite the third outer boundary, and a central region halfway between the first outer boundary and the second outer boundary;

a first element with a convex outer surface extending from the first outer boundary toward the central region and having a peak located between the central region and the first outer boundary, the peak being spaced from the central region, the peak of the first element being vertically spaced from a circuit board on which the respective LED is arranged by a first distance;

a second element with a convex outer surface extending from the second outer boundary toward the central region and having a peak located between the central region and the second outer boundary, the peak being spaced from the central region, the peak of the second element being vertically spaced from the circuit board on which the respective LED is arranged by a second distance, wherein a portion of the convex outer surface of the first element intersects with a portion of the convex outer surface of the second element at an angle in a region between the first element and the second element;

a third element disposed between the third outer boundary and a region halfway between the third outer boundary and the fourth outer boundary, wherein the third element has a peak that is vertically spaced from the circuit board on which the respective LED is arranged by a third distance that is greater than the first distance and is greater than the second distance; and

a fourth element positioned proximate the respective LED, wherein the first, second and third elements are positioned above the fourth element, the fourth element having a first boundary enclosing a first surface adjacent the respective LED and a second boundary enclosing a second surface adjacent the first, second and third elements, the first boundary being smaller than the second boundary.

23. The method of claim **22**, wherein the circuit board of the first lighting assembly comprises a planar substrate upon which one of the LEDs are attached.

24. The method of claim **23**, wherein the plurality of optical elements are arranged in only two rows on each optical panel, each optical element overlying only one LED.

25. The method of claim **23**, wherein the LEDs are arranged such that overlapping light from adjacent LEDs does not create interference patterns that result in dead spots on the billboard display surface.

26. The method of claim **22**, wherein the first lighting assembly further comprises a heat sink;

wherein the circuit board is substantially planar;

wherein the plurality LEDs are arranged in a plurality of rows on a first surface of the circuit board, the rows extending along a longitudinal axis of the circuit board;

wherein the heat sink is arranged on a second surface of the circuit board so that each LED is spaced from the heat sink by the circuit board;

wherein the heat sink comprises a first section substantially parallel to the second surface of the circuit board and a plurality of fins extending away from the first section and substantially perpendicular thereto, a longitudinal axis of each fin being substantially perpendicular to the longitudinal axis of the circuit board; and

wherein the method further comprises extracting heat generated while illuminating the billboard, the heat being extracted from the plurality LEDs using the heat sink.

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