

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HESAI TECHNOLOGY CO., LTD.
Petitioner

v.

OUSTER, INC.
Patent Owner

U.S. Patent No. 11,422,236
Inter Partes Review No. 2023-01458

**PETITION FOR *INTER PARTES* REVIEW
UNDER 35 U.S.C. § 312 AND 37 C.F.R. § 42.104**

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Statutes

35 U.S.C. § 102	<i>passim</i>
35 U.S.C. § 314	82
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EXHIBIT LIST

No.	Short Name	Exhibit
1001	‘236 Patent	U.S. Patent No. 11,422,236 to Pacala <i>et al.</i>
1002	‘236 Prosecution History	Prosecution history for U.S. Patent No. 11,422,236
1003	Hesselink Declaration	Declaration of Prof. Lambertus Hesselink, Ph.D.
1004	Hall	U.S. Patent No. 7,969,558 to Hall
1005	Borowski	U.S. Patent Pub. No. 2013/0300840 to Borowski
1006	Lipson	U.S. Patent No. 9,831,630 to Lipson
1007	Hipp	U.S. Patent No. 7,787,105 to Hipp
1008	Tan	U.S. Patent No. 7,544,945 to Tan <i>et al.</i>
1009	Albert	U.S. Patent Pub. No. 2016/0327639 to Albert <i>et al.</i>
1010	Grzesik	U.S. Patent No. 9,911,774 to Grzesik
1011	Hipp-747	U.S. Patent No. 6,747,747 to Hipp
1012	NIST	<i>Performance Analysis of Next-Generation LADAR for Manufacturing, Construction, and Mobility</i> , National Institute of Standards and Technology (2004)
1013	HDL-64	User Manual and Technical Drawings for Velodyne HDL-64E
1014	DGC	<i>Report to Congress: DARPA Prize Authority</i> (2006)
1015	Team DAD	Hall <i>et al.</i> , <i>Team DAD Technical Paper</i> , DARPA Grand Challenge (2005)

No.	Short Name	Exhibit
1016	McManamon	McManamon, <i>Field Guide to LiDAR</i> , SPIE Field Guides, Vol. FG36 (2015)
1017	Marino	Marino <i>et al.</i> , <i>A compact 3D imaging laser radar system using Geiger-mode APD arrays: system and measurements</i> , MIT Lincoln Lab (2003)
1018	Matsubara	Matsubara <i>et al.</i> , <i>Development of Next Generation LiDAR</i> , R&D Review of Toyota CRDL (2012)
1019	Pennecot-117	U.S. Patent Pub. No. 2015/0055117 to Pennecot <i>et al.</i>
1020	ITC Complaint	Complaint in ITC Inv. No. 337-TA-1363
1021	Delaware Complaint	Complaint in <i>Ouster, Inc. v. Hesai Group et al</i> , No. 23-cv-00406 (D. Del.)
1022	Stay Order	Order Granting Stay in <i>Ouster, Inc. v. Hesai Group et al.</i> , No. 23-cv-00406 (D. Del.)
1023	Preliminary Constructions	Preliminary Claim Constructions in ITC Action
1024	Niclass	Niclass <i>et al.</i> , <i>A Single Photon Avalanche Diode Array Fabricated in Deep-Submicron CMOS Technology</i> , (2006)
1025	Grage	U.S. Patent No. 5,210,586 to Grage
1026	Osram	Osram Datasheet
1027	Rodrigo	U.S. Patent Pub. No. 2016/0084945 to Rodrigo
1028	Lorenzoni	U.S. Patent No. 9,964,437 to Lorenzoni
1029	Weimer	U.S. Patent No. 8,736,818 to Weimer

No.	Short Name	Exhibit
1030	Retterath	U.S. Patent No. 10,203,399 to Retterath
1031	Matsui	Certified English Translation of PCT Patent Pub. No. WO2017/110573 to Matsui
1032	Matsui Priority	Certified English Translation of Japanese Patent Application No. 2015-251136 to Matsui
1033	Imai	U.S. Patent No. 10,114,110 to Imai
1034	Higashi	Certified English Translation of Japanese Patent Publication No. 2015-78953
1035	Matsui-JP	PCT Patent Pub. No. WO2017/110573 to Matsui
1036	Matsui Priority-JP	Japanese Patent Application No. 2015-251136 to Matsui
1037	Higashi-JP	Japanese Patent Publication No. 2015-78953
1038	Droz	U.S. Patent No. 8,742,325 to Droz
1039	Jarosinski	U.S. Patent Pub. No. 2018/0045816 to Jarosinski et al.
1040	Pennecot	U.S. Patent No. 9,651,658 to Pennecot <i>et al.</i>
1041	Hesselink CV	Curriculum Vitae of Dr. Lambertus Hesselink, Ph.D.
1042	ITC Order	Order No. 10 in ITC Inv. No. 337-TA-1363
1043	Higashi Patent	Certified English Translation of Japanese Patent No. JP6314418B2 to Higashi
1044	Higashi Patent-JP	JP Patent No. JP6314418B2 to Higashi

CLAIM LIST

Hesai challenges claims 1, 2, and 7-27 of the '236 Patent, reproduced below:

Claim 1	
1(a)	An optical system for collecting distance information, the optical system comprising:
1(b)	an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter in the plurality of optical emitters can project light at a nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;
1(c)	an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and
1(d)	an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;
1(e)	wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.
Claim 2	
2	The optical system of claim 1 further comprising an optical filter disposed in front of each pixel in the plurality of pixels and operable to allow a set of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.

Claim 7	
7	The optical system of claim 1 wherein the circular paths traversed by pixels from the second set of pixels in the second column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first column.
Claim 8	
8	The optical system of claim 1 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.
Claim 9	
9	The optical system of claim 1 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.
Claim 10	
10(a)	An optical system for collecting distance information, the optical system comprising:
10(b)	an output circuit comprising a bulk transmitting optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter can project an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;
10(c)	an input circuit comprising a bulk receiving optic disposed adjacent to the bulk transmitting optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

10(d)	an electric motor configured to rotate the input circuit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the input circuit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by each other pixel in the optical system;
10(e)	wherein the optical system collects data from each pixel in the plurality of pixels at a plurality of different arcuate sampling position as the input circuit is rotated through 360 degrees during each scan cycle.
Claim 11	
11	The optical system of claim 10 wherein each pixel in the plurality of pixels has a field-of-view that is non-overlapping with fields of view of all other pixels in the plurality of pixels, and the illumination source is configured to project illuminating beams into the field ahead of the optical system according to an illumination pattern where each beam in the illumination pattern is coincident with a field-of-view of one pixel in the plurality of pixels.
Claim 12	
12	The optical system of claim 11 wherein each scan cycle includes a plurality of sampling periods and, during each sampling period in the plurality of sampling periods, the optical system activates each emitter in the plurality of optical emitters to project the illumination pattern and determines a number of SPADs in each pixel that recorded an incident photon since a previous sampling period.
Claim 13	
13	The optical system of claim 12 wherein, during each sampling period of the plurality of sampling periods within one scan cycle, the optical system determines distances to objects in the field based on a difference between a time at which an optical emitter is fired and a time at which incident photons are detected at a pixel having a field-of-view that overlaps with a field-of-view of the fired optical emitter.
Claim 14	
14(a)	The optical system of claim 10 wherein

14(b)	the input circuit further comprises a plurality of apertures and stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures comprises a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;
14(c)	the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;
14(d)	the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and
14(e)	the first pixel has a field-of-view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field-of-view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field-of-view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field-of-view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.
Claim 15	
15	The optical system of claim 10 further comprising and an optical filter disposed between the bulk receiving optic and the plurality of pixels and configured to allow a narrow band of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the narrow band.

Claim 16	
16(a)	An optical system for collecting distance information, the optical system comprising:
16(b)	a light receiving unit comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and has a field-of-view that is non-overlapping with the fields of view of all other pixels in the plurality of pixels, and wherein the plurality of pixels includes a first set of pixels arranged in a first pixel column and a second set of pixels arranged in a second pixel column horizontally and vertically offset from the first pixel column;
16(c)	a light transmitting unit comprising a bulk transmitting optic spaced apart from the bulk receiving optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter projects an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system such that the plurality of optical emitters project a plurality of illuminating beams according to an illumination pattern that substantially matches, in size and geometry across a range of distances from the optical system, the fields of view of the plurality of pixels; and
16(d)	an electric motor operable to rotate the light receiving unit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the light receiving unit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by the other pixels in the plurality of pixels.
Claim 17	
17	The optical system of claim 16 wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system and implements time of flight techniques to transform the generated data into distances from the optical system.

Claim 18	
18	The optical system of claim 16 further comprising and an optical filter disposed between the bulk receiving optic and each pixel in the plurality of pixels, wherein the optical filter is configured to allow a set of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.
Claim 19	
19	The optical system of claim 16 wherein: the first set of pixels includes a first pixel and the second set of pixels includes a second pixel; the light receiving unit further comprises a plurality of apertures including a first aperture and a second aperture horizontally and vertically offset from the first aperture; the first aperture is disposed in a first optical path that extends from the bulk imaging optic, through the first aperture and to the first pixel; and the first aperture is disposed in a second optical path that extends from the bulk imaging optic, through the second aperture and to the second pixel.
Claim 20	
20	The optical system of claim 19 wherein: the plurality of optical emitters includes a first emitter and a second emitter; and the first pixel has a field-of-view that is coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the first aperture; and the second pixel has a field-of-view that is coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the second aperture.
Claim 21	
21(a)	The optical system of claim 16 wherein:

21(b)	the light receiving unit further comprises a plurality of apertures including a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;
21(c)	the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;
21(d)	the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and
21(e)	the first pixel has a field-of-view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field-of-view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field-of-view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field-of-view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.
Claim 22	
22	The optical system of claim 16 wherein the circular paths traversed by pixels from the second set of pixels in the second pixel column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first pixel column.
Claim 23	
23(a)	An optical system for collecting distance information, the optical system comprising:

23(b)	an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein the plurality of optical emitters project a plurality of beams of light at an operating wavelength through the bulk transmitting optic and into a field ahead of the optical system;
23(c)	an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and
23(d)	an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;
23(e)	wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.
Claim 24	
24	The optical system of claim 23 wherein the optical system further comprises an optical bandpass filter disposed between the bulk transmitting optic and the plurality of pixels and having a center wavelength matched to the operating wavelength of the plurality of optical emitters.
Claim 25	

25	The optical system of claim 23 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.
Claim 26	
26	The optical system of claim 23 wherein the illumination source comprises a plurality of vertical cavity surface emitting lasers (VCSELs).
Claim 27	
27	The optical system of claim 26 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.

I. INTRODUCTION

Petitioner Hesai Technology Co., Ltd. requests *inter partes* review of claims 1, 2, and 7-27 of U.S. Patent No. 11,422,236, assigned to Patent Owner Ouster, Inc.

II. MANDATORY NOTICES

A. Real Party-In-Interest

Hesai Technology Co., Ltd., Hesai Group, and Hesai, Inc. are the real-parties-in-interest.

B. Related Matters

Ouster asserted the '236 Patent against Hesai in parallel complaints filed on April 11, 2023 in the U.S. District Court for the District of Delaware and the U.S. International Trade Commission. *Ouster, Inc. v. Hesai Group et al*, No. 23-cv-00406 (D. Del.) and *Certain LiDAR (Light Detection and Ranging) Systems and Components Thereof*, Inv. No. 337-TA-1363 (USITC). EX1020-1021.

The Delaware action is presently stayed, with no procedural schedule in place and Hesai having yet to file a responsive pleading. EX1022. In the ITC Action, the presiding Administrative Law Judge has issued an initial determination granting Hesai's motion to terminate in view of an arbitration Hesai filed against Ouster. EX1042.

Hesai has filed petitions for *inter partes* review of U.S. Patent Nos. 11,175,405; 11,287,515, 11,178,381; and 11,190,750, which Ouster has asserted in the aforementioned litigation. *See* IPR Nos. 2023-1421, -1422, -1456, -1457.

C. Lead and Backup Counsel and Service Information

The designations of counsel and address for service are listed below.

Petitioner consents to electronic service at the email addresses below.

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III. STANDING

Hesai certifies that the '236 Patent is available for IPR, and that Hesai is not barred from requesting review. Ouster filed a complaint alleging infringement of the '236 Patent on April 11, 2023, and service was effectuated no sooner than May 4, 2023.

IV. PAYMENT OF FEES

Hesai authorizes the PTO to charge Deposit Account No. 505708 for the fees in this proceeding.

V. IDENTIFICATION OF CHALLENGE AND RELIEF REQUESTED

Hesai requests cancellation of claims 1, 2, and 7-27 on the following grounds:

Ground	Claims	References
1A	1, 7, 9-10, 23	Hall-Borowski
1B	2, 15, 24	Hall-Borowski-Lipson
1C	8, 25	Hall-Borowski-Hipp
1D	26, 27	Hall-Borowski-Tan
1E	11-13, 16-17, 22	Hall-Borowski-Weimer
1F	14, 19-21	Hall-Borowski-Hipp-Weimer
1G	18	Hall-Borowski-Weimer-Lipson
2A	1, 7, 9-13, 16-17, 22-23, 26-27	Matsui-Imai
2B	1-2, 7, 9-13, 15-18, 22-24, 26-27	Matsui-Imai-Higashi
2C	8, 14, 19-21, 25	Matsui-Imai-Hipp
2D	8, 14, 19-21, 25	Matsui-Imai-Higashi-Hipp

Each reference predates the August 24, 2016 earliest effective filing date of the '236 Patent. The references qualify as prior art as shown below:

Reference	Date	Section
Hall (US7969558)	6/28/2011 (issued)	§102(a)(1)
Borowski (US2013/0300840)	11/14/2013 (published)	§102(a)(1)
Lipson (US9831630)	2/3/2015 (filed)	§102(a)(2)
Hipp (US7787105)	8/31/2010 (issued)	§102(a)(1)
Tan (US7544945)	6/9/2009 (issued)	§102(a)(1)
Weimer (US8736818)	5/27/2014 (issued)	§102(a)(1)
Matsui (WO2017/110573) ¹	12/24/2015 (priority)	§102(a)(2)
Imai (US10114110)	3/14/2016 (filed)	§102(a)(2)
Higashi (JP2015-78953) ²	4/23/2015 (published)	§102(a)(1)

None of the above references was applied in any claim rejection in any office action during prosecution. EX1002.

Matsui is an international publication that claims priority to JP2015-251136, which fully supports the teachings of Matsui, including near-identical drawings and

¹ Certified English translations of the Matsui international publication and its underlying foreign priority application are provided as EX1031 and EX1032. The original publication and application are provided as EX1035 and EX1036.

² A certified English translation of the Higashi publication is provided as EX1034. The original Japanese version is provided as EX1037. The reference is referred to as “Higashi” herein, which reflects the name change of the first lead inventor after the application issued as a patent. See EX1043, EX1044.

disclosures. *Compare* EX1031 with EX1032. As such, Matsui qualifies as prior art under § 102(a)(2). *See* MPEP 2152.05. To further confirm that JP2015-251136 provides support for Matsui's teachings, both documents are cited in this Petition when discussing Matsui in order to show that the subject matter relied upon is also found in JP2015-251136. *Forescout Techs., Inc. v. Fortinet, Inc.*, IPR2021-01328, Paper 12, 9-10 (PTAB Jan. 27, 2022). Furthermore, the table below demonstrates how JP2015-251136 provides support for claim 1 of Matsui:

Claim 1 of Matsui Publication No. WO2017/110573	Support in Matsui Priority Application No. JP2015-251136
A light projection/reception unit comprising:	Fig. 2 [0011]-[0012], [0015], [0017]
a light source;	Claim 1 Fig. 2, item LD [0011]-[0012], [0017]
a light projection optical system that emits a light beam, emitted from said light source, toward an object;	Claim 1 Fig. 2, items LD, CL, LB [0011]-[0012], [0017]-[0018]
a scanning mechanism that drives said light projection optical system and scans the light beam emitted from said light projection optical system;	Claim 1 Fig. 2, items MT, SFT [0011]-[0012], [0016]
a first light receiving part that receives a first reflected light beam produced by reflection of the aforementioned light beam from said object; and	Claim 1 Fig. 2, item PD1 [0011]-[0012], [0017]-[0019]
a second light receiving part that receives a second reflected light beam	Claim 1 Fig. 2, item PD2

reflected from said object concurrently with said first reflected light beam;	[0011]-[0012], [0017]-[0019]
wherein said first light receiving part and said second light receiving part are spaced apart in a second direction corresponding to the direction in which the light beam emitted from said light projection optical system is scanned;	Claim 1 Fig. 2, items PD1, PD2, RO [0011]-[0012], [0018], [0028]
said first light receiving part comprises a plurality of first light receiving elements spaced apart and arranged side by side in a first direction orthogonal to said second direction;	Claim 1 Fig. 3, items PX1 [0011]-[0012], [0019]-[0020], [0028]
said second light receiving part comprises a plurality of second light receiving elements spaced apart and arranged side by side in said first direction; and	Claim 1 Fig. 3, items PX2 [0011]-[0012], [0019]-[0020], [0028]
said first light receiving elements and said second light receiving elements are arranged such that two adjacent said first light receiving elements would come into gapless contact with, or partially overlap, the second light receiving element interposed therebetween if said first light receiving elements were to be shifted relative to said second light receiving elements in said second direction.	Claim 1 Fig. 3, items PX1, PX2 [0011]-[0012], [0019]-[0020], [0028]

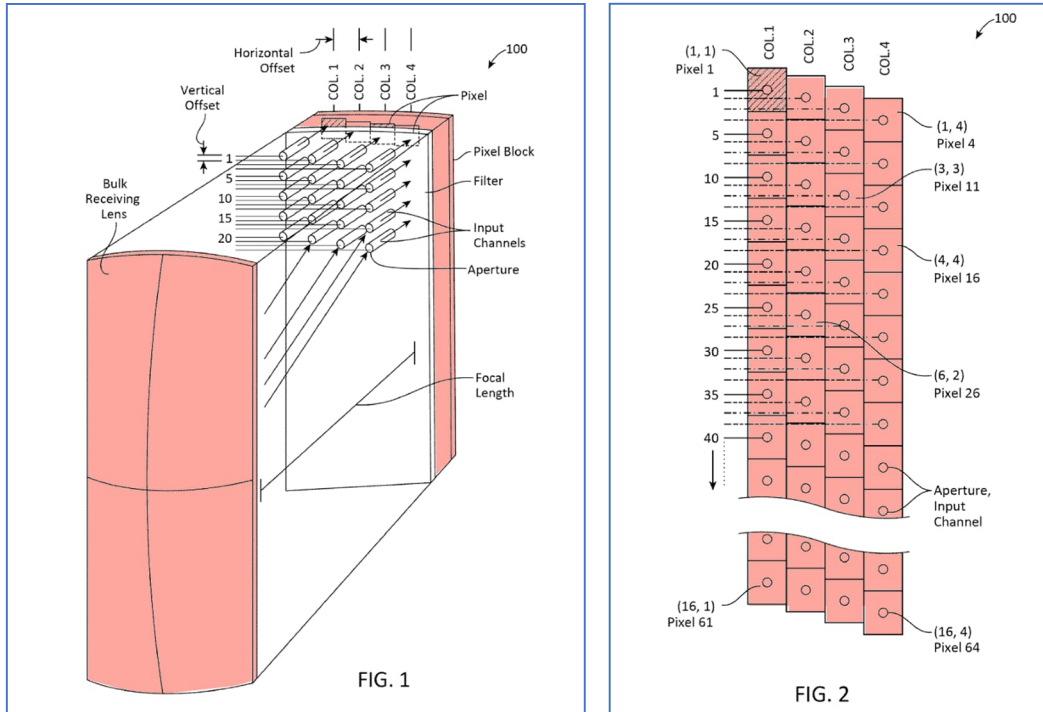
VI. TECHNOLOGY BACKGROUND

A discussion of the technology background, including known design features and techniques for improving the performance of LiDAR devices, is provided in the declaration of Professor Lambertus Hesselink, Ph.D. EX1003 ¶¶20-52.

VII. THE ‘236 PATENT

A. Specification

The ‘236 Patent describes a LiDAR device with an output circuit that includes a plurality of laser emitters and lens to generate and transmit laser pulses to the surrounding environment. EX1001, 11:6-14, 11:36-41. The device also includes an input circuit that includes a lens and plurality of pixels to receive and detect laser pulses reflected from objects in the environment. *Id.*, 4:20-43. The figures of the ‘236 Patent focus on the input circuit, with Figures 1 and 2 showing the receiving lens and pixel array:



Id., Figs. 1-2.³

As shown in Figure 1, the input circuit includes a plurality of apertures and a filter positioned between the receiving lens and pixels. *Id.* As shown in Figure 2, the pixels are arranged in a plurality of columns, with the pixels in column-1 horizontally and vertically offset from the pixels in column-2. *Id.*

The specification states that each pixel may “include an array of single-photon avalanche diode detectors (‘SPADs’)...” *Id.*, 6:8-15. The emitters may include a “monolithic VCSEL array.” *Id.*, 11:15-17. And the device can be rotated via a

³ Colors and annotations added unless otherwise noted.

motor to collect time-of-flight distance measurements in 360-degrees. *Id.*, 12:18-38.

B. Prosecution History

The '236 Patent application was filed with twenty-seven claims. EX1002. On February 28, 2022, the Examiner issued a rejection finding certain claims obvious for non-statutory double patenting. *Id.*, 182-190. The Examiner objected to the remaining claims and indicated they would be allowable if written in independent form. *Id.* Thereafter, the applicant filed a terminal disclaimer and the claims were allowed in their original form. *Id.*, 9, 37.

VIII. LEVEL OF ORDINARY SKILL IN THE ART

A POSITA as of August 24, 2016 would have had an undergraduate degree in mechanical engineering, electrical engineering, or physics, and two to three years of experience in LiDAR design. EX1003 ¶¶59-64.

IX. CLAIM CONSTRUCTION

For purposes of this proceeding, the challenged claims should receive their ordinary and customary meaning. *Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005). Prior to the order granting Hesai's motion to terminate the ITC action, the parties exchanged preliminary constructions for certain terms of the '236 Patent. EX1023. The prior art in this Petition maps to the embodiments of the '236 Patent and renders the challenged claims obvious under any proposed construction.

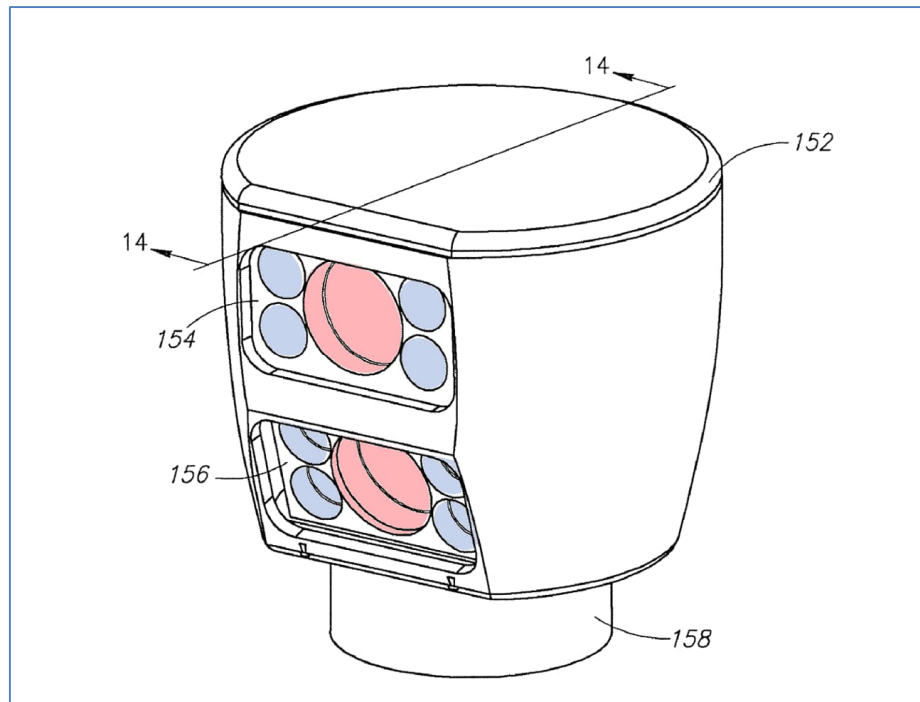
Accordingly, no formal constructions are necessary in this proceeding. *Wellman, Inc. v. Eastman Chem. Co.*, 642 F.3d 1355, 1361 (Fed. Cir. 2011).

X. DETAILED EXPLANATION OF GROUNDS FOR INVALIDITY

A. Ground 1A: Hall and Borowski Render Obvious Claims 1, 7, 9-10, and 23

1. Hall

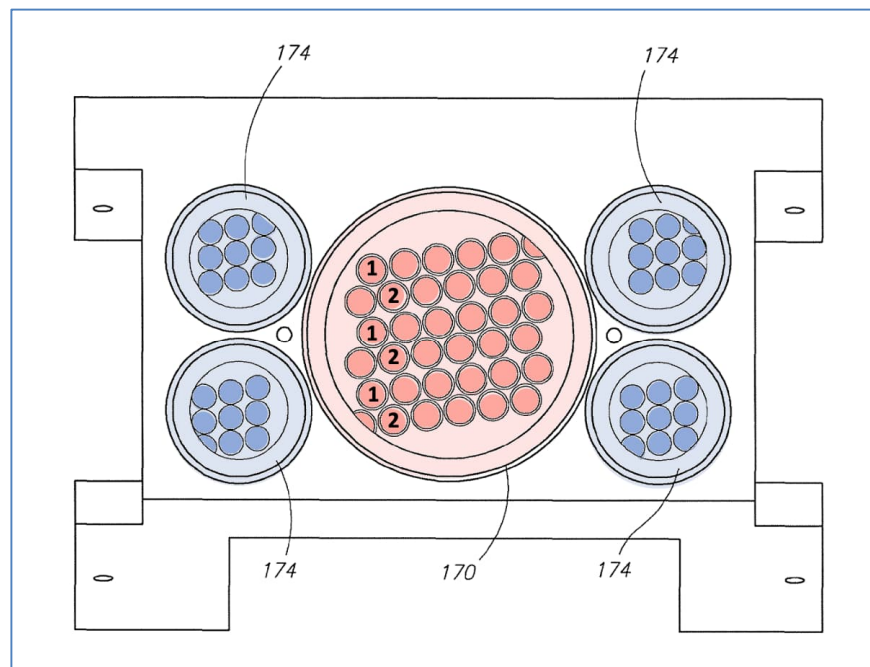
Hall describes a “lidar-based 3-D point cloud measuring system and method.” EX1004, Abstract. Hall proposes a LiDAR device that mounts multiple emitters and detectors in a housing that rotates around a stationary base. *Id.*, 6:42-63. An embodiment is illustrated below, where the transmit section is shown in blue, and the receive section is shown in red:



Id., Fig. 13.

The device includes first and second LiDAR systems 154, 156 designed to capture different angles across the vertical field-of-view. *Id.*, 6:64-7:9. Each system includes a plurality of emitters positioned behind four outer transmit lenses, and a plurality of photodetectors positioned behind a receive lens. *Id.*, 6:64-7:17. The emitters and detectors are mounted in a housing 152 that rotates about a base 158 via an actuator such as a DC motor. *Id.*, 6:42-63.

Hall teaches the emitters and detectors are arranged in columns, whereby each emitter/detector in a given column is horizontally and vertically offset from the emitters/detectors in other columns. *Id.*, Fig. 22. This is illustrated below, where each detector in the first column labeled “1” is horizontally and vertically offset from each detector in the second column labeled “2”:

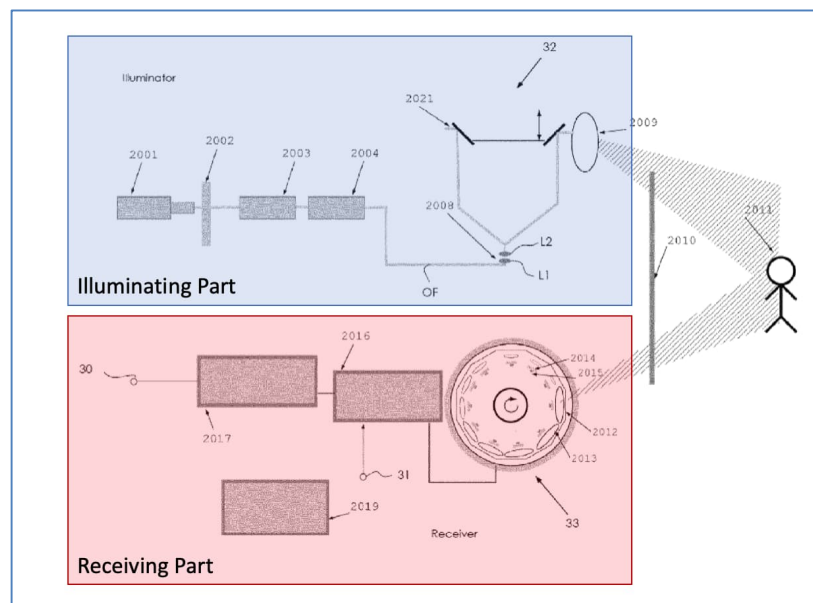


Id., Fig. 22.

The arrangement allows each detector to trace a unique circular path as the device rotates through 360-degrees. *Id.*, 6:67-7:3, 7:14-17, 8:15-17; EX1003 ¶73. Hall explains that a device with the foregoing structure generates approximately one million time-of-flight measurements per second to create a dense 3D point cloud for autonomous vehicle navigation. *Id.*, 4:3-13, 8:30-32.

2. Borowski

Borowski describes a rotating 3D landscape imagers that use time-of-flight to obtain distance measurements. EX1005, [0001]-[0002], [0058]. The device includes an “illuminating part” to generate ultra-short laser pulses and distribute them into the surrounding environment, and a “receiving part” to detect returned photons. *Id.*, [0006]-[0007]. The illuminating part and receiving part are illustrated below:



Id., Fig. 2.

The illuminating part includes one or more lasers emitting short pulses at the gigahertz frequency range. *Id.*, [0061]. The receiving part includes one or more SPAD arrays 2014 on a rotating mount 33. *Id.*, [0078]. The focus of Borowski's disclosure is on the plurality of SPAD arrays, including their structure, operation, electronics, and circuitry. *Id.*, [0040]-[0060].

Borowski teaches that each "SPAD detector array is built onto a chip and includes mainly a detector part and a processing part." *Id.*, [0079]. "The detector part comprises a set of SPAD detector cells which are arranged in a 2D rectangular matrix." *Id.* The electronics part includes time-to-digital converters ("TDC") and digital-signal-processors ("DSP") to process data at the level of an individual SPAD cell or "macro-cell." *Id.*, [0050]-[0052]. The macro-cell is a cluster of individual SPAD cells that "acts as the equivalent of a single 'perfect' SPAD having no recovery time." *Id.*, [0053], [0171], [0192].

In operation, the SPAD arrays rotate in synchrony with emission of the illuminating beams to generate time-of-flight data for distance measurements. *Id.*, [0018], [0102]. The device also includes a "rotation sensor" to provide "angular orientation" used to associate the distance measurement with a specific position in the horizontal field-of-view. *Id.*, [0191]. The "combination of the 3D data of all SPAD detector arrays generates a complete image of the landscape around the 3D real-time landscape imager's available field-of-view." *Id.*, [0043], [0192].

3. Combined Teachings of Hall and Borowski

Hall teaches the overall structure of a rotating LiDAR device, including transmit and receive modules, a plurality of emitters, and a plurality of pixels that are horizontally and vertically offset to trace unique circular paths as the device rotates. Borowski teaches the use of multi-SPAD pixels for improved detection capability in LiDAR devices. A POSITA would have been motivated to apply Borowski's SPAD teaching to Hall, with a reasonable expectation of success in achieving the claimed subject matter. EX1003 ¶¶105-115.⁴

First, a known benefit of SPADs was excellent detection sensitivity. *Id.* ¶107. EX1018, 8; EX1017, 4. The ability to detect individual photons with high sensitivity was beneficial to a LiDAR device like Hall, which has a wide horizontal and vertical field-of-view, and is designed for long-range detection in all weather conditions. EX1003 ¶¶24-25, 45-49, 107. These factors would impact the number of photons returned to the device; for example, a given object may need to be detected and classified with only a few returns. *Id.* Using SPAD detectors in place of Hall's traditional APDs would have increased sensitivity and improved the ability of the device to detect objects in the field. *Id.*

⁴ Hall and Borowski are analogous art because they are in the same field of endeavor as the '236 Patent—optical systems for distance measurement—and pertinent to the problem of improving detection capability in such systems. EX1003 ¶105; EX1004, 1:11-31, 3:65-4:13; EX1005, [0001]-[0005], [0035], [0058].

Second, another known benefit of SPADs was their ability to be grouped in an array or pixel. *Id.* ¶¶108, 50-51; EX1018, 8 (“SPADs... can be easily incorporated into an array since their operating voltage is low.”); EX1009, [0049]-[0050], [0138]-[0139]. This was beneficial because each individual SPAD will have a “dead time” during which it is quenched and reset. EX1003 ¶108. By grouping multiple SPADs together, the array or macro-pixel can continue to register detections, even if one of the SPADs is subject to “dead time.” *Id.* Borowski recognizes this advantage through its teaching of a multi-SPAD macro-pixel that can be filtered and averaged such that it “acts as the equivalent of a single ‘perfect’ SPAD having no recovery time.” EX1005, [0053]. Applying the teachings of Borowski to Hall, a POSITA would have been motivated to replace each APD with a multi-SPAD pixel. EX1003 ¶108.

Third, another known benefit of SPADs was their fast detection speed and data output. *Id.* ¶109; EX1010, 1:19-26, 1:42-52. Borowski expressly teaches that its multi-SPAD arrays allow photons to be “efficiently detected” in a “ultrafast” manner. EX1005, [0022], [0053], [0190]-[0193]. This benefit would have further motivated a POSITA to use multi-SPAD pixels in place of Hall’s traditional APDs, because faster detection and data output would have produced a higher-resolution point cloud—an express goal of Hall. EX1004, 2:35-49; EX1003 ¶109. Indeed, a POSITA in 2016 would have considered the **digital** operation and output of SPAD

arrays to provide a significant advantage for a device like Hall, which relied on traditional *analog* APDs common in 2007. *Id.*

Fourth, additional known benefits of SPADs were compactness, low-power consumption, and ease of integration with circuitry. EX1010, 1:42-52, 3:66-4:4; EX1018, 7-8. These benefits would have further motivated a POSITA to use multi-SPAD pixels in Hall's LiDAR device to reduce cost while improving performance. EX1003 ¶110.

Fifth, a POSITA would have a reasonable expectation of success combining the multi-SPAD pixels of Borowski with the LiDAR device of Hall. EX1003 ¶¶111-114, 45-51. Borowski teaches the electronics and associated circuitry necessary to integrate multi-SPAD arrays or pixels into a LiDAR device like Hall. *Id.* EX1005, [0036], [0051], [0079], [0095]-[0106], [0190]-[0192]. Applying these teachings and basic electrical engineering principles, it would have been predictable for a POSITA to integrate Borowski's SPAD arrays and associated electronics into Hall's LiDAR device. EX1003 ¶¶111-114. Indeed, the predictable nature of the combination is confirmed by evidence showing that the operation of SPAD arrays—and their application to LiDAR sensors—was well-understood at the time of the alleged priority date. *Id.* Finally, a POSITA would have understood that minor differences between Hall and Borowski—such as operating wavelength—amount to routine design choices that do not render the combination any less predictable. *Id.* ¶115.

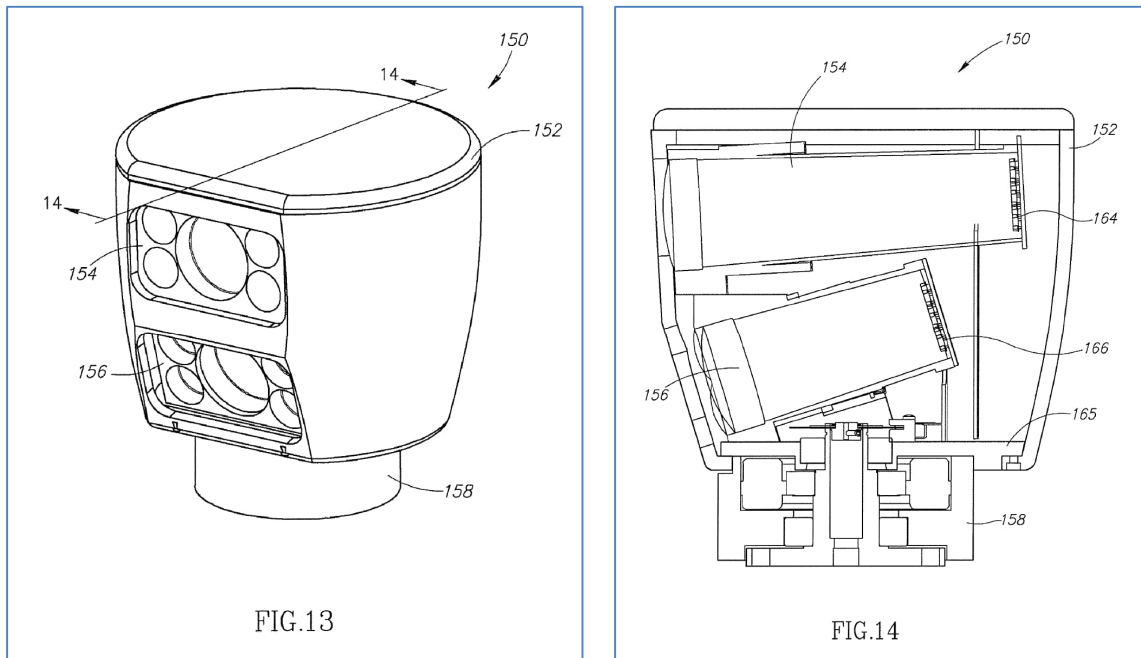
4. Application to the Claims

a) Limitation 1(a)

Hall teaches limitation 1(a). EX1003, 59.⁵ Hall teaches a “lidar-based 3-D point cloud measuring system and method.” EX1004, Abstract. The system “can collect approximately 1 million time of flight (TOF) distance points per second.” *Id.*, 4:9-11.

b) Limitation 1(b)

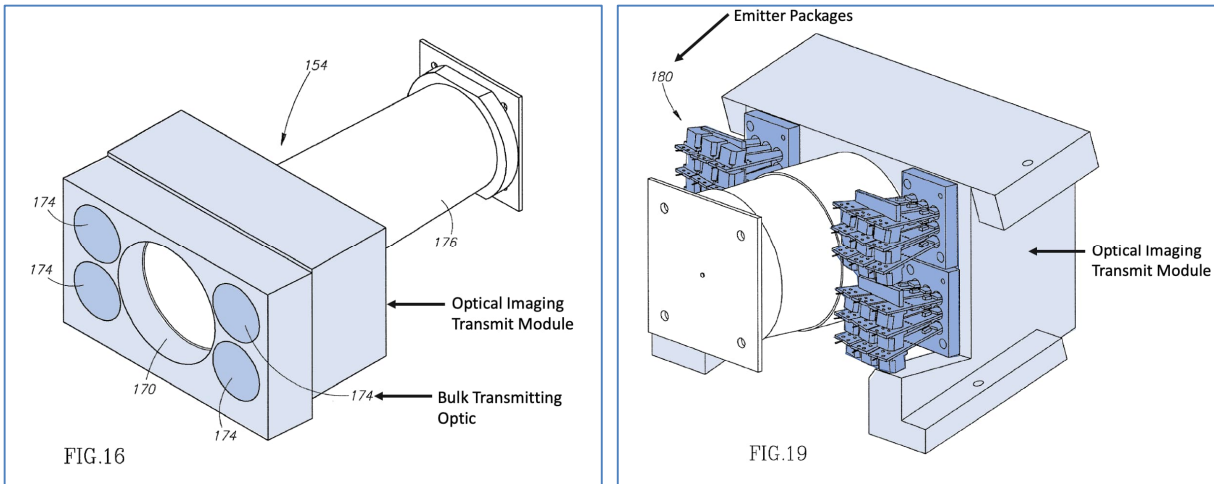
Hall teaches limitation 1(b). EX1003, 59-63. The device 150 includes first and second LiDAR systems 154 and 156, as illustrated in Figures 13-14:



EX1004, Figs. 13-14, 6:43-49, 2:55-67, 7:5-8.

⁵ Citations to EX1003 without paragraph symbols refer to page numbers.

The first LiDAR system 154 includes four cavities 174, each with a lens positioned in front of emitter packages 180. *Id.*, 6:64-7:17. Each emitter package includes a plurality of emitters 188. *Id.* Figures 16 and 19 illustrate the structure of the cavities 174, their lenses, and corresponding emitter packages 180:



Id., Figs. 16, 19.

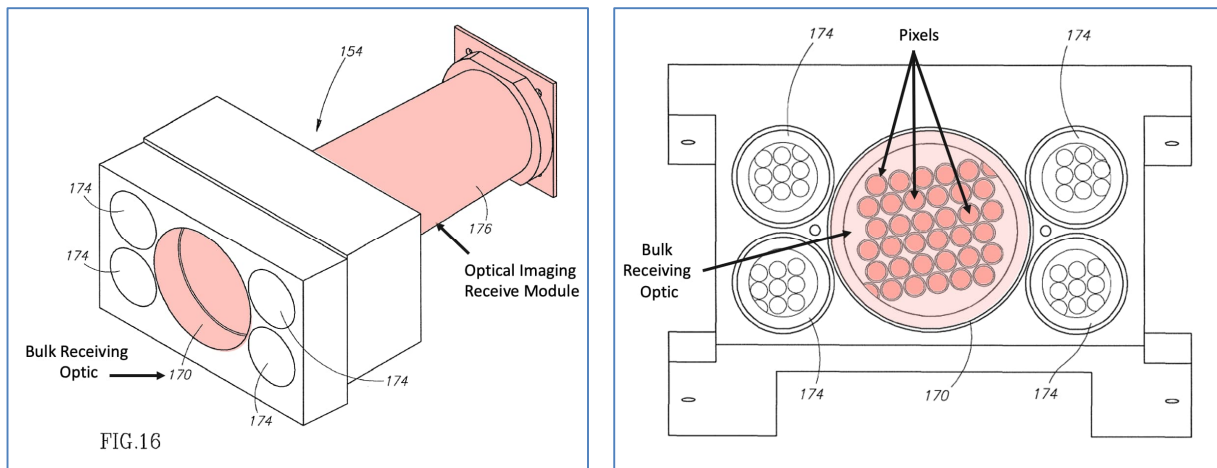
As shown above, the emitter cavities and packages form an optical imaging transmit module, which is a structure to generate and transmit laser pulses. EX1003, 62-63. The lenses positioned in cavities 174 comprise a bulk transmitting optic because they collect light from a plurality of emitters and pass it to the surrounding environment.⁶ The emitter packages 180 are an illumination source comprising a

⁶ “A bulk transmitting optic” encompasses one or more optics due to use of the indefinite article “a.” *KCJ Corp. v. Kinetic Concepts, Inc.*, 223 F. 3d 1351, 1356 (Fed. Cir. 2000). Accordingly, the lenses in the first LiDAR system 154 are together “a bulk transmitting optic.” Alternatively, the lenses individually are each “a bulk transmitting optic.”

plurality of optical emitters 188 arranged behind the bulk transmitting optic. EX1004, Figs. 19, 22. And each emitter projects light at a nominal wavelength—*e.g.*, 905 nm—through the bulk optic and into a field ahead of the optical system. *Id.*, 5:5-7, 8:52-54.

c) Limitation 1(c)

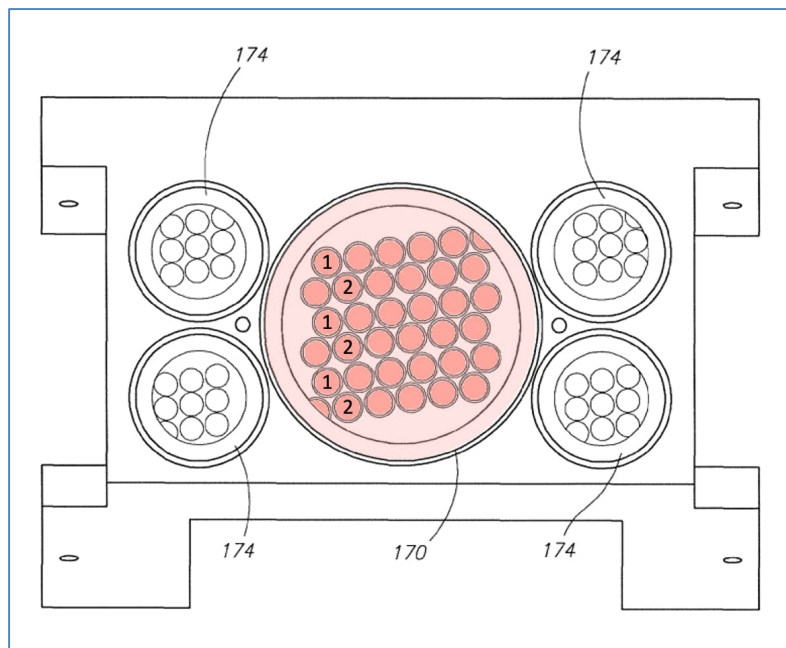
Hall and Borowski teach limitation 1(c). EX1003, 63-68. Hall teaches that the first LiDAR system 154 includes a cavity 170 with a detector lens positioned in front of a plurality of detectors mounted in tube 176. EX1004, 6:64-7:9. Figures 16 and 22 illustrate the structure:



Id., Figs. 16, 22.

As shown, the cavity 170, lens, and tube 176 form an optical imaging receive module, which is a combined structure to detect photons returning to the device. EX1003, 64-65. The lens positioned in cavity 170 is a bulk receiving optic because it collects light from the surrounding environment and focuses it on a plurality of

detectors. *Id.* Each detector is a pixel because it collects incident light for a specific location in the array. *Id.*, 65; EX1004, 5:5-7, Fig. 22. This is the same operation and configuration of the pixels in the '236 Patent, which explains that a pixel may comprise a single detector. EX1001, 5:50-53, Fig. 2. Hall further teaches the pixels are arranged in columns, including a first set defining a first column and a second set defining a second column that is horizontally and vertically offset from the first column. EX1003, 65-66; EX1004, Fig. 22. The arrangement is shown in Figure 22, with the second set of pixels (annotated as “2”) horizontally and vertically offset from the first set of pixels (annotated as “1”):



*Id.*⁷

⁷ Figure 22 teaches the arrangement and relative position of pixels in cavity 170. *In re Mraz*, 455 F.2d 1069, 1072-73 (CCPA 1972) (what is shown clearly in patent drawings is not disregarded); *In re Heinle*, 342 F.2d 1001, 1007 (CCPA 1965)

To the extent Ouster contends Hall does not disclose horizontal and vertical offset pixels, a POSITA would have found it obvious to arrange the pixels in this manner. EX1003, 66-67, ¶¶30-36. Hall teaches the desire for high resolution, with emitter-detector pairs having an angular separation of $1/3^\circ$. *Id.* To achieve that goal, a POSITA would have organized the emitters and detectors in arrays with an offset arrangement as was well known in the art. *Id.* The array design would allow for more emitter-detector pairs without compromising the height of the device. *Id.* The offset arrangement would also allow for tight angular separation of each emitter-detector pair without any two pairs tracing the same path, which would be wasteful. *Id.*

Hall does not expressly teach that each pixel includes a plurality of SPADs. EX1004, 5:5-7. However, it would have been obvious to modify Hall to include this limitation in view of Borowski. EX1003, 67-68, ¶¶ 105-115. Borowski teaches a laser scanning device with a plurality of photodetectors on a rotating mount, where each photodetector includes an array of SPAD detector cells. EX1005, [0040], [0078]. Each “SPAD detector array is built onto a chip and includes mainly a

(relying on patent drawing to show relative proportions); *Oticon Med. AB v. Cochlear Ltd.*, IPR2019-00975, Paper 15 at 15-16 (Oct. 16, 2019) (*precedential*) (same); EX1003 65-66. Indeed, Figure 22 of Hall shows the same “skewed grid” arrangement of pixels as Figure 2 of the ‘236 Patent. *Id.*; EX1001, Fig. 2.

detector part and a processing part.” *Id.*, [0079]. “The detector part comprises a set of SPAD detector cells which are arranged in a 2D rectangular matrix” and “[t]he detection voltage which appears at the output of the respective SPAD corresponds to an event which is detected and then timestamped to measure the time of flight....” *Id.*, [0079]. Borowski advantageously teaches that a group of SPAD cells in an array may be formed into “macro cells,” each of which includes a cluster of “several SPAD detector cells.” *Id.*, [0053]. Each macro-cell is programmed such that it “acts as the equivalent of a single ‘perfect’ SPAD,” such that time-of-flight operations can be computed at the level of the macro-cell. *Id.*, [0051]-[0053], [0092].

When the teachings of Borowski are applied to the LiDAR structure of Hall, the resulting device would implement each of Hall’s pixels as a plurality of pixels in a manner that meets limitation 1(c). EX1003, 67-68, ¶¶ 105-115.

d) Limitation 1(d)

Hall teaches limitation 1(d). EX1003, 68-70. The LiDAR device is mounted on a rotating platform driven by an actuator that rotates the optical imaging receive module about a vertical axis through 360-degrees. EX1004, 5:39-40 (“A simple DC motor controller driving a high reliability brushed motor controls the rotation of the emitter/detectors.”), 8:30-32. The motor components are shown in Figures 14 and 15, including a rotary coupling 161, bearing 162, rotor 159 and stator 160:

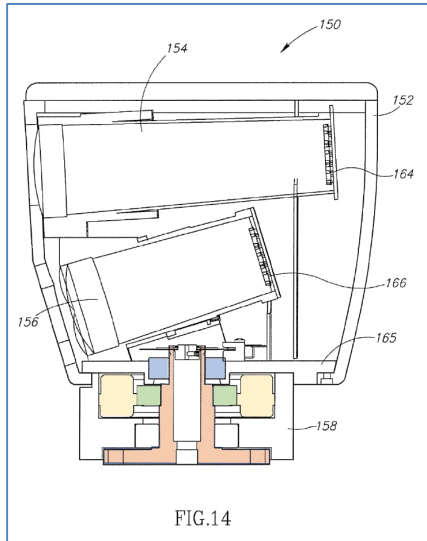


FIG.14

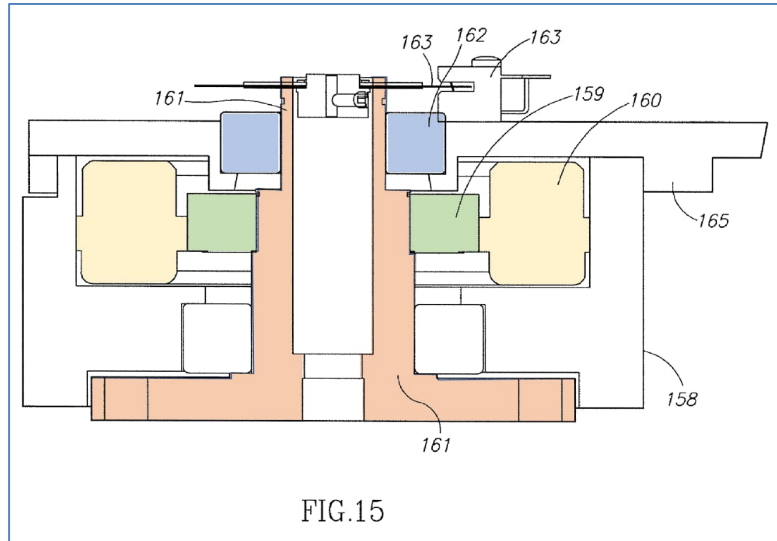
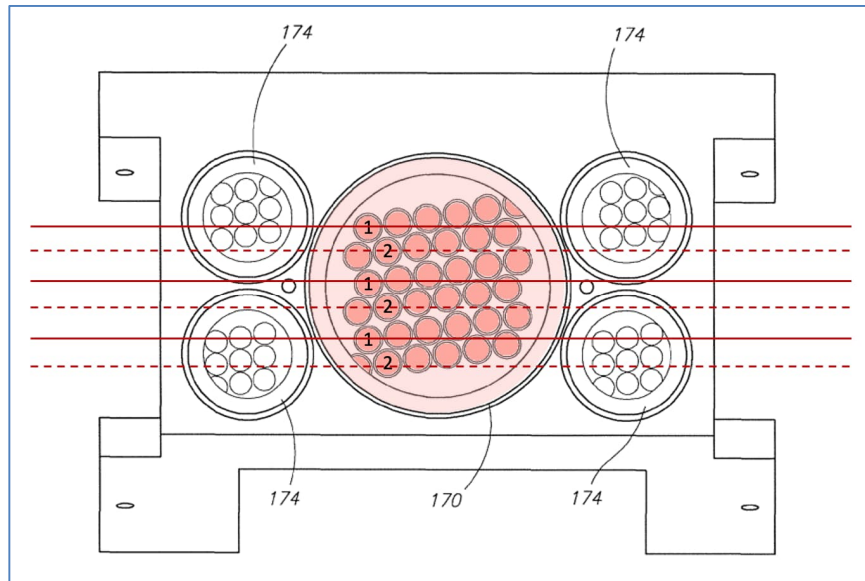


FIG.15

Id., Figs. 14-15, 6:50-63.

As the device rotates, each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system. EX1003, 70. This is evident from the annotated version of Figure 22 below, which shows the unique path each pixel in the first and second columns traverses in operation. *Id.* The path of pixels in the first column is shown with solid lines, and the path of pixels in the second column is shown with dashed lines:



EX1004, Fig. 22.

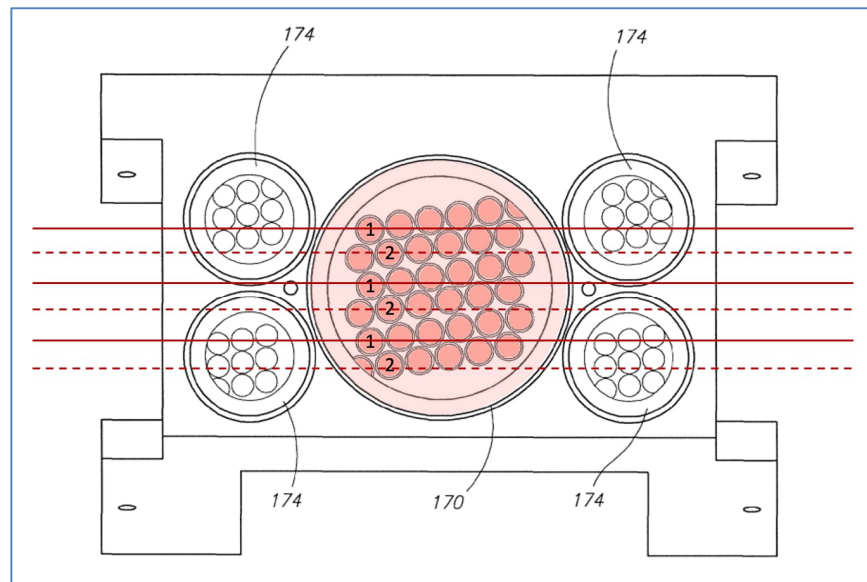
To the extent Ouster contends Hall does not disclose each pixel tracing a unique circular path as the device rotates, Hall renders the limitation obvious as discussed in Sections X.A.4(c)-(d). EX1003, 66-67.

e) Limitation 1(e)

Hall teaches limitation 1(e). EX1003, 70-71. Hall explains that the LiDAR device rotates at 200 RPM, which corresponds to a scan cycle of 0.33 seconds. EX1004, 4:9-14, 8:65-67. Hall also explains the device collects about 1 million distance measurements per second, or 300,000 measurements per scan cycle. *Id.* The device rotates through a 360-degree horizontal FOV and includes a rotary encoder to determine the rotational position of the device as measurements are taken. *Id.*, 5:11-15, 5:39-44. Thus, the device provides distance measurements at a plurality of arcuate sampling positions within each scan cycle. *Id.*; EX1003, 70-71.

f) Claim 7

Hall and Borowski teach claim 7. EX1003, 71-72. Hall teaches that the pixels in the second column are interleaved with the pixels in the first column. EX1004, Fig. 22. When the device rotates, the pixels in the second column will traverse paths that are interleaved with the paths traversed by pixels in the first column. The interleaved arrangement is illustrated in the annotated Figure 22 below:



EX1004, Fig. 22.

g) Claim 9

Hall and Borowski teach claim 9. EX1003, 72. Hall's LiDAR device uses time-of-flight techniques to measure distances between the device and objects in the surrounding environment. EX1004, 1:11-18, 4:9-11 ("At this configuration, the system can collect approximately 1 million time of flight (TOF) distance points per second"), 4:47-49.

h) Limitation 10(a)

Hall teaches limitation 10(a). Section X.A.4(a).

i) Limitation 10(b)

Hall teaches limitation 10(b). The “output circuit” of claim 10 is synonymous with the “transmit module” of claim 1, which Hall discloses. Section X.A.4(b).

j) Limitation 10(c)

Hall and Borowski teach limitation 10(c). The “input circuit” of claim 10 is synonymous with the “receive module” of claim 1, which Hall discloses. Section X.A.4(c). Limitation 10(c) also requires “a bulk receiving optic disposed adjacent to the bulk transmitting optic.” Hall teaches this requirement as shown in Fig. 16, where Hall’s bulk receiving optic 170 is adjacent to the bulk transmitting optic 174. EX1004, Fig. 16.

k) Limitation 10(d)

Hall teaches limitation 10(d). Limitation 10(d) requires an “electric motor,” which Hall teaches. Section X.A.4(d).

l) Limitation 10(e)

Hall teaches limitation 10(e). Section X.A.4(e).

m) Limitation 23(a)

Hall teaches limitation 23(a). Section X.A.4(a).

n) Limitation 23(b)

Hall teaches limitation 23(b). Section X.A.4(b). Limitation 23(b) also requires that “the plurality of optical emitters project a plurality of beams of light at an operating wavelength,” which is not recited verbatim in limitation 1(b). Hall teaches this requirement through its disclosure of a plurality of emitters that project beams at an operating wavelength of, *e.g.*, 905 nanometers. EX1004, 5:5-7, 8:52-54; EX1003, 75.

o) Limitation 23(c)

Hall and Borowski teach limitation 23(c). Section X.A.4(c).

p) Limitation 23(d)

Hall teaches limitation 23(d). Section X.A.4(d).

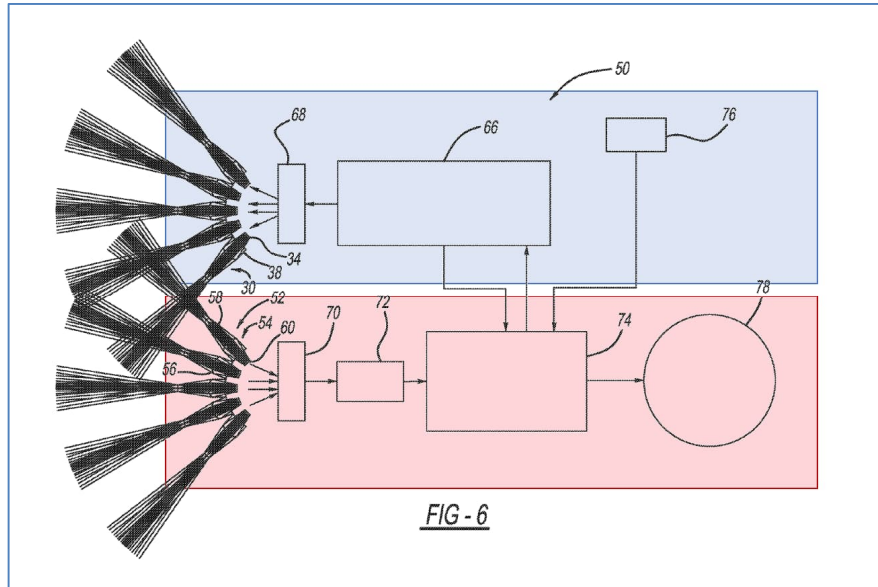
q) Limitation 23(e)

Hall teach limitation 23(e). Section X.A.4(e).

B. Ground 1B: Hall, Borowski, and Lipson Render Obvious Claims 2, 15, and 24

1. Lipson

Lipson describes a LiDAR sensor that uses a plurality of VCSEL arrays and SPAD detectors to achieve a wide field-of-view for autonomous vehicles. *Id.*, 1:15-26, 3:8-18, 7:12-15. A simplified view of the device is shown in Figure 6, with transmit section (blue) and receive section (red):



Id., Fig. 6.

The transmit section includes laser arrays 34 that emit beams into the target environment. *Id.*, 6:24-29. The receive section includes receiver elements 54, each having a receiving lens 56 that receives optical beams from the target and focuses the beams on a detector 60. *Id.*, 6:1-7. Lipson teaches that the emitter arrays may use VCSELs, while the detectors may use SPADs. *Id.*, 6:61-7:15. Lipson further teaches that “a narrow pass-band filter can be employed in front of the detector 60 to eliminate ambient light, such as from the sun, where the VCSEL array 34 has a unique wavelength...” *Id.*, 6:20-23.

2. Combined Teachings of Hall, Borowski, Lipson

A POSITA would have found it obvious to apply Lipson’s optical filter to the LiDAR device of Hall and Borowski. EX1003 ¶¶121-128.⁸

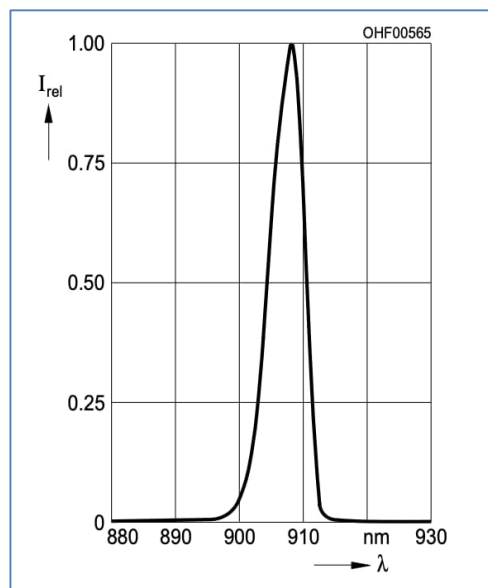
First, a POSITA would have been motivated to use Lipson’s bandpass filter to improve the signal-to-noise ratio (“SNR”) of the Hall-Borowski LiDAR system. EX1003 ¶123. A POSITA would have understood that unwanted light—such as background light from the sun—may enter a LiDAR device and cause interference or false detections. *Id.* Bandpass filters were a well-known design feature to block unwanted wavelengths, while allowing a desired wavelength band to pass through to the detectors, which improved SNR and detection accuracy. *Id.*

Second, a POSITA would have recognized that the teachings of Lipson are complementary to the Hall-Borowski device. *Id.* ¶124. Indeed, Hall teaches a “proprietary filter to reject sunlight,” but does not detail the exact arrangement of the filter. EX1004, 4:18-20. The bandpass filter of Lipson, placed in front of SPAD detectors, would fulfill the design goal with a predictable design feature known to improve SNR. EX1006, 6:20-23, 6:61-7:15.

⁸ Lipson is analogous art because it is in the same field of endeavor as the ‘236 Patent—optical systems for distance measurement—and pertinent to the problem of improving detection capability in such systems. EX1003 ¶122; EX1006, 1:15-26, 3:8-18, 7:12-15.

Third, a POSITA also would have been motivated to position the bandpass filter between the SPAD array and bulk receiving optic to ensure maximum filtering of unwanted light. *Id.* ¶125. This common design choice is reflected in Albert, which teaches a filter layer formed on the surface of a receiver comprising an array of SPAD detectors such that it is positioned between the array and a bulk lens. EX1009, [0138]-[0139], [0146], Fig. 8. A POSITA would have been motivated to use this known design technique to easily and cost-effectively integrate the optical filter of Lipson into pixel array of Hall and Borowski. EX1003 ¶125.

Fourth, a POSITA would have been motivated to select a narrowband filter centered on the operating wavelength of the emitters (*e.g.*, 905 nm). *Id.* ¶¶126-127. The wavelength profile for a typical emitter has a peak emission at the operating wavelength and tapering intensity at values above and below:



Id.; EX1026.

A narrowband filter centered on the operating wavelength provided a margin of error for slightly off-peak emissions while still blocking non-desired bands. EX1003 ¶127. For this reason, designers selected narrowband filters centered on the operating wavelength of the system's emitters. *Id.*; EX1027 at [0017]-[0019]; EX1028, 7:37-41.

Finally, a POSITA would have had a reasonable expectation of success combining the teachings of Hall, Borowski, and Lipson, because the use and implementation of optical filters in LiDAR devices was widely known and routine before the priority date. EX1003 ¶128. For example, Albert teaches vapor deposition of an optical filter over a SPAD array, and Retterath teaches integration of an optical filter into the layers of a semiconductor substrate. EX1009, [0146]; EX1030, 12:57-66. Using these known techniques, a POSITA would have had a reasonable expectation of success implementing a narrow-band filter in a known LiDAR device.

3. Application to the Claims

a) Claims 2 and 15

Hall, Borowski, and Lipson teach claims 2 and 15. EX1003, 81-82. Lipson teaches an optical filter positioned in front of each pixel to allow a narrow set of wavelengths, including that of the emitters, to pass through while blocking non-desirable wavelength bands. EX1006, 6:20-23. Applying this teaching to Hall and

Borowski, a POSITA would have positioned the filter between each SPAD pixel and the bulk imaging optic to ensure the pixels receive only a desired band of wavelengths. EX1003, 81-82.

b) Claim 24

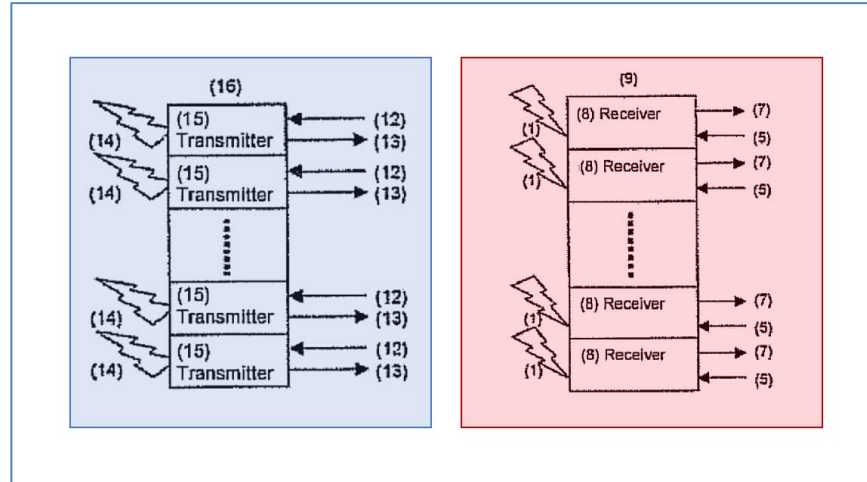
Hall, Borowski, and Lipson teach claim 24. EX1003, 82. Lipson teaches an optical bandpass filter positioned in front of SPAD pixels as discussed above for claim 2. EX1006, 6:20-23. Claim 24 requires the filter to be “disposed between the bulk *transmitting* optic and the plurality of pixels.” This language conflicts with the specification and drawings of the ‘236 Patent, which show the filter placed between the *receiving* optic and pixels. EX1001, Fig. 1. In either case, Lipson renders the claim requirement obvious because the filter is “employed in front of the detector 60” in an optical path between the pixels and the bulk optics. EX1006, 6:20-23. A POSITA would have been motivated to use the same placement in Hall and Borowski, and to select a bandpass filter centered on the peak wavelength of Hall’s emitters as detailed in Section X.B.2.

C. Ground 1C: Hall, Borowski, and Hipp Render Obvious Claims 8 and 25

1. Hipp

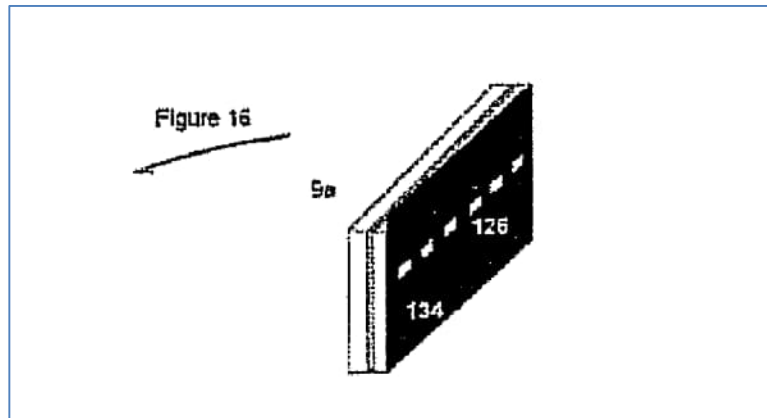
Hipp teaches a laser scanning device that uses pulsed time-of-flight to take distance measurements. EX1007, 1:27-37. The goal of Hipp is to improve the speed of taking distance measurements over existing 2D and 3D devices. *Id.*, 4:27-33. The

device includes a transmit section with an array of laser diodes and a receive section with an array of APDs:



Id., Figs. 3, 6, 11:63-65, 12:16-22.

Hipp recognizes that a problem associated with densely packed emitter and detector arrays is signal interference. *Id.*, 21:46-56. To address that concern, Hipp teaches a “shadow mask ... designed such that only that light is transmitted which would also be incident on the active zones of the APDs.” *Id.*, 21:57-67. The shadow mask 134 is shown in Figure 16, and includes small holes that allow light to pass through to an intended detector:



Id., Fig. 16.

Hipp teaches that the shadow mask “is attached directly to the APD array,” and “[t]he remaining light can be avoided in that the shadow mask is mirror coated superficially, with it thus being achieved that the unwanted light does not enter into the region of the active zones at all or in that the shadow mask is printed onto the cover plate of the APD array or onto an APD with impermeable material.” *Id.*, 21:60-67. Hipp also recognizes that “some of the light which passes through the holes of the shadow mask could be reflected by the APD” and “backscattered” in a manner that causes interference with other APDs. *Id.*, 22:1-7. To prevent this, Hipp uses light-absorptive material on the underside of the shadow mask. *Id.*, 22:7-10.

2. Combined Teachings of Hall, Borowski, Hipp

A POSITA would have found it obvious to apply Hipp’s shadow mask to the combined system of Hall and Borowski. EX1003 ¶¶131-135.⁹

⁹ Hipp is analogous art because it is in the same field of endeavor as the ‘236 Patent—optical systems for distance measurement—and pertinent to the problem of

First, a POSITA would have had an express motivation to use Hipp’s shadow mask to improve SNR. EX1003 ¶133. Signal interference was a well-known concern for multi-beam LiDAR devices, and Hipp’s shadow mask was designed specifically to address it. EX1007, 21:46-56. The shadow mask is designed to avoid interference such that “the unwanted light does not enter into the region of the active zones at all...” *Id.*, 21:57-67. Hall and Borowski would be susceptible to the same type of interference and therefore benefit from Hipp’s known shadow mask.

Second, Hipp’s shadow mask would complement the Hall-Borowski device. EX1003 ¶134. Hall relies on an array of pixels, while Hipp teaches a shadow mask designed to improve detection efficiency for multi-pixel sensors. EX1004, Fig. 22; EX1007, 21:46-67. In the same respect, Borowski aims to improve detection efficiency in a SPAD array that would benefit from blocking interference as taught by Hipp. EX1005, [0022].

Third, a POSITA would have had a reasonable expectation of success when combining the teachings of Hall, Borowski, and Hipp. EX1003 ¶135. Hipp teaches that the shadow mask can be attached to the detector array, with apertures in the mask aligned with individual detectors. EX1007, 21:60-67, Fig. 16. Similar designs

improving detection capability in such systems. EX1003 ¶132; EX1007, 1:27-37, 4:27-33.

were well-known in the art. EX1010, 4:65-5:18; Fig. 3. A POSITA would have predictably used these known techniques to implement the shadow mask of Hipp in a known LiDAR device like Hall.

3. Application to the Claims

a) Claims 8 and 25

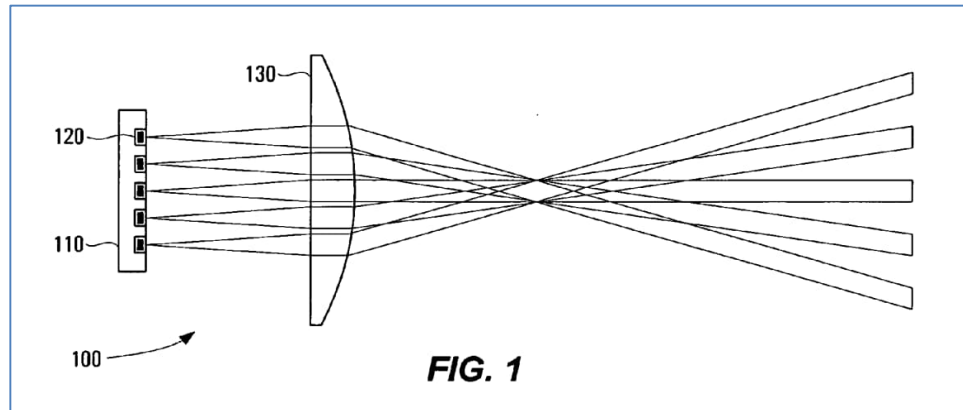
Hall, Borowski, and Hipp teach claims 8 and 25. EX1003, 85-86. Hipp teaches a shadow mask comprising a plurality of apertures formed over pixels in a detector array, and a stop region formed between the apertures to block undesired light from entering the pixels and thereby define a field-of-view for each pixel. EX1007, 21:57-67, Fig. 16. When the teachings of Hipp are applied to Hall and Borowski, the resulting structure would include a plurality of pixels, each having a SPAD array, aperture, and stop region, with the offset arrangement disclosed in Hall. EX1003, 85-86. The first set of pixels would include a first pixel disposed in a first optical path that extends through the first aperture, and the second set of pixels would include a second pixel disposed in a second optical path that extends through the second aperture. *Id.*

D. Ground 1D: Hall, Borowski, and Tan Render Obvious Claims 26 and 27

1. Tan

Tan discloses vehicle-based lidar systems that use multiple lasers to provide more compact and cost-effective lidar functionality. EX1008, Abstract. The system

includes a semiconductor laser array 110 and optics 130 to focus light into the external environment. *Id.*, 3:1-11. The system also includes a plurality of detectors placed in proximity to the laser array 110 to collect light reflected off objects in the field:



Id., Fig. 1, 3:22-28.

A key design aspect of Tan’s LiDAR device is the use of VCSEL emitters. *Id.*, 4:51-56. Tan explains that “vertical cavity surface-emitting lasers (VCSELs) are particularly useful for the disclosed lidar applications because they have a small angular divergence and emit light normal to the surface of the wafer in which they are fabricated.” *Id.* Tan goes on to describe various benefits associated with VCSEL emitters, including tight spacing, high-speed activation, improved alignment, and ease of manufacturing. *Id.*, 4:51-5:21.

2. Combined Teachings of Hall, Borowski, Tan

A POSITA would have found it obvious to apply Tan’s VCSEL emitter teaching to the LiDAR device of Hall and Borowski. EX1003 ¶¶137-143.¹⁰

First, Tan details numerous known benefits for the use of VCSEL emitters in LiDAR devices:

- “VCSELs[] are particularly useful for the disclosed lidar applications because they have a small angular divergence”
- “VCSELs ... allow for fabrication of integrated one-dimensional or two-dimensional laser arrays with close device spacing....”
- VCSELs “emit circularly symmetric Gaussian beams, as compared to highly eccentric elliptical beams of edge emitting lasers.”
- “VCSELs can be fabricated with relatively small active areas [and] activated quickly....”
- VCSELs provide “simpler lidar device manufacturing and reduction in overall device complexity and cost.”

Id., 4:51-5:21.

¹⁰ Tan is analogous art because it is in the same field of endeavor as the ‘236 Patent—optical systems for distance measurement—and pertinent to the problem of improving performances and reducing costs in such systems. EX1003 ¶138; EX1008, Abstract, 1:25-62, 1:65-2:8, 3:1-35, 4:51-56.

These benefits were known more than a decade before the earliest priority date of the '236 Patent. EX1003 ¶¶139-140. A POSITA would have understood that the benefits are directly applicable to a LiDAR device like Hall-Borowski—a point Tan makes throughout its disclosure. EX1008, 4:51-56, 5:12-15, 5:19-21.

Second, Tan's VCSEL array would further improve the operation of Hall and Borowski. EX1003 ¶141. As noted above, Hall describes an early LiDAR device for autonomous vehicles that employed traditional laser diodes. Incorporating the VCSEL emitters disclosed in Tan would allow Hall to maintain the same principle of operation, but with improved laser output that is faster and more accurate. The VCSELs of Tan are also complementary to Borowski because they operate at example wavelengths of 1-1.5 μm —which Borowski identifies as desirable for eye safety. *Id.*; EX1008, 5:12-15; EX1005, [0003].

Third, a POSITA would have understood that techniques for integrating VCSELs into a known LiDAR device were well-known and predictable. EX1003 ¶143. Tan teaches VCSELs fabricated in one-dimensional or two-dimensional arrays and integrated with optic elements in a single package. EX1008, 4:67-5:3, 5:16-19. Thus, integrating the VCSELs of Tan in place of Hall's traditional laser diodes would simplify the overall device by allowing the emitter arrays to be fabricated on a single printed circuit board rather than individual boards. This is

evident from Tan and other prior art references that identify VCSEL among the class of emitters suitable for automotive LiDAR. EX1008, 4:51-5:21, EX1040, 4:55-62.

3. Application to the Claims

a) Claim 26

Hall, Borowski, and Tan teach claim 26. EX1003, 89. Hall discloses the use of laser diodes as an illumination source for the disclosed LiDAR system, but does not expressly disclose VCSELs. EX1004, 5:5-7. Tan teaches a vehicle LiDAR system “using multiple lasers to provide more compact and cost-effective lidar functionality.” EX1008, Abstract. To achieve that goal, Tan uses VCSEL emitters. *Id.*, 4:51-56. In the combined structure, the VCSELs of Tan would be predictably used in place of the laser diodes of Hall to improve device performance and cost. EX1003, 89.

b) Claim 27

Hall, Borowski, and Tan teach claim 27. EX1003, 90. Hall teaches time-of-flight techniques to measure distances between the device and objects in the external environment. EX1004, 1:11-18; 4:9-11; 4:47-49.

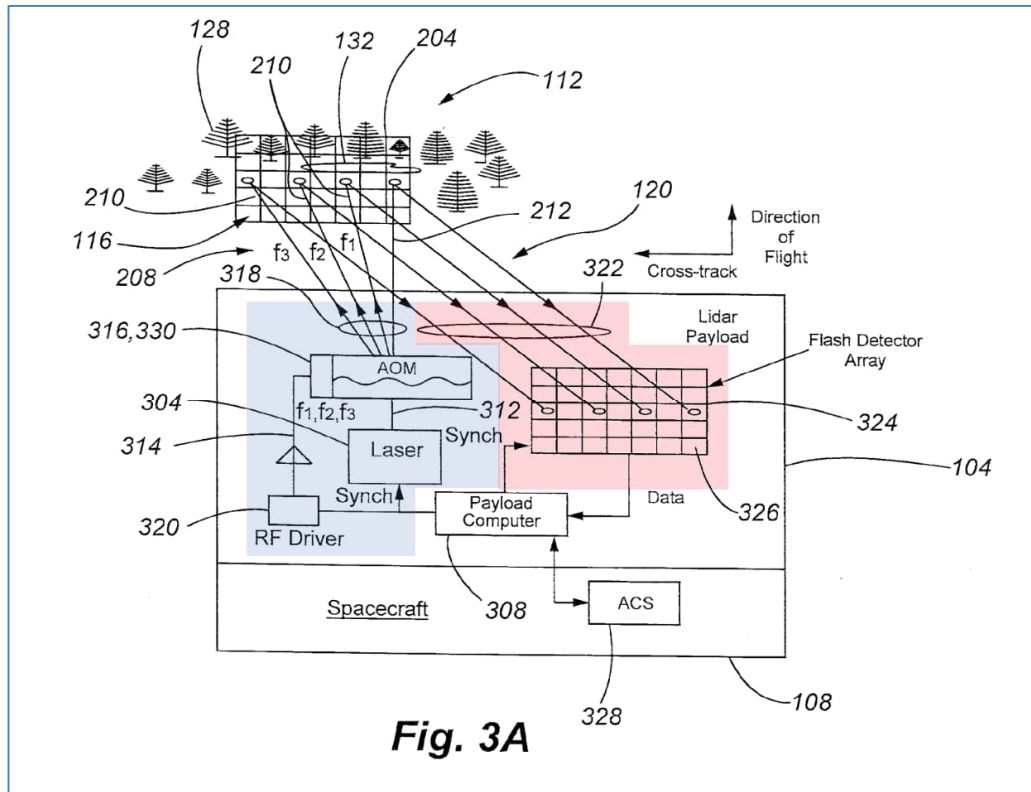
E. Ground 1E: Hall, Borowski, and Weimer Render Obvious Claims 11-13, 16-17, and 22

1. Weimer

Weimer is directed to vehicle-based LiDAR devices. EX1029, Figs. 1A-D, 4:4-6. Weimer notes that a particular challenge in such devices is their ability to

illuminate large scenes at long distances. *Id.*, 1:36-46. In this regard, Weimer explains that: “Large fields of view per detector are not desirable because a wide field-of-view results in the acceptance of more background light than a narrower field-of-view, reducing the signal to noise ratio.” *Id.*, 1:53-56. Thus, “the goal for good daytime performance has been to have the laser spot size only slightly smaller than the receivers instantaneous field-of-view.” *Id.*, 1:56-59. To achieve that goal, Weimer teaches controlling the emission pattern of individual laser beams to match the field-of-view of a corresponding detector. *Id.*, 4:56-58.

The embodiment shown in Figure 3A includes a transmit section with a multi-beam laser output 208 passed through a bulk optic 318, and a receiver section with a multi-pixel detector array 324 and a bulk optic 322:



Id., Fig. 3A, 10:17-45.

Weimer explains that the illumination source may include a VCSEL array, and that “individual beams 208 can be directed to cover an area corresponding to a single pixel of the detector,” as shown above. *Id.*, 4:56-58, 9:32, 11:39-41.

2. Combined Teachings of Hall, Borowski, Weimer

A POSITA would have found it obvious to apply Weimer’s alignment teaching to the LiDAR system of Hall and Borowski. EX1003 ¶¶146-150.¹¹

¹¹ Weimer is analogous art because it is in the same field of endeavor as the ‘236 Patent—optical systems for distance measurement—and pertinent to the problem of improving the performance in such systems. EX1003 ¶147; EX1029, 15:49-60, 1:53-61, 4:56-58.

First, a POSITA would have had an express motivation to use Weimer's disclosed technique. EX1003 ¶148. As Weimer explains: "Large fields of view per detector are not desirable because a wide field-of-view results in the acceptance of more background light than a narrower field-of-view, reducing the signal to noise ratio." EX1029, 1:53-56. By controlling the emission pattern of individual laser beams to match the field-of-view of a corresponding pixel, Weimer avoids background light and improves SNR. *Id.*, 1:56-61, 4:56-58. The design would offer a significant benefit to the Hall-Borowski device, by allowing it to achieve a high-resolution point cloud with reduced interference. *Id.*

Second, a POSITA would have recognized that Weimer is complementary to the Hall-Borowski device. EX1003 ¶¶149, 37-40. Hall teaches a pixel array with an angular separation of $1/3^\circ$ to achieve high resolution in a LiDAR device. EX1004, 8:14-17. Weimer teaches techniques to improve SNR in a pixel array, by matching the field-of-view of each pixel to the emission region of a corresponding illumination beam. EX1029, 1:53-61, 4:56-58.

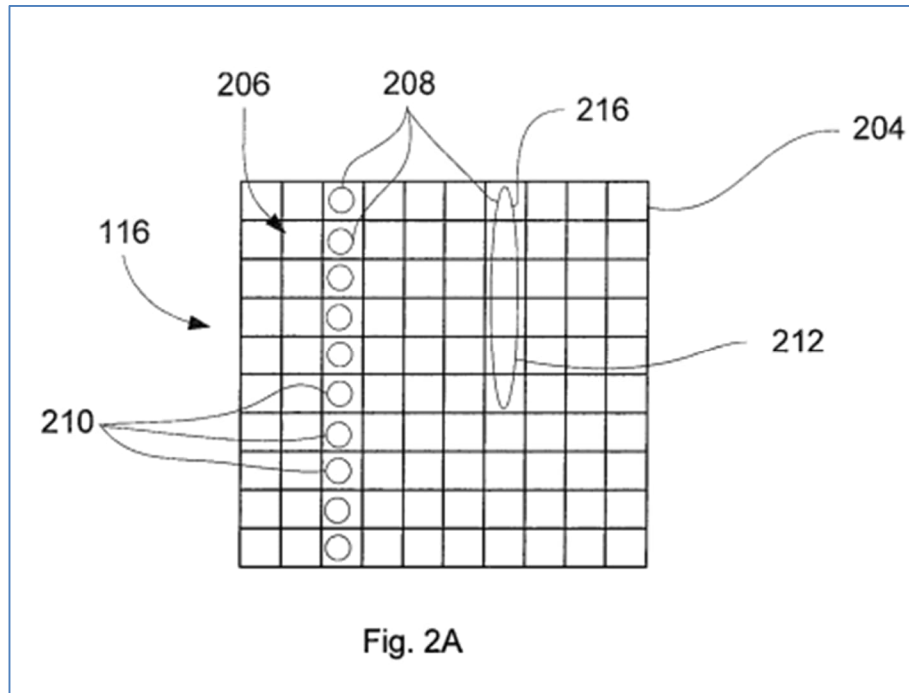
Third, a POSITA would have had a reasonable expectation of success when combining the teachings of Hall, Borowski, and Weimer. EX1003 ¶¶150, 37-40. Techniques to define the emission region of a laser and match it to the field-of-view of a corresponding pixel were well known in the art. *Id.* For example, Hipp teaches the use of a shadow mask with apertures to define the field-of-view for a

corresponding pixel, which could be sized and shaped to the emission pattern of a given emitter. EX1007, 21:57-67. And Retterath teaches the use of collimating lenses, directional lenses, and angular waveguides to match the pattern and direction of an emitter with the field-of-view for a corresponding detector. EX1030, Figs 4-10, 8:36-50, 9:29-10:22. A POSITA would have had a reasonable expectation of success using these known techniques to implement the teachings of Weimer in a LiDAR device like Hall. EX1003 ¶150.

3. Application to the Claims

a) Claim 11

Hall, Borowski, and Weimer teach claim 11. EX1003, 92-94. Hall teaches that each pixel has a non-overlapping field-of-view with all other pixels, defined by an angular separation of $1/3^\circ$, but does not expressly state that the field-of-view for each pixel is coincident with the emission beam of a corresponding emitter. EX1004, 8:15-17. Weimer teaches an optical system comprising an illumination source 304 that projects a plurality of beams 208 into the field ahead. EX1029, Fig. 3A. Each beam has a discrete, non-overlapping emission region as shown in Figure 2A:



Id., Fig. 2A.

Weimer further teaches a pixel array 324, where each pixel 326 has a field-of-view that matches a corresponding beam 208 from the illumination source 304. *Id.*, Fig. 3A, 10:17-45. In this regard, Weimer teaches a “laser spot size only slightly smaller than the receivers instantaneous field-of-view” such that “individual beams 208 can be directed to cover an area corresponding to a single pixel of the detector.” *Id.*, 1:56-59, 4:56-58. Thus, each pixel field-of-view is coincident with the emission region of a corresponding illumination beam. *Id.* And the field-of-view for each pixel is non-overlapping with the fields-of-view for all other pixels. *Id.*; EX1003, 92-94.

When combined, the Hall-Borowski-Weimer device would include a plurality of pixels, each with a non-overlapping field-of-view and coincident alignment with a corresponding illumination beam. *Id.*

b) Claim 12

Hall, Borowski, and Weimer teach claim 12. Hall teaches a scan cycle that includes a plurality of sampling periods as discussed in Section X.A.4(e). Hall explains that each cycle includes 300,000 measurements; thus each sampling period involves firing each emitter in the plurality of emitters. EX1003, 94-95; EX1004, 5:40-42. Borowski likewise teaches a scan cycle comprising sampling periods at specific angular orientations, during which emitters in the device are fired and return pulses are measured by multi-SPAD pixels. EX1005, [0051]-[0053], [0102]-[0106]. Borowski explains that each SPAD cell in a multi-SPAD pixel is measured and the outputs are added together to determine both an average value and intensity for the pixel. *Id.*

When combined, the Hall-Borowski-Weimer device would operate such that, for a given sampling period, each emitter is activated and the number of SPADs in each pixel that record an incident photon since the last period are determined. EX1003, 94-95.

c) Claim 13

Hall, Borowski, and Weimer teach claim 13. EX1003, 95. Hall and Borowski teach time-of-flight distance measurements for each sampling period within a cycle, where each measurement is based on a difference between the laser firing time and the pixel detection time. EX1004, 1:11-18, 4:9-11; EX1005, [0051]-[0053], [0102]-[0106]. Weimer teaches that each pixel has a field-of-view that overlaps with a field-of-view of the fired optical emitter. EX1029, 1:56-59, 4:56-58, Fig. 3A.

d) Limitation 16(a)

Hall teaches limitation 16(a). Section X.A.4(a).

e) Limitation 16(b)

Hall, Borowski, and Weimer teach limitation 16(b) as discussed with respect to limitation 1(c) and claim 11. Section X.A.4(c), X.E.3(a).

f) Limitation 16(c)

Hall, Borowski, and Weimer teach limitation 16(c) as discussed with respect to limitation 1(b) and claim 11. *See* X.A.4(b), X.E.3(a). Weimer further teaches that the illuminating beams produce an illumination pattern that substantially matches, in size and geometry, across a range of distances, the fields of view of the plurality of pixels. EX1003, 96-97. The geometry of the beam pattern matches that of the pixels. EX1029, Fig. 3A, 10:17-45. The beam spot size is “only slightly smaller than the receiver’s instantaneous field-of-view” such that “individual beams 208 can

be directed to cover an area corresponding to a single pixel of the detector.” *Id.*, 1:56-59, 4:56-58. And the range of distances includes the distances of a target scene. *Id.*, Fig. 3A, 15:49-60.

g) Limitation 16(d)

Hall teaches limitation 16(d). Section X.A.4(d).

h) Claim 17

Hall, Borowski, and Weimer teach claim 16, and Hall teaches the additional limitation of claim 17 as discussed above with respect to limitation 1(e) and claim 9. Section X.A.4(e), (g).

i) Claim 22

Hall, Borowski, and Weimer teach claim 16, and Hall teaches the additional limitation of claim 22 as discussed above with respect to claim 7. Section X.A.4(f).

F. Ground 1F: Hall, Borowski, Hipp, and Weimer Render Obvious Claims 14 and 19-21

1. Combined Teachings of Hall, Borowski, Hipp, Weimer

A POSITA would have found it obvious to combine the teachings of Hall, Borowski, Hipp, and Weimer as discussed in Sections X.A.3, X.C.2, and X.E.2. A POSITA also would have found Weimer and Hipp highly compatible because Weimer teaches the benefit of a narrow field-of-view for pixels in an array, and Hipp teaches a shadow mask to define a narrow field-of-view and reduce cross-talk interference. EX1029, 1:51-61, EX1007, 21:57-67; EX1003 ¶¶157-158.

2. Application to the Claims

a) Claim 14

Hall and Borowski render obvious claim 10 as discussed in Ground 1A. Section X.A.4(h)-(l). Hipp teaches a shadow mask that defines a plurality of apertures. Section X.C.1. Weimer teaches a pixel array, where each pixel has a field-of-view coincident with the emission region of a corresponding beam. Section X.E.1.

When the teachings of the references are combined, the input circuit in Hall's LiDAR device would include a plurality of pixels, each comprising a SPAD array and dedicated aperture to define a field-of-view coincident with a corresponding beam emission, and a stop region between adjacent apertures to block stray light. EX1003, 100-101. The position of each aperture would correspond to Hall's offset pixel layout, with first, second, third, and fourth pixels and apertures meeting the requirements of limitation 14(b). *Id.*; EX1004, Fig. 22.

b) Claims 19, 20, and 21

Hall, Borowski, and Weimer render obvious claim 16 as discussed above. Section X.E.3(d)-(g). Hipp teaches a shadow mask that defines a plurality of apertures. Section X.C.1. When the teachings of the references are combined, the

resulting device would meet the requirements of claims 19, 20, and 21 as discussed with respect to claim 14. Section X.F.2(a), EX1003, 101-104.¹²

G. Ground 1G: Hall, Borowski, Weimer, and Lipson Render Obvious Claim 18

1. Combined Teachings of Hall, Borowski, Weimer, Lipson

A POSITA would have found it obvious to combine the teachings of Hall, Borowski, Weimer, and Lipson as discussed in Sections X.A.3, X.B.2, and X.E.2.

2. Application to the Claims

a) Claim 18

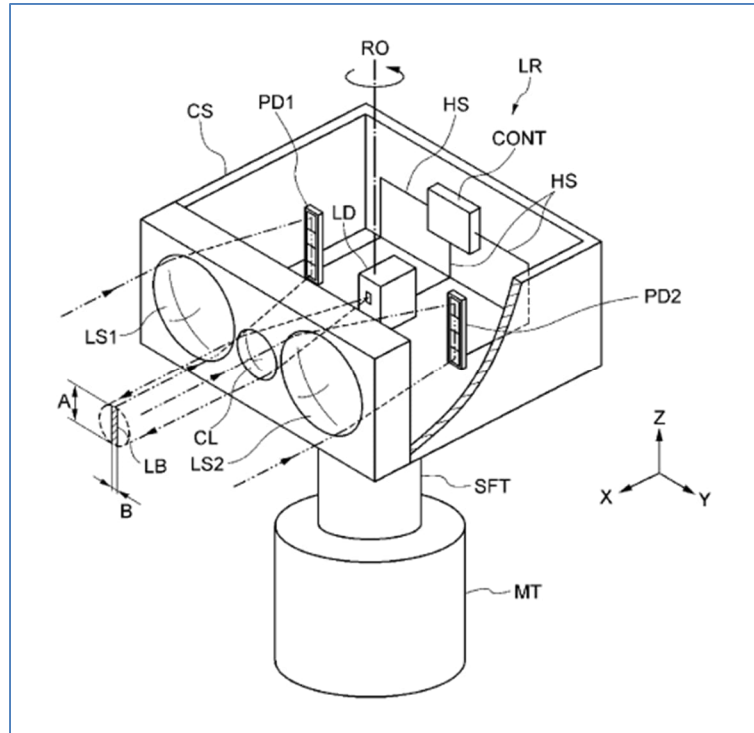
Hall, Borowski, and Weimer render obvious claim 16 as discussed above. Section X.E.3(d)-(g). Lipson teaches a narrowband filter as discussed in Section X.B.1. When the teachings of the references are combined, the resulting device would meet the requirements of claim 18. EX1003, 104-105.

H. Ground 2A: Matsui and Imai Render Obvious Claims 1, 7, 9-13, 16-17, 22-23, 26-27

1. Matsui

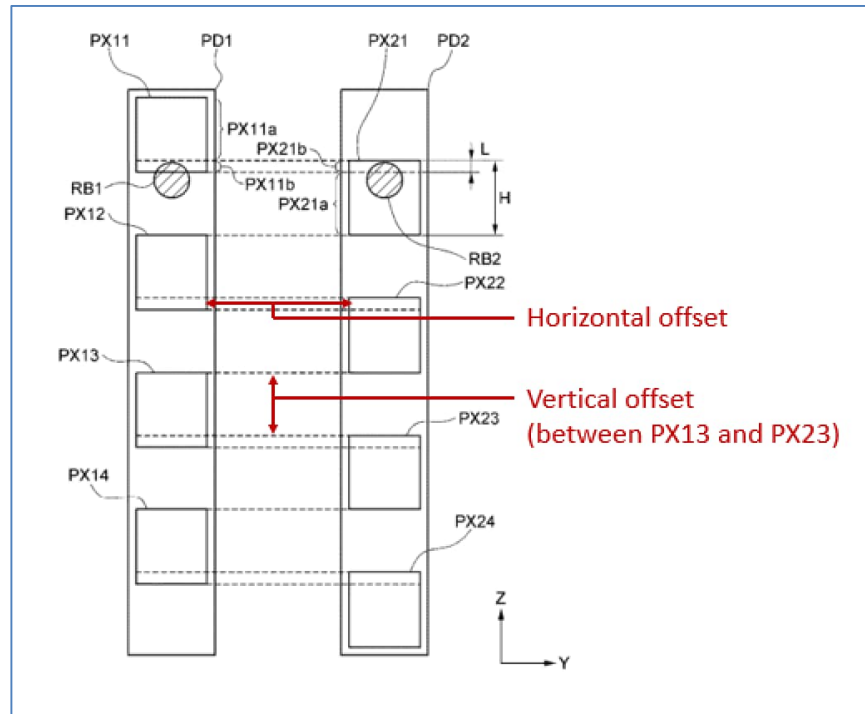
Matsui discloses a laser radar (LR) that includes a casing (CS) mounted on the rotary shaft (SFT) of a motor (MT):

¹² Claim 19 contains an error referring to the “the first aperture [] disposed in a second optical path....” Hall, Borowski, Weimer, and Hipp teach the same structure disclosed in the specification, where a second aperture is disposed in a second optical path. EX1001, Fig. 1.



EX1031, Fig. 2; EX1032, Fig. 2.

The casing includes a semiconductor laser (LD) that emits pulsed laser light through a collimating lens (CL). EX1031, [0016]; EX1032, [0016]-[0017]. The casing also includes first and second light-receiving parts (PD1, PD2) arranged as columns behind lenses (LS1, LS2). EX1031, [0019], [0036]; EX1032, [0019], [0036]. Matsui teaches that the light-receiving parts can be arranged in columns of pixels (PX11, PX12, etc.), with pixels in the first column (PD1) horizontally and vertically offset from pixels in the second column (PD2):



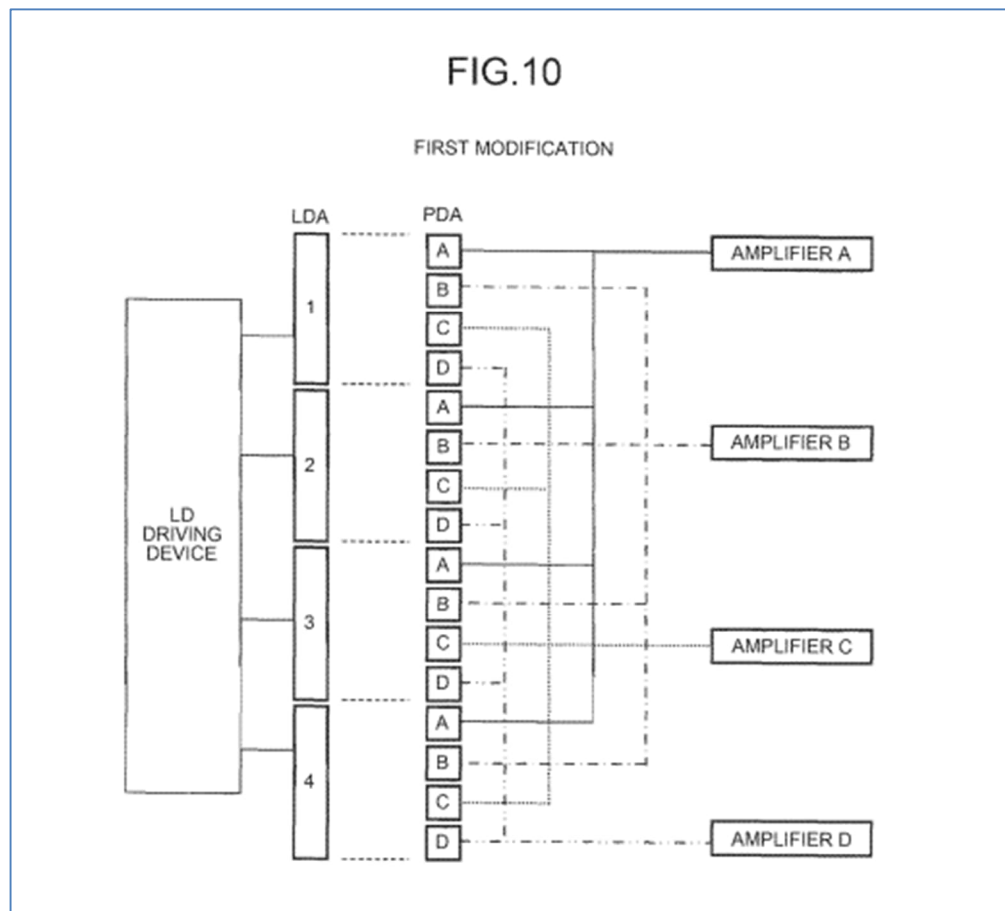
EX1031, Fig. 14; EX1032, Fig. 14.

Matsui explains that the offset pixels “achieve high resolution and reduce detection failure” by eliminating “non-detection regions” of the device. EX1031, [0029]-[0030]; EX1032, [0010]-[0013].

2. Imai

Imai discloses a laser radar for measuring the distance to objects in the field. EX1033, 2:42-48, Fig. 1. The system includes a laser diode array (LDA) with a plurality of laser diode (LDs), each of which may include a VCSEL. *Id.*, 2:48-55, 3:5-12, 14:44-54. The system also includes a photodiode array (PDA) with a plurality of photodiodes (PDs), each of which may include a SPAD *Id.*, 6:24-28, 5:1-8. Imai describes different arrangements for the LDA and PDA. *Id.*, Figs. 7-11.

In Figure 7, for example, sixteen PDs detect light emitted from a single LD. *Id.*, 7:10-20. Imai explains that using a single LD in this example is non-ideal because “the light quantity per one PD is small ... so that detection distance is forced to be shorter.” *Id.* To overcome that concern, the embodiment of Figure 10 includes four LDs (LD1-4), each of which corresponds to four PDs (PD1-16):



Id., Fig. 10, 10:17-20.

In this embodiment, “it is possible to efficiently irradiate the light receivable range, so that a light reception quantity in the light receivable range may be increased and detection accuracy and a detection distance may be improved.” *Id.*, 10:23-26.

3. Combined Teachings of Matsui and Imai

Matsui teaches the structure of a rotating laser-radar device with a laser diode and plurality of pixels. EX1031, Figs. 2, 14; EX1032, Figs. 2, 14. Imai teaches the benefit of using multiple lasers as opposed to a single laser, in order to improve detection distance and accuracy. EX1033, 7:10-20, 10:23-26. Imai also teaches the benefit of using VCSELs and SPADs, both of which were known to improve detection capability. *Id.*, 5:6-8; EX1003 ¶¶41-51, 156-175. A POSITA would have been motivated to apply these teachings to Matsui to achieve the same benefits. *Id.*

In the combined device, the transmission section of Matsui would use multiple VCSEL emitters (*e.g.*, four) as disclosed in Imai. *Id.* ¶166. This would allow the device to improve detection distance and accuracy as taught in Imai, without overly compromising cost (a goal of Matsui). *Id.* Furthermore, each pixel in Matsui would be implemented with a plurality of SPADs (*e.g.*, four) as disclosed in Imai, which would further the goal of improved detection accuracy. *Id.* A POSITA would have been motivated to pursue the combined device, with a reasonable expectation of success.¹³

¹³ Matsui and Imai are analogous art because they are in the same field of endeavor as the '236 Patent—optical systems for distance measurement—and pertinent to the problem of improving detection capability in such systems. EX1003 ¶167; EX1031, [0015]-[0016]; EX1032, [0015]-[0016]; EX1033, 2:48-55, 3:5-12, 14:44-54.

First, a POSITA would have been motivated to use Imai's plurality of lasers in place of Matsui's single laser. *Id.* ¶168. Imai teaches that the use of a single laser in combination with multiple detectors limits detection distance of the overall device due to low light reception at each detector. EX1033, 7:15-20, Fig. 7. To improve detection distance, Imai teaches increasing the number of lasers, with each laser corresponding to multiple SPADs. *Id.* Fig. 10, 10:17-26. A POSITA would have been motivated to apply that teaching to Matsui to improve its detection distance and broaden its utility to longer-range LiDAR applications. EX1031, [0002]; EX1032, [0002].

A POSITA also would have understood that the modification could be implemented in a manner that is not overly cost prohibitive. EX1003 ¶169. For example, Imai teaches going from one laser to four while maintaining the same number of SPADs, thus providing only a minor increase in cost. *Id.*, EX1033 Figs. 7, 10. In view of these teachings, a POSITA would have understood that the number of lasers could be selected and scaled to balance cost and performance of the device. EX1003 ¶169 Further benefits of using multiple lasers as taught in Imai would include improved system reliability and redundancy. *Id.*

Second, a POSITA would have been motivated to use VCSELs as disclosed in Imai to achieve the known benefits of reduced angular divergence, symmetric beam profiles, fast activation time, and improved integration that allows for simpler

device design and reduced manufacturing costs. *Id.* ¶170; EX1008, 4:51-5:21. These benefits were known to be applicable for laser-radar devices like Matsui, and they would have furthered Matsui’s goal of providing accurate detection for automotive and robotics applications, while ensuring low cost and complexity. EX1033, [0002], [0016]; EX1003 ¶170.

Third, a POSITA would have been motivated to implement each of Matsui’s pixels using multiple SPADs as taught in Imai. *Id.* ¶171. As detailed in Section X.A.3, a known benefit of SPADs was excellent detection sensitivity. *Id.* ¶¶45-51, 107-115; EX1018, 8; EX1017, 4. The ability to detect individual photons with high sensitivity was beneficial to laser-radar devices like Matsui designed for autonomous-vehicle applications. EX1003 ¶171. Indeed, Imai teaches that SPADs provide for “higher sensitivity” and “are advantageous in detection accuracy and detection distance.” EX1033, 5:1-8.

Fourth, using multiple SPADs for each pixel in Matsui would take advantage of the SPADs’ ability to be grouped into an array or macro-cell. EX1018, 8; EX1009 [0049]-[0050], [0138]-[0139]; EX1003 ¶¶45-51, 107-115, 172. Each individual SPAD will have a dead time during which it is quenched and reset. *Id.* Thus, by grouping multiple SPADs together, the pixel can continue to register detections, even if one or more SPADs is subject to dead time. *Id.* Matsui would benefit from

this known design technique, which would ensure that its pixels remain active during the entire detection interval. *Id.*

Fifth, other known benefits of multi-SPAD pixels were fast detection speed and data output, compactness, low-power consumption, and ease of integration with circuitry. *Id.* ¶¶173-174; EX1010, 1:19-26, 1:42-52, 3:66-4:4; EX1005, [0022], [0053], [0190]-[0193]. These benefits would have further motivated a POSITA to use multi-SPAD pixels in Matsui's device.

Finally, a POSITA would have had a reasonable expectation of success when modifying Matsui to include multi-SPAD pixels and VCSEL emitters as disclosed in Imai. EX1003 ¶175. Imai teaches electronics and associated circuitry to process output of the SPADs and calculate time-of-flight measurements. EX1033, 5:9-42. A POSITA would have found it predictable to integrate these components into the device of Matsui, which is agnostic to the type of detection circuitry employed in the device. EX1003 ¶175, 111-115. As discussed in Sections X.A.3 and X.D.2, techniques for integrating SPAD arrays and VCSEL in laser-radar devices and processing their output were widely known before the priority date. *Id.*

4. Application to the Claims

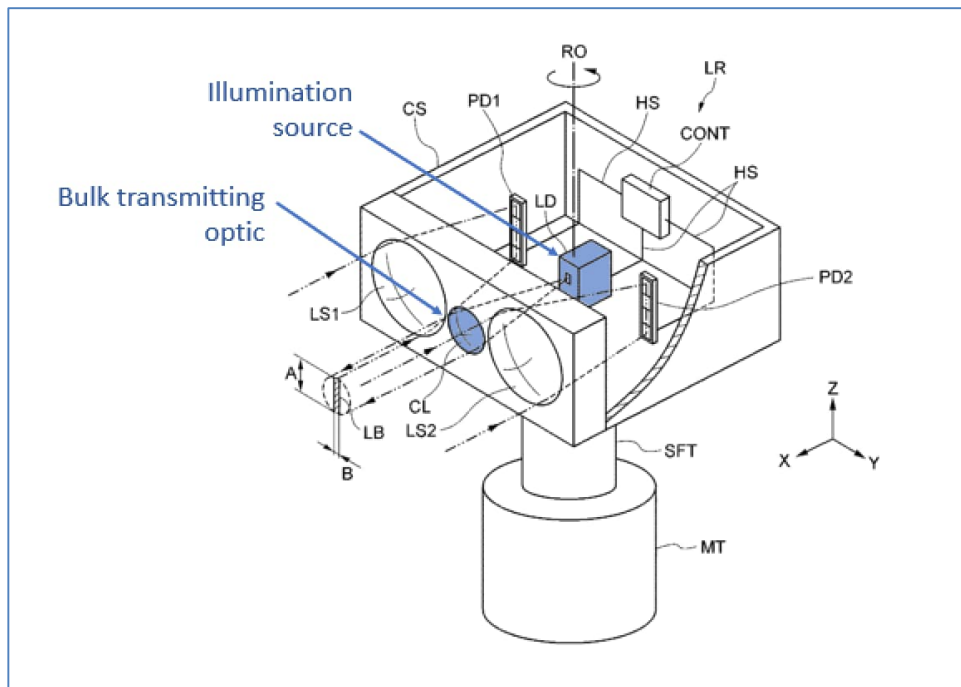
a) Limitation 1(a)

Matsui teaches limitation 1(a). EX1003, 110. Matsui teaches a laser-radar device that uses time-of-flight to measure the distance to objects in the surrounding

environment. EX1031, Abstract, [0001]-[0003]; EX1032, [0001]-[0003]. The system “measures the distance to the object based on the difference between the emission time of the semiconductor laser LD and the light reception time of the [light receiving parts].” EX1031, [0025]; EX1032, [0025].

b) Limitation 1(b)

Matsui and Imai teach limitation 1(b). EX1003, 111-112. The laser radar (LR) in Matsui includes an illumination source in the form of semiconductor laser (LD), which is arranged behind a collimating lens (CL) and configured to emit pulsed light through the lens into a field ahead of the device:



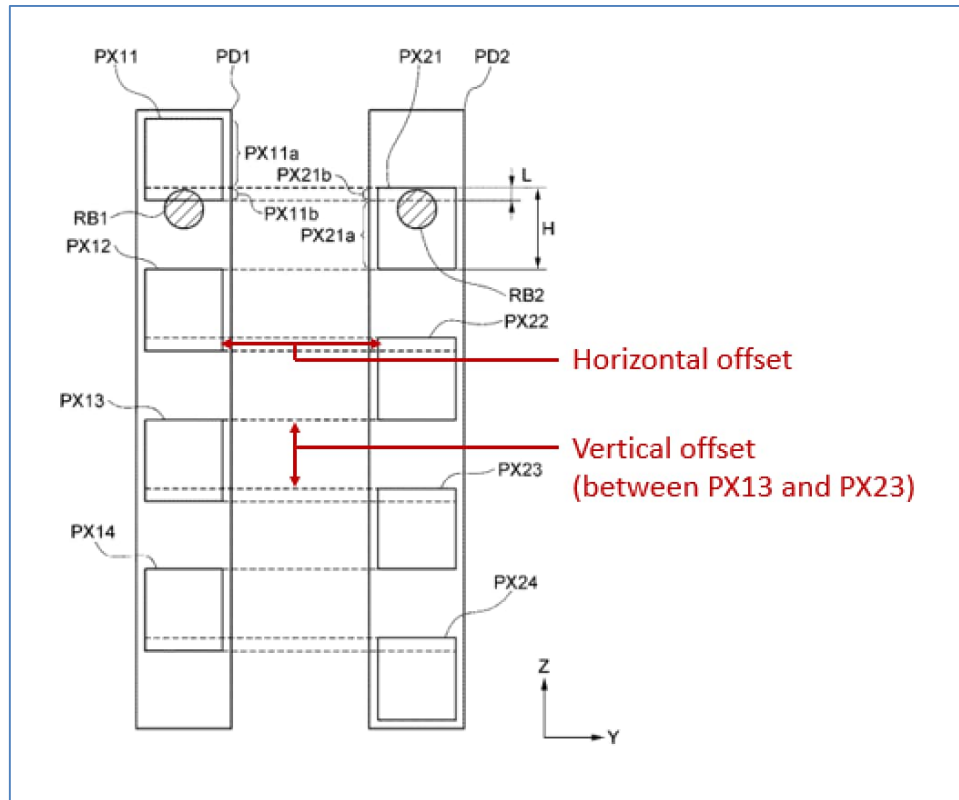
EX1031, Fig. 2, [0016]-[0017]; EX1032, Fig. 2, [0016]-[0017].

The collimating lens is a bulk transmitting optic because it collects light from an emission source and passes it to the surrounding environment, which is the same

configuration of the bulk transmitting optic in the '236 Patent. EX1003, 111-112. In the combined structure, the semiconductor laser (LD) is implemented using the laser-diode array (LDA) from Imai, which includes a plurality of VCSEL emitters configured to output light at a nominal or operating wavelength. *Id.*; EX1033, 6:11-20, 14:40-54. Alternatively, a POSITA would have found it obvious to select a known nominal wavelength for LiDAR applications, such as 905-nm or 1.5- μ m, both of which were known for low absorption and human-eye safety. EX1003, 112; EX1008, 5:12-15. Together, the collimating lens and laser-diode array are an optical imaging transmit module with the same structural elements as the '236 Patent. EX1003, 111-112.

c) Limitation 1(c)

Matsui and Imai teach limitation 1(c). EX1003, 112-113. The laser-radar device in Matsui includes lenses (LS1, LS2) which comprise a bulk receiving optic because they collect returned light from the surrounding environment and focus it onto a plurality of pixels in the same manner as the '236 Patent embodiments. *Id.*; EX1031, [0017]-[0019], Figs. 2-3; EX1032, [0017]-[0019], Figs. 2-3. As shown in Figure 14, for example, the plurality of pixels includes a first set of pixels (PX11, PX12, PX13, PX14) arranged in a first column (PD1) and a second set of pixels (PX21, PX22, PX23, PX24) arranged in a second column (PD2) horizontally and vertically offset from the first column:



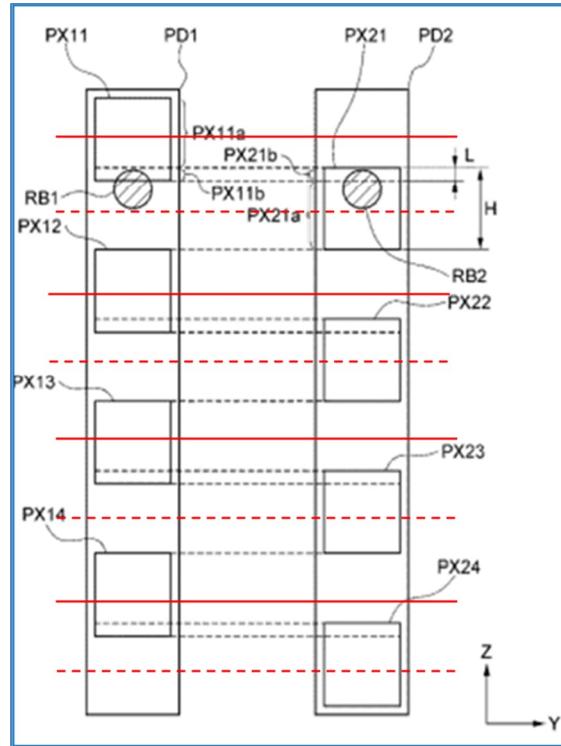
EX1031, Fig. 14, [0036]-[0038], [0045], Fig. 11; EX1032, Fig. 14, [0036]-[0038], [0045], Fig. 11.

In the combined structure, each pixel (PX11, PX12, etc.) is implemented using a plurality of SPADs as taught in Imai. EX1033, 6:24-28, 5:1-8; EX1003, 112-113. Together, the lenses (LS1, LS2) and plurality of multi-SPAD pixels comprise an optical imaging receive module with the same structural elements as the '236 Patent. *Id.*

d) Limitation 1(d)

Matsui teaches limitation 1(d). EX1003, 113-114. The laser radar includes an actuator in the form of motor (MT) operable to rotate casing (CS)—including the

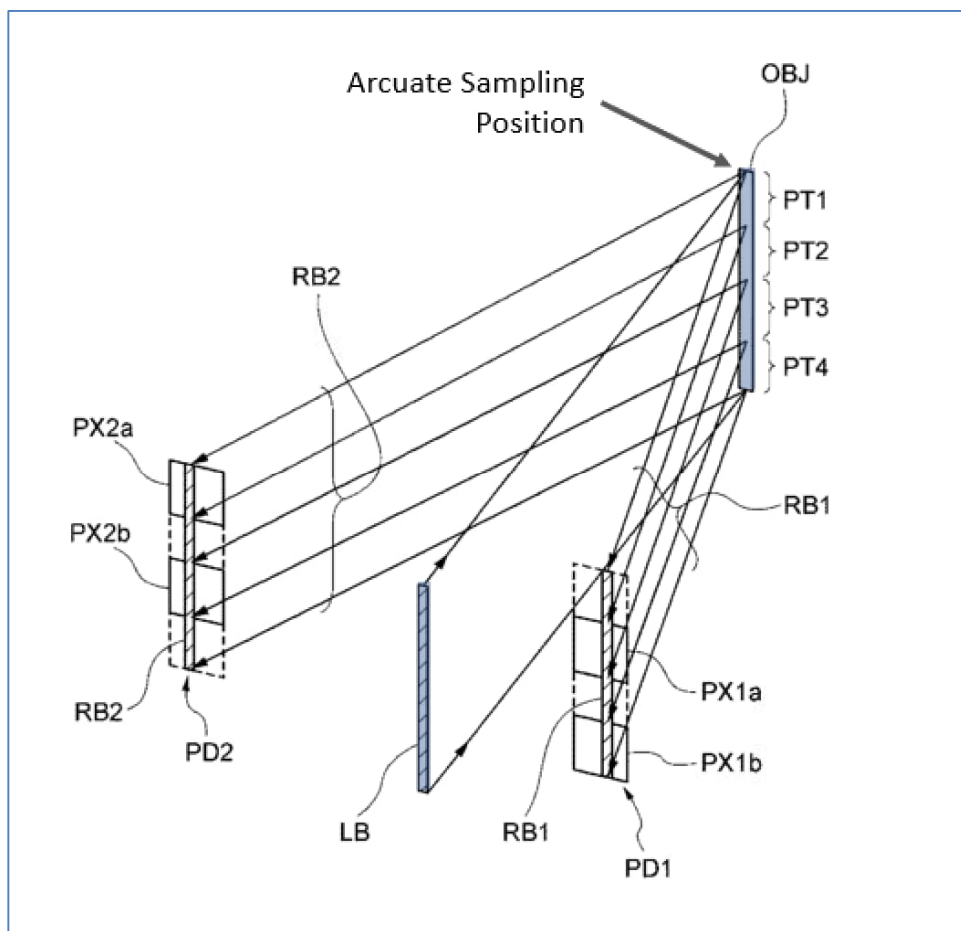
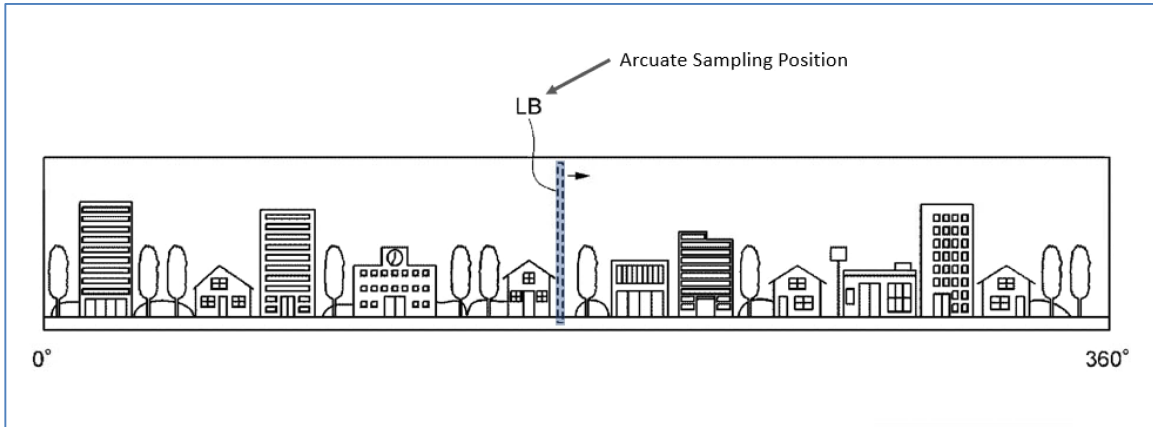
lenses (LS) and pixels (PX) of the optical imaging receive module—about a vertical axis of rotation (RO). EX1031, Fig. 2, [0016], [0024]; EX1032, Fig. 2, [0016], [0024]. The motor rotates the device through 360-degrees, which corresponds to a single scan cycle as shown in Figure 5. *Id.* (“Here, since the casing CS is rotated about the axis of rotation RO by the motor MT, the collimated light beam LB will be scanned horizontally 360 degrees in the external world where the object is present, in accordance with the rotation of the casing CS (see FIG. 5).”). As the device rotates, each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel. EX1003, 113-114. This is evident from the annotated Figure 14 below, which shows the unique path each pixel in the first (solid) and second (dashed) columns traverses in operation:



EX1031, Fig. 14, [0036]-[0038], [0045]; EX1032, Fig. 14, [0036]-[0038], [0045].

e) Limitation 1(e)

Matsui teaches limitation 1(e). EX1003, 114-115. The laser-radar device captures distance measurements at discrete locations using the collimated light beam (LB). EX1031, [0018]; EX1032, [0018]. As shown in Figures 5 and 6, each location of an object that the light beam (LB) illuminates corresponds to an arcuate sampling position within a 360-degree scan cycle:

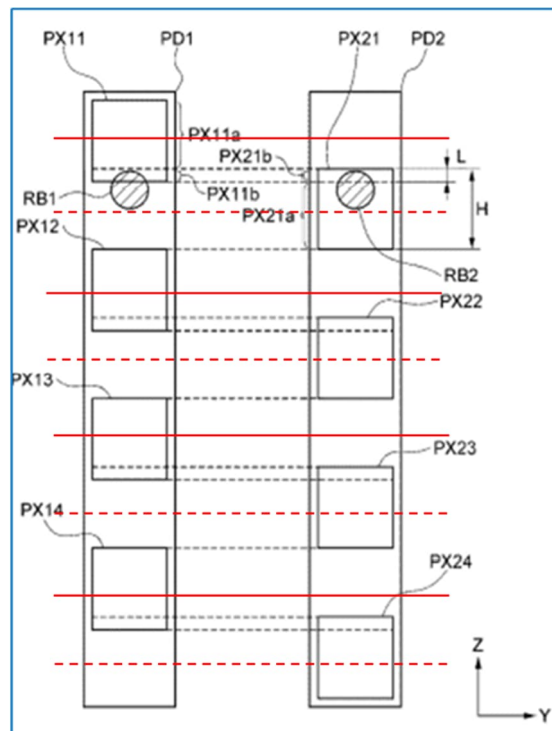


EX1031, Figs. 5-6; EX1032, Figs. 5-6.

f) Claim 7

Matsui and Imai teach claim 7. EX1003, 115-116. Matsui teaches that the pixels (PX21, PX22, PX23, PX24) in the second column (PD2) are interleaved with

the pixels (PX11, PX12, PX13, PX14) in the first column (PD1). EX1031, Figs. 11, 14, [0036]-[0038], [0045]; EX1032, Figs. 11, 14, [0036]-[0038], [0045]. Thus, as the device rotates, the pixels in the second column will traverse paths that are interleaved with the paths traversed by pixels in the first column, as shown in the annotated Figure 14 below:



EX1031, Fig. 14; EX1032, Fig. 14.

g) Claim 9

Matsui and Imai teach claim 9. EX1003, 117. The laser-radar device in Matsui uses time-of-flight “to measure the distance to an object by measuring the time it takes for pulsed laser light to strike an object and return.” EX1031, [0003], [0025]; EX1032, [0003], [0025].

h) Limitation 10(a)

Matsui teaches limitation 10(a). Section X.H.4(a).

i) Limitation 10(b)

Matsui and Imai teach limitation 10(b). The “output circuit” in limitation 1(b) is synonymous with the “transmit module” in claim 1(b), which Matsui discloses. Section X.H.4(b).

j) Limitation 10(c)

Matsui and Imai teach limitation 10(c). The “input circuit” in limitation 1(c) is synonymous with the “receive module” in claim 1(c), which Matsui discloses. Section X.H.4(c). Limitation 10(c) further requires “a bulk receiving optic disposed adjacent to the bulk transmitting optic.” Matsui teaches this requirement in Figure 2, where lenses LS1, LS2 are adjacent to collimating lens CL. EX1031, Fig. 2; EX1032, Fig. 2; EX1003, 118.

k) Limitation 10(d)

Matsui teaches limitation 10(d). Section X.H.4(d). A POSITA would have understood that Matsui’s motor (MT) is an electric motor, which would have been necessary to drive rotation of the casing (CS) within the size constraint of the overall laser radar device. EX1003, 118-119. A POSITA also would have found it obvious to implement Matsui’s motor (MT) as an electric motor, which was a widely known, reliable, and predictable structure for driving rotation of LiDAR devices. *Id.* This

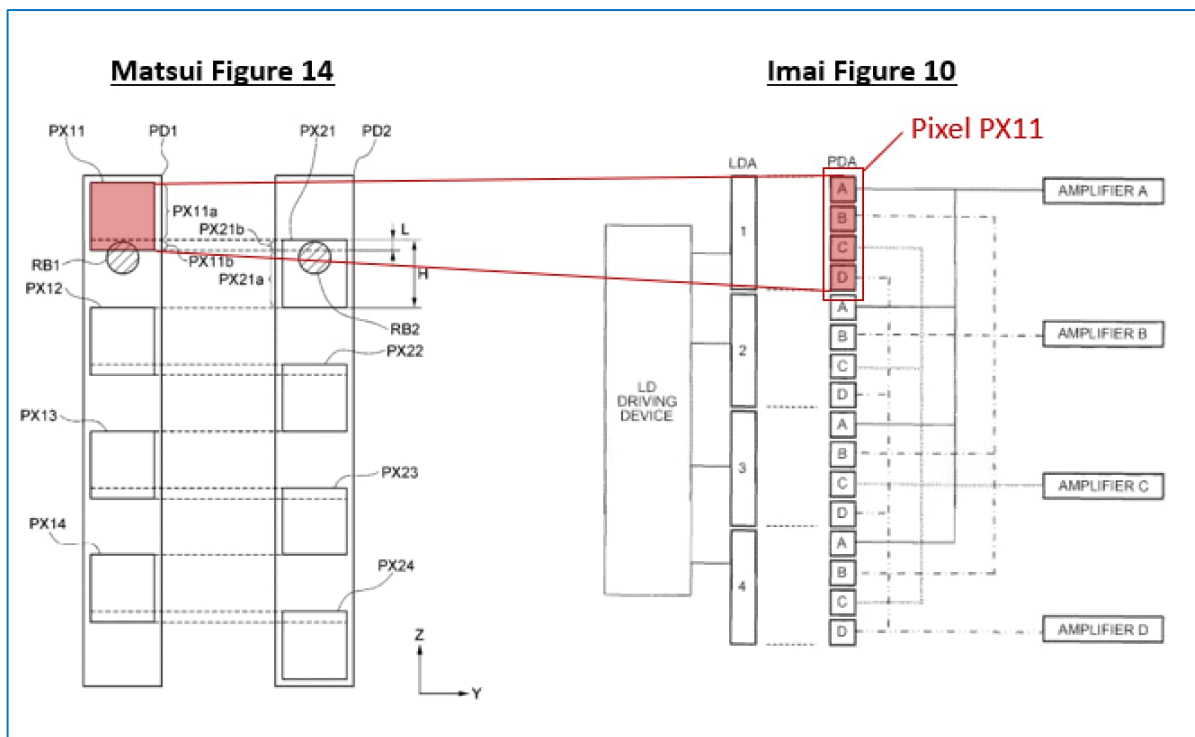
is evident from Hall, discussed above, which teaches a widely known rotational LiDAR device driven by a simple DC motor. *Id.*; EX1004, 5:39-40.

l) Limitation 10(e)

Matsui teaches limitation 10(e). Section X.H.4(e).

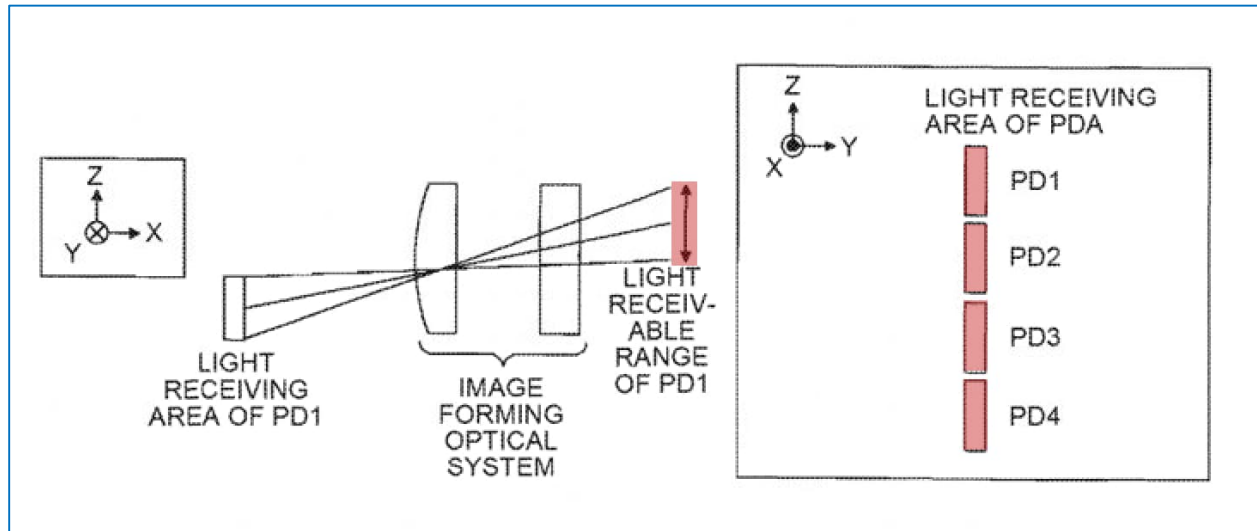
m) Claim 11

Matsui and Imai teach claim 11. EX1003, 119-121. In the combined structure, each pixel in Matsui (PX11, PX12, PX13, etc.) would be implemented as an array of SPADs as disclosed in Imai. *Id.* This is shown in the image below, where pixel PX11 in Matsui is implemented as the plurality of SPADs from Imai Figure 10:
Figure 10:



Id.; EX1031, Fig. 14; EX1032, Fig. 14; EX1033, Fig. 10.

Imai further teaches that individual pixels—represented by photodiodes (PD1, PD2, etc.)—have light-receiving areas that define their field-of-view external to the device. *Id.*, Fig. 4B; EX1003, 120. As shown in Figure 4B below, the light-receiving areas—and therefore the fields-of-view—are non-overlapping:



EX1033, Fig. 4B.

A POSITA would have applied this teaching to the combined Matsui-Imai structure such that the field-of-view for each pixel in Matsui (PX11, PX21, PX12, PX22, etc.) is non-overlapping with the field-of-view for each other pixel. EX1003, 120-121. The arrangement would beneficially avoid interference among pixels and further Matsui's goal of ensuring that each pixel detects a specific point in the field. *Id.*

Imai further teaches that LDs in the LDA project illuminating beams into the field ahead of the optical system according to an illumination pattern where each

beam in the illumination pattern is coincident with a field of view of one pixel in the plurality of pixels. EX1033, Fig. 4, 10:21-22; EX1003, 120-121. In the combined structure, the field-of-view for each pixel in Matsui would be coincident with the beam of an LD. *Id.*

n) Claim 12

Matsui and Imai teach claim 12. EX1003, 122. Matsui teaches a scan cycle with a plurality of sampling periods corresponding to the position of light beam (LB) as discussed in Section X.H.4(e). EX1031, Figs. 5-6; EX1032, Figs. 5-6. In the combined structure, the light beam would be generated by a plurality of lasers as taught in Imai, each of which would fire for each sampling period to capture points (PT) along the detected object (OBJ). *Id.*; EX1033, 10:10-20.

Furthermore, in the combined structure, each pixel of Matsui would be implemented as a plurality of SPADs as taught by Imai and discussed in Section X.H.4(c). In implementing that teaching, a POSITA would have found it obvious to determine the number of SPADs in a pixel that detect an incident photon in a given sampling period. EX1003, 121-122. This was the fundamental operation of multi-SPAD pixels: they allowed photons to be counted, summed, and averaged to obtain a precise representation of the amount of light received at a pixel. *Id.* For example, photon count was useful to determine whether a threshold value had been met before registering a detection event, which would avoid false hits and improve SNR. *Id.*

Photon count also would provide an indication of intensity useful to improve the accuracy of distance measurements. *Id.*

o) Claim 13

Matsui and Imai teach claim 13. EX1003, 122. Matsui teaches time-of-flight distance measurements for each sampling period within a cycle, where each measurement is based on a difference between the laser firing time and the pixel detection time. EX1031, [0003], [0025]; EX1032, [0003], [0025]; Section X.H.4(e). Furthermore, in the combined structure, the field-of-view of each multi-SPAD pixel would overlap the field-of-view for a fired laser emitter as taught in Imai. EX1033, 10:10-30; Section X.H.4(m).

p) Limitation 16(a)

Matsui teaches limitation 16(a). Section X.H.4(a).

q) Limitation 16(b)

Matsui and Imai teach limitation 16(b) as discussed with respect to limitation 1(c) and claim 11. Section X.H.4(c), (m).

r) Limitation 16(c)

Matsui and Imai teach limitation 16(c) as discussed with respect to limitation 1(b) and claim 11. Section X.H.4(b), (m).

s) Limitation 16(d)

Matsui teaches limitation 16(d). Section X.H.4(d).

t) Claim 17

Matsui and Imai teach claim 17 as discussed with respect to limitation 1(e) and claim 9. Sections Section X.H.4(e), (g).

u) Claim 22

Matsui and Imai teach claim 22 as discussed with respect to claim 7. Section X.H.4(f).

v) Limitation 23(a)

Matsui teaches limitation 23(a). Section X.H.4(a).

w) Limitation 23(b)

Matsui and Imai teach limitation 23(b). In the context of the ‘236 Patent, the term “operating wavelength” is synonymous with “nominal wavelength,” which Matsui and Imai teach. Section X.H.4(b).

x) Limitation 23(c)

Matsui and Imai teach limitation 23(c). Section X.H.4(c).

y) Limitation 23(d)

Matsui teaches limitation 23(d). Section X.H.4(d).

z) Limitation 23(e)

Matsui discloses limitation 23(e). Section X.H.4(e).

aa) Claim 26

Matsui and Imai teach claim 26. EX1003, 128. In the combined structure, the illumination source of Matsui would be implemented using “a plurality of VCSELs” arranged in an array, as taught in Imai. EX1033, 14:44-54.

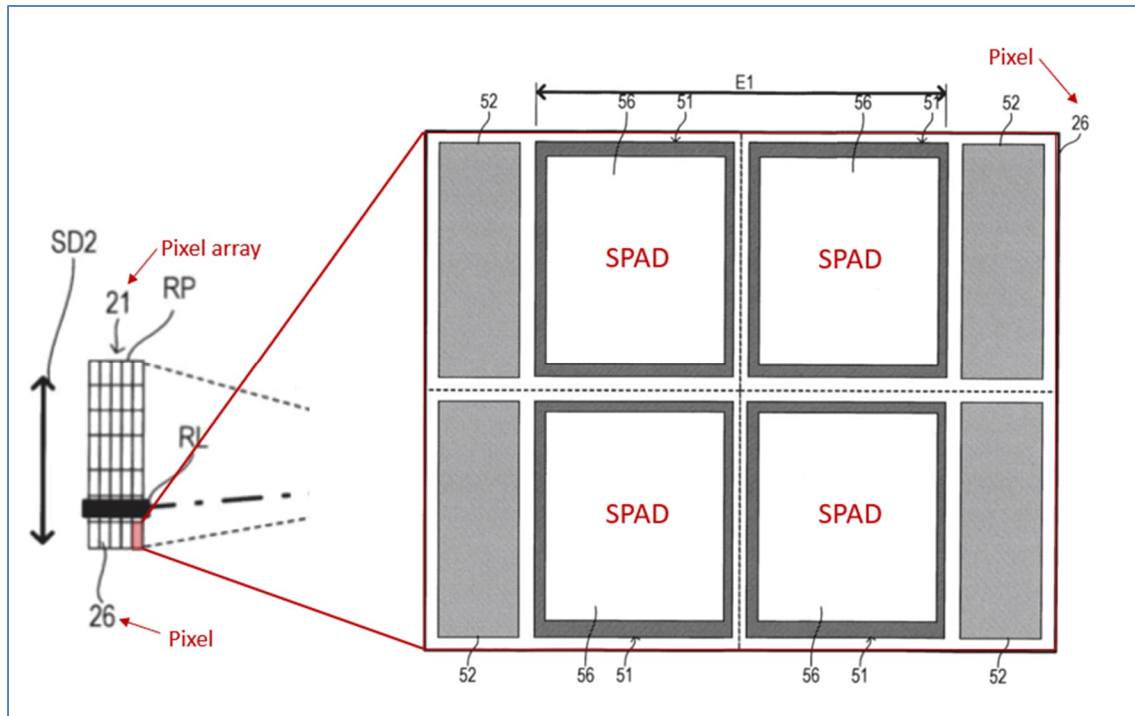
bb) Claim 27

Matsui and Imai teach claim 27 as discussed with respect to claim 9. EX1003, 129; Section X.H.4(g).

I. Ground 2B: Matsui, Imai, and Higashi Render Obvious Claims 1-2, 7, 9-13, 15-18, 22-24, 26-27

1. Higashi

Higashi describes a vehicle-mounted laser-radar device that acquires distance measurements using time-of-flight. EX1034, [0002], [0015]. The device includes a semiconductor laser that emits light pulses into a scanning mirror that distributes the pulses into the surrounding environment. *Id.*, [0015]-[0017]. Light reflected off objects in the field returns to the device and is detected by a pixel array 21, which includes a plurality of pixels 26. *Id.*, [0018], [0024]. Each pixel, in turn, includes an array of light-receiving elements implemented as SPADs 51 with corresponding readout circuits 52. *Id.*, [0027]. This is shown in Figure 3 (excerpted) and Figure 4 below:



Id., Figs. 3-4.

Higashi teaches that the pixel arrangement allows the device to “increase the number of times one pixel 26 is irradiated with the reflected light within a certain period of time [and] increase the number of detection results that can be accumulated for one pixel 26 within a certain period of time” to improve “detection accuracy.”

Id., [0068]. Higashi further teaches that “a bandpass filter corresponding to the wavelength of the pulsed laser light may be provided to eliminate the effect of background light.” *Id.*, [0086], [0006].

2. Combined Teachings of Matsui, Imai, Higashi

Matsui and Imai render obvious claims 1, 7, 9-13, 16-17, 22-23, and 26-27 as detailed in Ground 2A. To the extent Ouster contends the pixels in the combined

Matsui-Imai device do not include a plurality of SPADs, it would have been obvious to further modify the device based on the teachings of Higashi. EX1003 ¶¶190-197. Like Matsui and Imai, Higashi teaches an array of pixels arranged in columns. EX1034, [0027], Figs. 3-4. Higashi further teaches that each pixel can be advantageously implemented as a plurality of SPAD cells to improve detection accuracy—which would directly benefit time-of-flight devices like Matsui and Imai. *Id.* Higashi teaches additional features that would benefit such devices, including the bandpass filter to eliminate background light. *Id.*, [0086], [0006]. A POSITA would have had numerous reasons to apply these teachings to Matsui and Imai.¹⁴

First, the use of multi-SPAD pixels as disclosed Higashi would provide the known benefits associated with SPAD technology, including increased detection sensitivity, fast detection speed and data output, compactness, reduced power consumption, and ease of integration. Section X.A.3; EX1003 ¶¶192, 107-114, 45-51.

Second, a POSITA would have recognized that Higashi’s teaching of multi-SPAD pixels ensures uninterrupted detection at each pixel. *Id.* ¶193. As Professor

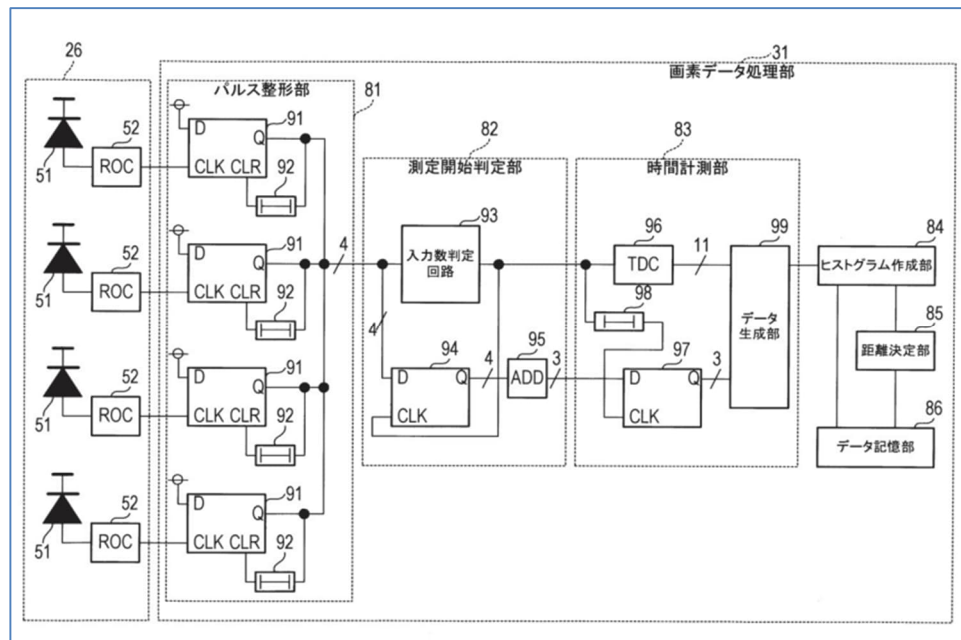
¹⁴ Higashi is analogous art because it is in the same field of endeavor as the ‘236 Patent—optical systems for distance measurement—and pertinent to the problem of improving detection capability in such systems. EX1034, [0006]-[0008], [0013]. EX1003 ¶191.

Hesselink explains, each individual SPAD cell will have a dead time during which it is quenched and reset. *Id.*; EX1018, 8; EX1009 [0049]-[0050], [0138]-[0139]. By grouping multiple SPADs together, each pixel in Higashi continues to register detection events even if one of the SPADs is subject to dead time. EX1003 ¶193, 47-51. Matsui and Imai would benefit from this known design technique, which would ensure each pixel remains active during the detection interval. *Id.*

Third, the multi-SPAD pixels and associated circuitry in Higashi provide for advantageous data processing techniques, including summation of photon counts and histogram generation. EX1003 ¶194; EX1034, [0027], [0049] (“In FIG. 6, because the number of light receiving elements 51 is four, the count value is any one of 0, 1, 2, 3, and 4. Because three bits are required to digitally represent integer values from 0 to 4, the addition circuit 95 has three signal output lines for outputting the digital signal representing the count value.”); [0055]-[0056]. Additional known advantages of photon counting were the ability to determine a threshold value for detection events and calculate intensity for returns at a given pixel. EX1003 ¶194. A POSITA would have been motivated to apply these techniques to the combined structure of Matsui and Imai to improve its detection accuracy. *Id.*

Fourth, a POSITA would have a reasonable expectation of success modifying Matsui and Imai to include multi-SPAD pixels as disclosed in Higashi. EX1003 ¶195. Higashi provides extensive detail concerning the circuitry and electronics

used to detect incident photons, generate output signals, compute time-of-flight distance measurements for objects in the surrounding environment, and quench and reset individual SPADs. EX1034, [0031]-[0054]. Figure 6, for example, illustrates the relationship between SPADs 51 in a given pixel 26, their readout circuits 52, a pulse shaping unit 81 to generate and output light-detection signals, and a pixel data processing unit to compute time-of-flight measurements:



Id., Fig. 6.

A POSITA would have found it predictable to integrate these components into the device of Matsui and Imai, based on the express teachings of Higashi and the known techniques for integrating SPAD arrays and associated electronics into laser-radar devices. Section X.A.3; EX1003 ¶¶195-196, 45-51, 111-114.

Finally, a POSITA would have been motivated to incorporate the bandpass filter of Higashi in front of the pixels in the combined structure of Matsui and Imai. EX1003 ¶197. The known benefit of a bandpass filter was to allow light having the operational or nominal wavelength of the emitters to pass through to the pixels, while blocking “background light” as disclosed in Higashi. *Id.*; EX1034, [0086], [0006]. In this way, the bandpass filter of Higashi would improve accuracy and SNR in the combined structure of Matsui and Imai, while reducing the likelihood of false detections at a given pixel. EX1003 ¶197. Likewise, a POSITA would have had a reasonable expectation of success implementing the bandpass filter of Higashi Using design techniques widely known in the art, such as vapor deposition or integration into a semiconductor layer. *Id.*; Section X.B.2; EX1009, [0146]; EX1030, 12:57-66.

3. Application to the Claims

a) Claims 1, 7, 9-13, 16-17, 22-23, 26-27

To the extent Ouster contends Matsui and Imai do not teach individual pixels each comprising a plurality of SPADs as required by limitations 1(c), 10(c), 16(b), and 23(c), Higashi teaches a pixel array 21 comprising a plurality of pixels 26, where each pixel includes a plurality of SPADs 51. EX1034, [0018], [0027], Fig. 4. Applying this teaching to Matsui and Imai, each pixel in Matsui would be implemented using the multi-SPAD pixel 26 in Higashi. EX1003 ¶¶198. The

resulting structure would meet the requirements of claims 1, 7, 9-13, 16-17, 22-23, 26-27 as discussed in Ground 2A. *Id.*

Further, to the extent Ouster contends the laser emitters in Matsui and Imai do not have a nominal or operating wavelength, Higashi teaches this requirement through its disclosure of a “wavelength of the pulsed laser light” that corresponds to a selected bandpass filter. EX1034, [0086]; EX1003 ¶199. The disclosed wavelength is a “nominal” or “operating” because it is the wavelength selected for detection by the plurality of pixels (whereas other background wavelengths are filtered out). *Id.* In the combined structure, the illumination source and emitters of Matsui and Imai would operate at a nominal or operating wavelength corresponding to the bandpass filter and SPADs of Higashi. *Id.*

b) Claims 2, 15, 18, 24

Higashi teaches “a bandpass filter corresponding to the wavelength of the pulsed laser light may be provided to eliminate the effect of background light.” EX1034, [0086], [0007]. Applying this teaching to the Matsui-Imai device, a POSITA would have predictably placed the bandpass filter in front of each pixel to ensure unwanted light is blocked from reaching the pixels. EX1003 ¶200. A POSITA also would have predictably selected a narrow bandpass filter, centered on the operating wavelength of the emitters. *Id.* As detailed in Section X.B.2, this well-known design technique would ensure that light emitted at the peak wavelength of

the emitters is allowed to pass through to the pixels, while also providing a margin for light emitted at slight higher and lower wavelengths. *Id.*; EX1026. The resulting structure would meet the requirements of claims 2, 15, 18, and 24. EX1003, 134-136.¹⁵

c) *Claim 12*

To the extent Ouster contends that Matsui and Imai fail to teach the additional requirements of claim 12, Higashi describes a scan cycle with a plurality of sampling periods corresponding to individual rows of the pixel array 21. EX1034, [0024]-[0025], Fig. 3. During each sampling period the system determines the number of SPADs in an illuminated pixel that recorded an incident photon since a previous sampling period. *Id.*, [0045]-[0050], Figs. 6-7. Combined with Matsui and Imai, the device would fire the plurality of laser diodes disclosed in Imai for each sampling period, and count the number of photons received at each multi-SPAD pixel as disclosed in Higashi. EX1003, 136. The resulting structure would meet claim 12, as well as claim 13, as discussed in Section X.H.4(n)-(o).

¹⁵ As discussed in Section X.B.3(b), claim 24 requires the filter to be “disposed between the bulk *transmitting* optic and the plurality of pixels,” which conflicts with the specification and drawings of the ‘236 Patent. Higashi renders the limitation obvious regardless because a POSITA would have found it obvious to position the filter directly in front of the pixels. EX1003, 134-136.

J. Ground 2C: Matsui, Imai, and Hipp Render Obvious Claims 8, 14, 19-21, and 25

1. Hipp

As detailed in Ground 1C, Hipp teaches a shadow mask with a plurality of apertures, each positioned in front of a pixel to define its field of view. Section X.C.1.

2. Combined Teachings of Matsui, Imai, and Hipp

A POSITA would have found it obvious to apply the shadow mask of Hipp to the structure of Matsui and Imai. EX1003 ¶¶203-206.

First, a POSITA would have had an express motivation to use Hipp’s shadow mask to reduce signal interference and improve the SNR. *Id.* ¶204. Hipp teaches that “interference pulses arise which superimpose themselves with the desired signals with is a basic problem of the array technique.” EX1007, 21:46-56. The shadow mask solves that problem by ensuring that light from a given emitter is received at its corresponding pixel. *Id.*, 21:57-67, 22:1-10.

Second, a POSITA would have understood that Hipp’s shadow mask would complement Matsui and Imai. EX1003 ¶205. Matsui teaches a laser-radar device with an array of pixels, while Hipp teaches a shadow mask designed to improve detection efficiency for multi-pixel sensors. EX1007, 21:46-67. Imai likewise teaches the desire for improved detection accuracy in a SPAD array, which would benefit from blocking unintended photons as taught by Hipp.

Third, a POSITA would have had a reasonable expectation of success combining the teachings of Matsui, Imai, and Hipp. EX1003 ¶ 206. Hipp teaches that the shadow mask can be attached to the detector array, with apertures in the mask aligned with individual detectors. EX1007, 21:60-67, Fig. 16. Similar designs were well-known in the art, including in Grzesik, which teaches a cross-talk absorption layer with apertures formed in a light-absorbing material. EX1010, 4:65-5:18; Fig. 3. A POSITA would have had a reasonable expectation of success using these known techniques to implement the shadow mask of Hipp in a known LiDAR device like Matsui and Imai.

3. Application to the Claims

Matsui and Imai render obvious claims 1, 10, 16, and 23 as detailed in Ground 2A. Section X.H. Combined with Hipp, the resulting device renders obvious claims 8, 14, 19-21, and 25. EX1003 ¶207. Hipp teaches a shadow mask comprising a plurality of apertures formed over pixels in a detector array, and a stop region formed between the apertures to block undesired light from entering the pixels and thereby define a field-of-view for each pixel. EX1007, 21:57-67, Fig. 16. Applied to Matsui and Imai, the resulting structure would include a plurality of pixels, each having a SPAD array, aperture, and stop region.

With respect to claims 8, 19, and 25, the first set of pixels would include a first pixel disposed in a first optical path that extends through the first aperture, and

the second set of pixels would include a second pixel disposed in a second optical path that extends through the second aperture, with the offset arrangement disclosed in Matsui. EX1003 ¶208.¹⁶

With respect to claims 14 and 21, the first set of pixels would further include a third pixel, and the second set of pixels would further include a fourth pixel. *Id.* ¶209.

With respect to claim 20, the first and second pixels in the resulting structure would have their respective fields-of-view coincident with first and second emitters as disclosed in Imai as discussed in Section X.H.4(m). *Id.* ¶210.

K. Ground 2D: Matsui, Imai, Higashi, and Hipp Render Obvious Claims 8, 14, 19-21, and 25

A POSITA would have found it obvious to combine the teachings of Matsui, Imai, Higashi, and Hipp as discussed in Sections X.I and X.J. The resulting device would meet the requirements of claims 8, 14, 19-21, and 25.

XI. SECONDARY CONSIDERATIONS

Hesai is not aware of evidence regarding secondary considerations of non-obviousness, and Ouster has not identified any such evidence in the specification, prosecution history, or related district court and ITC proceedings. EX1003 ¶212.

¹⁶ As noted above, claim 19 contains an error referring to the “the first aperture [] disposed in a second optical path....” Matsui, Imai, and Hipp teach the structure disclosed in the ‘236 Patent. EX1001, Fig. 1.

To the extent Ouster identifies such evidence at a later point in time, Hesai reserves the right to address it.

XII. DISCRETIONARY FACTORS

A. 35 U.S.C. § 314

The *Fintiv* factors weigh against discretionary denial. *Apple Inc. v. Fintiv, Inc.*, IPR2020-00019, Paper 11 at 5–6 (Mar. 20, 2020) (*precedential*). The district court action is stayed, with no responsive pleadings or procedural schedule having been filed. EX1022. It is highly unlikely the district court would address invalidity before a Final Written Decision. In the ITC action, the ALJ has issued an initial determination granting Hesai’s motion to terminate. EX1042. Further, the ITC action is not relevant under the *Fintiv* framework.

B. 35 U.S.C. § 325(d)

Discretionary denial under § 325(d) is not warranted. *Advanced Bionics, LLC v. Med-El Elekt. Gerate GmbH*, IPR2019-01469, Paper 6 at 8-9 (PTAB Feb. 13, 2020) (*precedential*).

Regarding Grounds 1A-G, although Hall and Borowski were cited in an IDS, they were not applied against the claims in an office action or otherwise discussed by the Examiner. EX1002, 194, 198. “The Board frequently holds that a reference that was neither applied against the claims nor discussed by the Examiner does not weigh in favor of exercising the Board’s discretion under § 325(d) to deny a

petition.” *Amazon.com, Inc. v. M2M Sols. LLC*, IPR2019-01205, Paper 14 at 15 (PTAB. Jan. 27, 2020) (quotation omitted). That rationale applies even more strongly here, where Hall and Borowski were listed among hundreds of references with no indication of the extent to which they were considered. EX1002, 194-205.

Furthermore, under step two of the *Advanced Bionics* framework, it was error for the Examiner not to rely on the teachings of Hall and Borowski to reject the claims. IPR2019-01469, Paper 6 at 8, n.9 (“An example of a material error may include misapprehending or overlooking specific teachings of the relevant prior art where those teachings impact patentability.”). This Petition and the accompanying Hesselink Declaration provide a detailed explanation of how Hall and Borowski render claims of the ‘236 Patent invalid. It was error for the Examiner to disregard these disclosures.

With respect to Grounds 2A-D, the office was not previously presented with Matsui, Imai, and Higashi or any substantially similar references or arguments based thereon. EX1001, 1-4. This fact weighs against discretionary denial under the first step of the *Advanced Bionics* framework. IPR2019-01469, Paper 6 at 8.

XIII. CONCLUSION

For the foregoing reasons, Hesai requests that the Board institute *inter partes* review and cancel claims 1, 2, and 7-27 of the ‘236 Patent.

Respectfully submitted,

Date: September 26, 2023

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CERTIFICATION UNDER 37 C.F.R. §42.24

Under the provisions of 37 C.F.R. §42.24, the undersigned hereby certifies that the word count for the foregoing Petition for *inter partes* review totals 13,874 words, not including the table of contents, table of authorities, mandatory notices, certificates, listing of exhibits, or listing of claims, as permitted under 37 C.F.R. § 42.24(a)(i).

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CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. §§ 42.6(e), 42.105(a), the undersigned hereby certifies service on the Patent Owner of a copy of this Petition, its respective exhibits, and Petitioner's Power of Attorney at the official correspondence address for the attorney of record for the '236 Patent as shown in USPTO PAIR via EXPRESS MAIL on September 26, 2023:

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