

Hesai Technology Co., Ltd. v. Ouster, Inc.

IPR2023-01421

U.S. Patent No. 11,175,405

Petitioner's Demonstratives

Hearing: December 17, 2024

Grounds

Ground	Claim(s) challenged
1. Pacala + Droz	21, 23, 26-31, 34
2. Pacala + Droz + Villeneuve	24-25, 32-33
3. Hall + Borowski + Spector	21, 23-33
4. Hall + Borowski + Spector + Droz	34

Patent Owner's Arguments

Grounds	Patent Owner's Arguments	Claims
1-2	Droz does not disclose a “stop region”	21, 26
1-2	No motivation to combine Pacala and Droz	All
3-4	No motivation to combine Hall and Spector	All
3-4	No motivation to combine Borowski and Spector	All
3-4	No motivation to combine Hall and Borowski	All
1-4	Secondary considerations of nonobviousness	21, 26

'405 Patent Overview

'405 Patent Overview

21. An optical system for performing distance measurements, the optical system comprising:

- a stationary housing having a base, a top and an optically transparent window disposed between the base and the top and extending fully around a periphery of the stationary housing;

- a light ranging device disposed within the housing and comprising:

 - a platform;

 - a light transmission module coupled to the platform and comprising a bulk transmitter optic and a plurality of optical emitters, each optical emitter in the plurality of optical emitters configured to generate and transmit pulses of radiation through the bulk transmitter optic and through the optically transparent window into a field external to the optical system; and

- a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and an optical filter disposed between the bulk receiver optic and the plurality of photosensors and configured to allow a band of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the filter to the plurality of

 - photosensors while blocking radiation outside the band from reaching the plurality of photosensors; and

- a motor disposed within the housing and operatively coupled to spin the platform and the light ranging device within the housing;

wherein:

 - each photosensor in the plurality of photosensors comprises a plurality of single photon avalanche diodes (SPADs);

 - the plurality of apertures comprises at least first, second, third and fourth apertures;

 - the plurality of photosensors comprises at least first, second, third and fourth photosensors; and

 - the light sensing module includes a first optical path to the first photosensor through the first aperture, a second optical path to the second photosensor through the second aperture, a third optical path to the third photosensor through the third aperture, and a fourth optical path to the fourth photosensor through the fourth aperture.

'405 Patent Overview

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 - a platform;

 - a light transmission module coupled to the platform and comprising a bulk transmitter optic and a plurality of optical emitters, each optical emitter in the plurality of optical emitters configured to generate and transmit pulses of radiation through the bulk transmitter optic and through the optically transparent window into a field external to the optical system; and

- a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and an optical filter disposed between the bulk receiver optic and the plurality of photosensors and configured to allow a band of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the filter to the plurality of

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 - the plurality of photosensors comprises at least first, second, third and fourth photosensors; and

 - the light sensing module includes a first optical path to the first photosensor through the first aperture, a second optical path to the second photosensor through the second aperture, a third optical path to the third photosensor through the third aperture, and a fourth optical path to the fourth photosensor through the fourth aperture.

'405 Patent Overview

Light sensing module **106** can include a sensor array **108**, which can be, e.g., a one-dimensional or two-dimensional array of photosensors. Each photosensor (also just called a “sensor” or sometimes referred to by one skilled in the art as a “pixel”) can include a collection of photodetectors, e.g., SPADs or the like, or a sensor can be a single photon detector (e.g., an APD). Light sensing module **106** includes an optical sensing system **110**, which when taken together with sensor array **108** can form a light detection system **112**. In some embodiments, optical sensing system **110** can include a bulk receiver optic **114** and optical components **116**, such as an aperture layer, a collimating lens layer and an optical filter, that can be combined with sensor array **108** to form an array of micro-optic receiver channels where each micro-optic receiver channel measures light that corresponds to an image pixel in a distinct field of view of the surrounding field in which system **100** is positioned. Further details of various embodiments of micro-optic receiver channels according to the present disclosure are discussed in detail in conjunction with FIGS. 17-30 below.

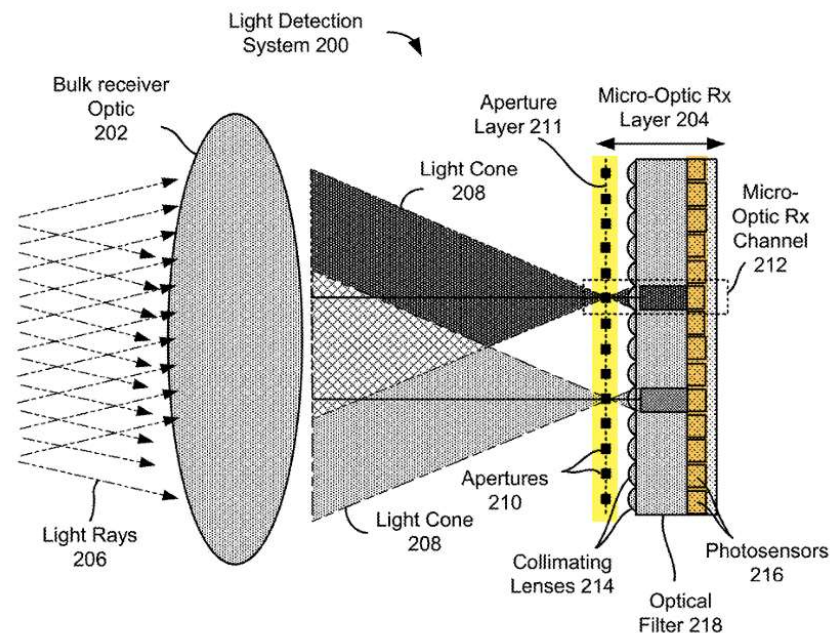


FIG. 2

'405 Patent Overview

row band of wavelengths. According to some embodiments of the present disclosure, micro-optic receiver channel structures, such as receiver channel 1700, can include the following layers:

An input aperture layer 1740 including an optically transparent aperture 1744 and optically non-transparent stop region 1746 configured to define a narrow field of view when placed at the focal plane of an imaging optic such as bulk receiver optic 202 or 1008 (shown in FIGS. 2 and 10, respectively; not shown in FIG. 17). Aperture layer 1740 is configured to receive the input marginal ray lines 1733. The term “optically transparent” herein refers to as allowing most or all light to pass through. Light herein refers to spectrum of light in the near-ultraviolet, visible, and near-infrared range (e.g. 300 nm to 5000 nm). Optically non-transparent herein refers to as allowing little to no light to pass through, but rather absorbing or reflecting the light. Aperture layer 1740 can include optically transparent apertures separated from each other by optically non-transparent stop regions. The apertures and stop regions can be built upon a single monolithic piece such as an optically transparent substrate. Aperture layer 1740 can optionally include a one-dimensional or two-dimensional array of apertures 1744.

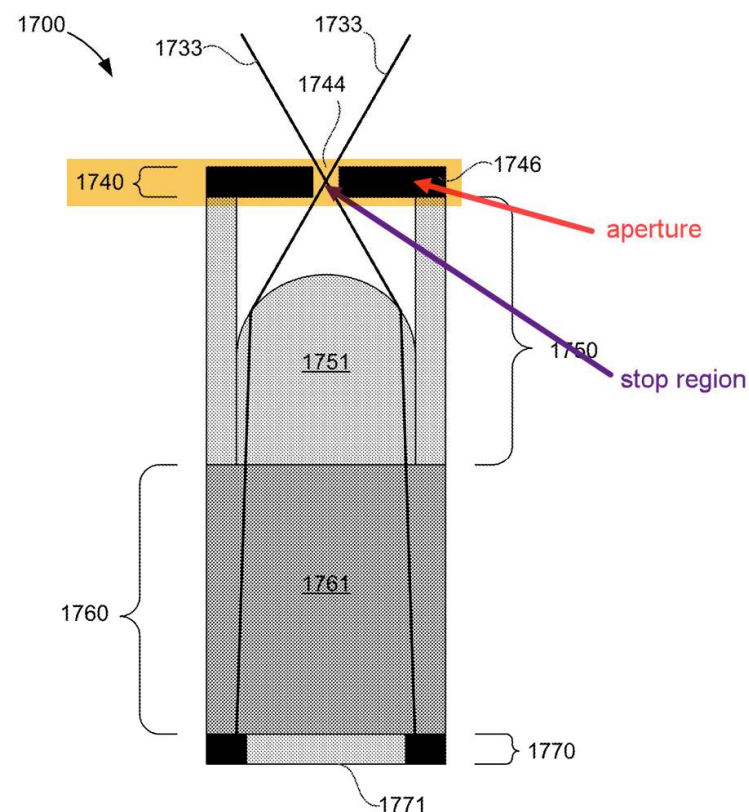


FIG. 17

Ex. 1001 (405 patent), 37:14-38, Fig. 17

Summary of Prior Art

Summary of Prior Art: Pacala (Ex. 1004)

[0013] The schematic diagram of FIG. 2 provides an internal view of a lidar sensor that can be used in the present invention, depicting a static base **50** that contains a motor and distributed electronics, and a spinning turret **60** that contains optoelectronic components **70** (including optical transmitters and receivers), collimation and focusing lenses **80** and distributed electronics. The multi-channel TDC electronic circuitry of the present invention can be located on said static base and/or on said spinning turret.

* * *

speed data bus. The multi-channel TDC electronic circuitry with multiple voltage thresholds can be implemented with discrete integrated circuits (ICs), in the form of FPGA logic, as part of an application-specific integrated circuit (ASIC), or integrated into the pixels of a detector array (e.g., Single-Photon Avalanche Diode [SPAD] array).

Ex. 1004, [0013]-[0014]; Pet. 14

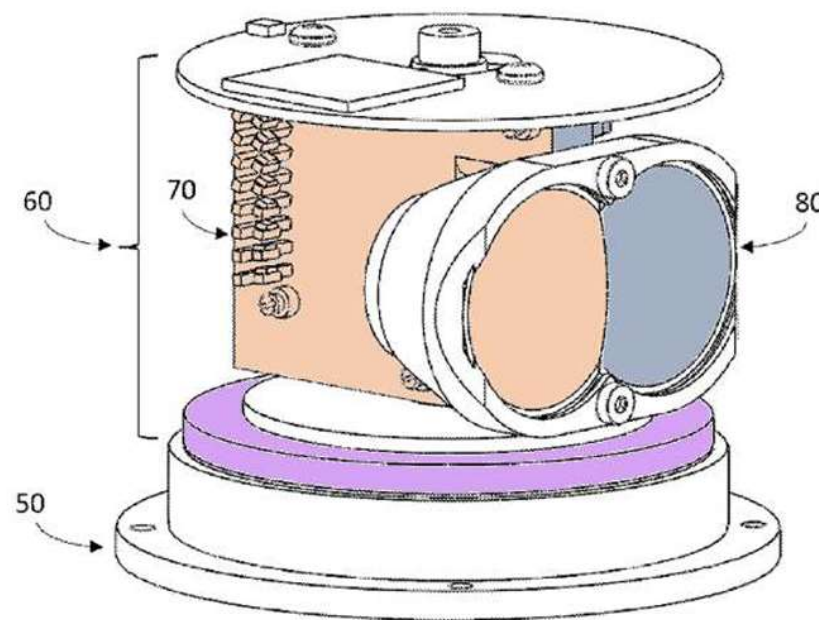


Fig. 2

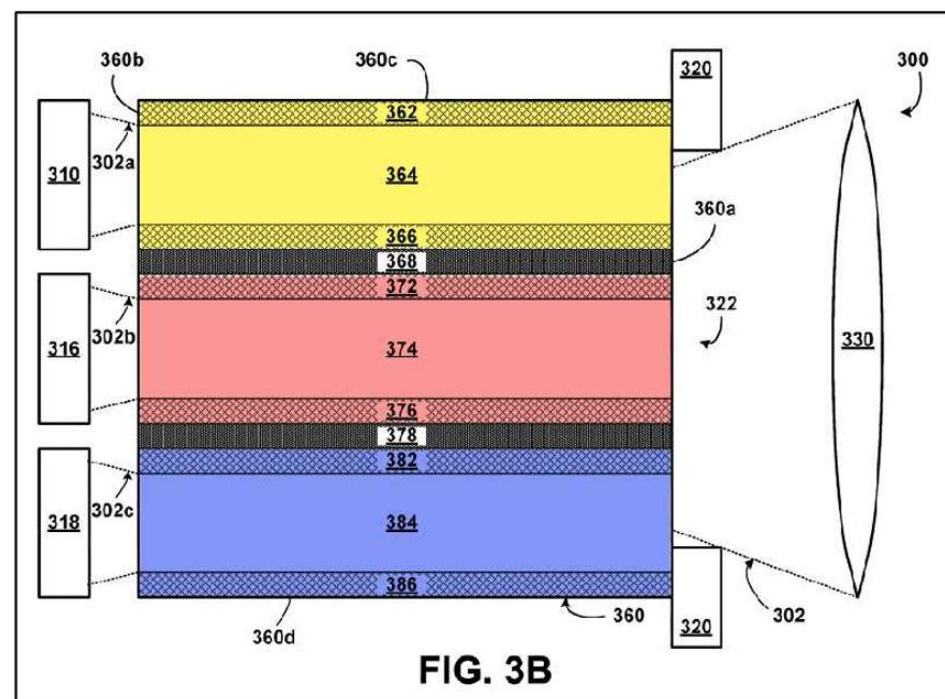
Ex. 1004, Fig. 2; Pet. 14

Summary of Prior Art: Droz (Ex. 1006)

Additionally, with this arrangement, a first array of light detectors coupled to a first waveguide may receive light transmitted through a first portion of the aperture, and a second array of light detectors coupled to a second waveguide may receive light through a second portion of the aperture. As a result, the system can determine a one-dimensional (1D) image of the scene, while still allowing for a larger detection area relative to the size of the aperture. For example, each array of light detectors can be connected in parallel to provide a combined output that represents a single image pixel of the scene.

Without the waveguides, for example, the portions of the light transmitted through the aperture may diverge and overlap prior to arriving at the array of light detectors. Whereas, with the plurality of waveguides, each waveguide can limit divergence of a portion of the light guided therein such that the guided portion does not overlap another guided portion of the light inside an adjacent waveguide. As a result, each array of light detectors can receive guided light that corresponds to a respective portion of the aperture regardless of the proximity of the portions of the aperture or the distance between the aperture and the respective arrays of light detectors. Additionally or alternatively, the system can detect light transmitted through multiple proximally arranged apertures (or portions of a single aperture) simultaneously to generate a 1D or 2D image of the scene, regardless of the distance between the apertures or the distance between a light detector array and an aperture.

Ex. 1006, 4:1-28; Pet. 6



Ex. 1006, Fig. 3B; Pet. 17

Summary of Prior Art: Hall (Ex. 1008)

As depicted in FIG. 3, light emission/collection engine 112 includes an array of light emitting elements 114 and an array of light detecting elements 113. Light emitted from each of the light emitting elements 114 is directed toward a mirror (not shown). Light reflected from the mirror passes through a series of illumination optics 115 that collimate the emitted light into an array of beams of light 105 that are emitted from 3-D LIDAR system 100 as depicted in FIG. 1. In general, any number of light emitting elements can be arranged to simultaneously emit any number of light beams from 3-D LIDAR system 100. Light reflected from objects in the environment is collected by collection optics 116. Collected light passes through collection optics 116 where it is focused onto each detecting element of the array of detecting elements 113. After passing through collection optics 116, the collected light is reflected from a mirror (not shown) onto each detector element.

Ex. 1008, 6:31-47; Pet. 45-46

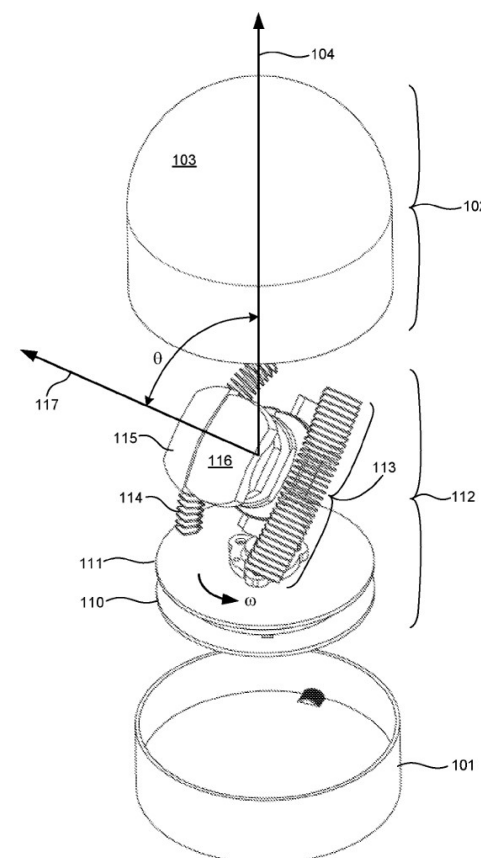


FIG. 3

Ex. 1008, Fig. 3; Pet. 45

Summary of Prior Art: Borowski (Ex. 1009)

[0078] The receiving part also comprises a rotating block **2012** which comprises multiple (e.g., 12) lenses **2013** adjusted for various focus and size, collecting simultaneously the faint light reflected from targets in several directions. The collected light from each lens is directed to a plurality of SPAD detector arrays **2014**.

Ex. 1009, [0078]; Pet. 47

[0053] Local DSPs are integrated into clusters of several SPAD detector cells between neighboring SPAD detector cells. Such a cluster is programmed in size and shape to perform various operations mainly for multiplexing and averaging the detected events of the SPAD detector cells of the said programmed macro-cell that acts as the equivalent of a single “perfect” SPAD having no recovery time.

Ex. 1009, [0053]; Pet. 47

Summary of Prior Art: Spector (Ex. 1005)

tion sites. A pixelated optical sensor array 20 may work alone or in conjunction with an aperture array 18 for defining the optical detection sites on the sensor array. For example, Princeton Lightwave, Inc. of Cranbury, N.J. makes a variety of pixelated optical sensor arrays, including for example the Merlin 32×32 free-running LiDAR camera, which may be used to perform the functions of the detector array 20. For an optical sensor array in which the detectors are much smaller than the spacing between the detectors (fill factors less than 10%), such as in the Princeton Lightwave camera, the individual optical detection sites for correspondence with individual light spots are defined by the array itself. For detectors with a large fill factor, an aperture array may be beneficial to establish the individual optical detection sites. As such, the receiver optics will include a mask 18 defining a plurality of transparent apertures arranged according to the two dimensional array. The plurality of transparent apertures limits visibility by each optical detection site to a single corresponding light spot in the two dimensional array.

Ex. 1005, 3:43-61; Pet. 48-49

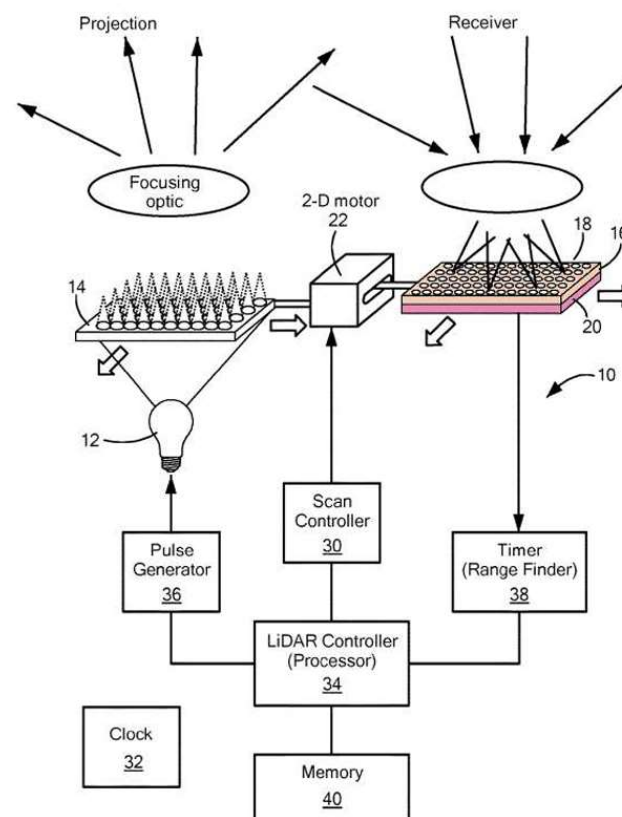


FIG. 1

Ex. 1005, Fig. 1; Pet. 49

Obviousness of the '405 Patent

Summary of Disputes

Grounds	Patent Owner's Arguments	Claims
1-2	Droz does not disclose a “stop region”	21, 26
1-2	No motivation to combine Pacala and Droz	21, 26
3-4	No motivation to combine Hall and Spector	21, 26
3-4	No motivation to combine Borowski and Spector	21, 26
3-4	No motivation to combine Hall and Borowski	21, 26
1-4	Secondary considerations of nonobviousness	21, 26

- **PO relies on an incorrect new construction of “stop region,” and Droz discloses a stop region even under PO’s construction**
- **PO’s arguments on motivation to combine relies on improper “bodily incorporation” and are not supported by the evidence**
- **PO lacks evidence of secondary considerations, and PO’s arguments cannot overcome the weight of the prior art**

Grounds 3-4, Motivation to Combine Hall and Spector: Summary of Dispute

Petitioner's Arguments

The Petition provides multiple reasons why a POSITA would combine Hall and Spector
PO raises improper “bodily incorporation” arguments

Patent Owner's Arguments

Spector's aperture array is too low resolution to use in Hall's LiDAR system

Grounds 3-4, Motivation to Combine Hall and Spector: PO's Bodily Incorporation Argument is Legally Incorrect



Contrary to Allied's position, “it is not necessary that [Caterpillar and Ogawa] be physically combinable to render obvious the ['489 patent].” ... “The test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference,” ... but rather whether “a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention.”

Allied Erecting & Dismantling Co. v. Genesis Attachments, 825 F.3d 1373, 1381 (Fed. Cir. 2016)

Grounds 3-4, Motivation to Combine Hall and Spector: Argument in the Petition

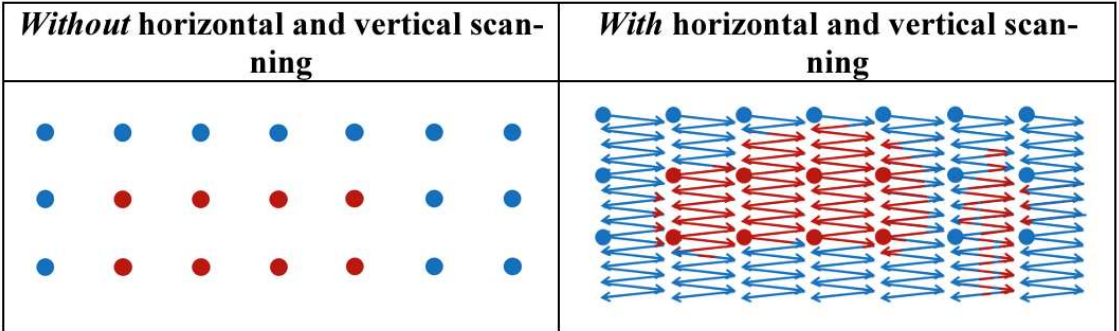
Third, a POSITA would have been motivated to modify Hall to incorporate an arrayed micro-optic (on the emitter side) and an aperture array (on the detector side) as taught by Spector. Ex. 1003 ¶191. Hall acknowledges that there is a need to “avoid cross-talk” in LiDAR systems with multiple emitters. Ex. 1008, 9:13-25. Spector teaches an arrayed micro-optic used to “project a two dimensional array of light spots on a scene.” Ex. 1005, 3:1-14. Spector also teaches an aperture array that “establish[es] ... individual optical detection sites.” *Id.*, 3:54-61. The array of isolated light spots generated by the arrayed micro-optic, in combination with the individual optical detection sites, in a one-to-one correspondence, reduce cross-talk and multipath signals. *Id.*, 6:12-15. A POSITA would have thus understood that applying Spector’s aperture array within Hall’s system would reduce cross-talk and associated errors, and improve the accuracy of the LiDAR system. Ex. 1003 ¶191. Spector’s system also provides additional advantages, such as permitting “smaller and/or simpler and less expensive scanning mechanisms.” Ex. 1005, 6:15-20.

**No dispute that Spector
would reduce cross-talk in
Hall’s system**

Pet. 57-58; Ex. 1003 (Shanley Decl.) ¶191

Grounds 3-4, Motivation to Combine Hall and Spector:
PO's Argument Assumes Bodily Incorporation

The horizontal and vertical scanning is thus an essential part of the Spector system; the figure below illustrates what would happen if one were to remove this feature from Spector:



(EX2010, ¶¶132-34.) The figure on the left shows how Spector would operate without the horizontal and vertical scanning – it would simply detect a disconnected series of discrete and spatially separated points with no accompanying detail. In this case, the car in the scene has been reduced to a non-descript rectangle. (*Id.*, ¶132.)

Grounds 3-4, Motivation to Combine Hall and Spector: PO's Bodily Incorporation Argument is Legally Incorrect

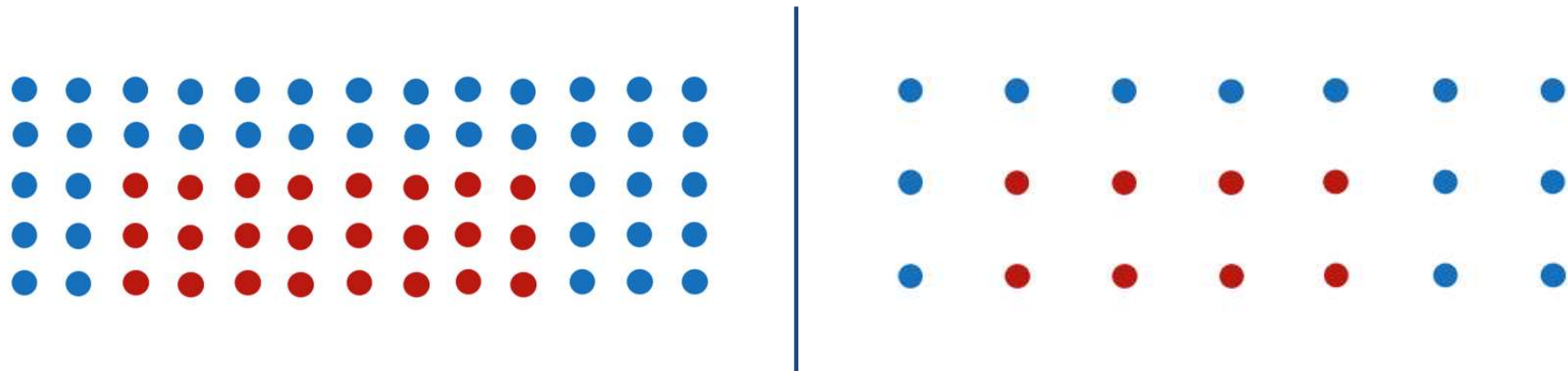


Second, Elbrus argues that combining Lu with Sukegawa would lead to an inoperable circuit absent significant additional design work. However, “it is not necessary that [Sukegawa and Lu] be physically combinable to render [a claim] obvious.” ... That is so because “ ‘[t]he test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference,’ but rather whether ‘a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention.’ ” ... Therefore, Elbrus’s argument that combining Sukegawa and Lu could lead to an unworkable circuit is “basically irrelevant.”

Elbrus Int’l Ltd. v. Samsung Elecs. Co., 738 F. App’x 694, 698 (Fed. Cir. 2018)

**Grounds 3-4, Motivation to Combine Hall and Spector:
No New Theory on Reply**

Neither Spector nor the Petition require a particular spacing between apertures in the aperture array



PO's argument challenges a combination Petitioner never advanced

Grounds 3-4, Motivation to Combine Hall and Spector: POSITA Would Be Capable of Fitting Spector's Aperture Array to Hall's System

4 A. Oh. Yeah. Oh, yeah. I mean, myself, today,
5 I myself can run the CAD programs and top-level. But
6 a mechanical engineer out of school or an optical
7 engineer or an electrical engineer, they all can run
8 these programs that does it.

9 And basically, between the optical CAD and
10 the mechanical CAD, it talks about how you wrap metal
11 around these objects once you've done your optical
12 design. It gives you the whole list of materials and
13 all the parameters associated with the materials and
14 the optics. And then the same thing happens with the
15 CAD programs. And then there's interfaces that marry
16 the two. And you can get all this information, just
17 drops out.

18 So you'll get the form, fit, and function,
19 including weight and all this right out of those
20 systems.

Reply at 16-17; Ex. 2011 (Shanley Dep.) 56:4-20

Grounds 3-4, Motivation to Combine Borowski and Spector: Summary of Dispute

Petitioner's Arguments

The Petition provides multiple reasons why a POSITA would combine Borowski and Spector

PO's argument is not supported by the weight of the evidence

Patent Owner's Arguments

A POSITA would not use Borowski's SPADs with Spector's aperture arrays because SPADs have a low fill factor

Grounds 3-4, Motivation to Combine Borowski and Spector: Argument in the Petition

Petition provides undisputed motivations to apply both Borowski's and Spector's teachings to Hall's system

Second, a POSITA would have been motivated to modify Hall to incorporate SPAD arrays in view of Borowski. Ex. 1003 ¶¶189-190. Hall acknowledges that in existing LiDAR systems, the “detection of return signals includes significant sources of measurement noise that are exacerbated as measurement ranges are extended,” and that conventional solutions required “increasing laser pulse intensity.” Ex. 1008, 2:27-33. Improvements are thus needed for “power management ... while maintaining sufficiently high levels of imaging resolution and range.” *Id.*, 2:46-48. Borowski teaches that SPADs can solve problems with light intensity because they “provide[] significant carrier amplification.” Ex. 1009, [0035]. Borowski further teaches that using a “cluster” of SPAD detector cells whose outputs are multiplexed and averaged is advantageous because the “programmed macro-cell ... acts as the equivalent of a single ‘perfect’ SPAD having no recovery time.” *Id.*, [0053]. A POSITA would have thus understood that using clusters of SPADs for LiDAR detection can improve detection at longer ranges and at lower light intensities. Ex. 1003 ¶¶189-190.

Third, a POSITA would have been motivated to modify Hall to incorporate an arrayed micro-optic (on the emitter side) and an aperture array (on the detector side) as taught by Spector. Ex. 1003 ¶191. Hall acknowledges that there is a need to “avoid cross-talk” in LiDAR systems with multiple emitters. Ex. 1008, 9:13-25. Spector teaches an arrayed micro-optic used to “project a two dimensional array of light spots on a scene.” Ex. 1005, 3:1-14. Spector also teaches an aperture array that “establish[es] ... individual optical detection sites.” *Id.*, 3:54-61. The array of isolated light spots generated by the arrayed micro-optic, in combination with the individual optical detection sites, in a one-to-one correspondence, reduce cross-talk and multipath signals. *Id.*, 6:12-15. A POSITA would have thus understood that applying Spector’s aperture array within Hall’s system would reduce cross-talk and associated errors, and improve the accuracy of the LiDAR system. Ex. 1003 ¶191. Spector’s system also provides additional advantages, such as permitting “smaller and/or simpler and less expensive scanning mechanisms.” Ex. 1005, 6:15-20.

Pet. 57-58; Ex. 1003 (Shanley Decl.) ¶¶ 189-191

Grounds 3-4, Motivation to Combine Borowski and Spector: PO's Argument Based on Spector

tion sites. A pixelated optical sensor array **20** may work alone or in conjunction with an aperture array **18** for defining the optical detection sites on the sensor array. For example, Princeton Lightwave, Inc. of Cranbury, N.J. makes a variety of pixelated optical sensor arrays, including for example the Merlin 32×32 free-running LiDAR camera, which may be used to perform the functions of the detector array **20**. For an optical sensor array in which the detectors are much smaller than the spacing between the detectors (fill factors less than 10%), such as in the Princeton Lightwave camera, the individual optical detection sites for correspondence with individual light spots are defined by the array itself. For detectors with a large fill factor, an aperture array may be beneficial to establish the individual optical detection sites. As such, the receiver optics will include a mask **18** defining a plurality of transparent apertures arranged according to the two dimensional array. The plurality of transparent apertures limits visibility by each optical detection site to a single corresponding light spot in the two dimensional array.

Reply 18; POR 56; Ex. 1005 (Spector) 3:49-54

Grounds 3-4, Motivation to Combine Borowski and Spector: PO Does Not Establish that SPADs Have Small Fill Factors



Article

Single-Photon Avalanche Diode with Enhanced NIR-Sensitivity for Automotive LIDAR Systems

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Abstract: A single-photon avalanche diode (SPAD) with enhanced near-infrared (NIR) sensitivity has been developed, based on 0.18 μm CMOS technology, for use in future automotive light detection and ranging (LIDAR) systems. The newly proposed SPAD operating in Geiger mode achieves a high NIR photon detection efficiency (PDE) without compromising the fill factor (FF) and a low dark count rate (DCR) at a voltage of approximately 20.5 V. These properties are obtained by employing two types of SPADs that are designed to provide a full-depletion layer with a high electric field profile. The evaluation of the proposed SPAD reveals an FF of 33.1% and a PDE of 19.4% at 1550 nm, which is the laser wavelength of our LIDAR system. The dark count rate (DCR) measurement results show that DCR levels of the proposed SPAD have a small effect on the ranging performance. The worst DCR (12.7 kcps) SPAD among the test samples is used. Furthermore, with the vehicle installations, the DCR is measured over a wide temperature range of 25–132 °C. The experiment demonstrates that target distances are successfully measured in the distance range of 50–180 cm.

Keywords: avalanche photodiodes; light detection and ranging (LIDAR); single-photon avalanche diode (SPAD); time-of-flight (TOF); depth sensor; rangefinder; 3-D imaging; single-photon detector; advanced driver assistance system (ADAS)

1. Introduction

Recently, advanced driver assistance systems (ADASs) have been designed and developed not only to make automobiles more comfortable, but also to reduce the number of traffic accidents [1]. Forward collision warning (FCW), autonomous emergency braking (AEB), and pedestrian detection, to cite a few examples, rely on various technologically advanced sensors. High-accuracy ranging sensors are particularly important components of ADASs. Among ranging sensor technologies, millimeter-wave RADARs and stereo-vision cameras remain the key sensors of choice. However, these sensors do have limitations, so a number of ADAS implementations rely on the data fusion of two or more sensors.

In this context, we have been developing an optical long-range sensor technology based on the time-of-flight (TOF) principle for next-generation ADASs [2–4]. This light detection and ranging (LIDAR) sensor offers a very good balance of overall performance in terms of spatial (image) resolution, field-of-view, precision, and depth range. In our LIDAR sensor, avalanche photodiodes operating in so-called Geiger mode have been employed as photodetectors (*i.e.*, optical receivers). The device, referred to as a single-photon avalanche diode (SPAD), is a highly sensitive photodetector capable of outputting a precise and digital trigger signal upon the detection of ultralow-power signals, down to

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Reply 20-21; Ex. 1032 (Takai), 1

Grounds 3-4, Motivation to Combine Borowski and Spector: PO Does Not Establish that SPADs Have Small Fill Factors

This paper presents a new SPAD structure to achieve a higher-performance, e.g., longer-range, higher-precision, and higher-measurement-rate, LIDAR system for future ADASs. In the proposed SPAD, two custom layers, p-SPAD and n-SPAD, are employed using the existing 0.18- μm CMOS technology. The doping concentrations of the customized layers are optimized to achieve a high electric field, while the p-type layer becomes fully depleted when the device is biased to operate in Geiger mode. This full-depletion layer enables the efficient collection of electrons generated by NIR light, without compromising the FF. Moreover, the p-epitaxial layer, which has a gradient doping profile, further enhances the NIR PDE.

In this study, various experiments are conducted to characterize the proposed SPAD. In SPAD PDE measurements, PDEs of 62.2% at 610 nm and 19.4% at 870 nm are attained. To the best of our knowledge, this is the highest PDE achieved for a CMOS SPAD under similar excess bias conditions, *i.e.*, 5 V. Moreover, the actual FF is measured by the special measurement system, and a high FF of 33.1% is obtained at 870 nm. Since SPAD sensitivity is characterized by the product of the PDE and FF, the proposed structure imparts the SPAD with higher NIR sensitivity, eliminating the PDE-FF tradeoff. The DCR levels of the proposed SPAD have only a small effect on the ranging performance, even when the worst SPAD among the test samples is used. The DCR measurement results at high temperature reveal new insight for actual vehicle installations. The ranging experiment demonstrates that target distances are successfully measured within an error of $\pm 2\%$. We believe that the proposed SPAD will pave the way for higher-performance LIDAR and ADAS systems.

Grounds 3-4, Motivation to Combine Borowski and Spector: PO Does Not Establish that SPADs Have Small Fill Factors

Although the SPAD is sensitive to a single photon, not all photons are detected. For example, photons that penetrate the SPAD are not detected. Also, photo-generated electrons do not always trigger an avalanche breakdown because it is a probabilistic process. Thus, a higher photon detection efficiency (PDE) is crucial for any sensing application. Until recently, CMOS SPAD technologies have shown a high PDE only in the visible light band. However, in the near-infrared (NIR) band between 800 nm and 1 μm , CMOS SPAD devices have exhibited rather low PDEs. For example, at the wavelength of interest in our application (870 nm), the PDEs have typically been below 5%. In order to increase the measurement range and/or rate of automotive LIDAR systems that generally employ NIR light sources, a much higher PDE in the NIR band is highly desirable. More generally, however, the ranging performance depends on the overall sensitivity, which, in turn, is characterized by the product of the PDE and the fill factor (FF) of the SPAD. Therefore, key to realizing a high-performance automotive LIDAR system is having both a high PDE in the NIR band and a high FF.

Significant improvements have recently been achieved in the NIR PDE [5,6]. For example, the current state-of-the-art PDE of 20% at 870 nm has been obtained with an excess bias (V_E) of 12 V [6]. Moreover, a fill factor of 21.6% has been reported [7]. This paper presents a new SPAD structure that achieves a similar PDE performance to that reported in [6], while also improving the sensitivity by optimizing the FF. Furthermore, the performance of this SPAD is described on the basis of various experimental results.

Grounds 3-4, Motivation to Combine Borowski and Spector: Vinogradov Does Not Support PO's Conclusion

In contrast, a 2D SPAD array/matrix could be applicable for a photon number resolving detection and it is considered as potentially an ideal photon detector due to the ability to readout every photon count timestamp asynchronously and independently due to direct access to every single SPAD in the array. Regretfully, even mature CMOS technology does not resolve a problem of a low fill factor (ratio of sensitive area to the total area occupied by electronics for active quenching of Geiger discharge) of the front-side SPAD arrays. For example, the recent development of MiSPIA (Microelectronic Single-Photon 3D Imaging Array) carried out by the world-recognized leaders in R&D of SPADs (Politecnico di Milano, Micro Photon Devices, Fraunhofer IMS) resulted in the fill factor of 3.14% for the 150 μm pitch 30 μm active area FrontSPAD array [20-21]. Regretfully, an attempt to eliminate the fill-factor problem by using backside illuminated SPAD technology with SOI substrate introduced prohibitively high dark count rate (DCR) of about 240 Kcps for a single pixel of the 150 μm pitch 143 μm active area BackSPAD array with the fill factor of 71.4% (about 40 times higher than DCR for the FrontSPAD). The better result (fill factor of 20% for the front-side SPAD array of 4x32 SPADs – so-called digital SiPM, dSiPM) has been reported by partially the same team (Politecnico di Milano, Micro Photon Devices) a year later [22].

Another approach to a SPAD array design has been demonstrated by Philips in their digital SiPM (dSiPM), where a direct access is provided to a sub-group of SPADs (sub-pixels of dSiPM) to reduce the number of electronic components and connections at the front-side area [23]. The fill factor of the dSiPM initially was achieved at the level of 50% (pixel size of 52 μm $\times$ 30 μm), i.e. about comparable with conventional analog SiPMs which fill factor is in a range of 30% - 80% depending on a pixel size. In the recent optimization of the dSiPM, the fill factor has been improved to 78% (pixel size of 59.4 μm $\times$ 64 μm) [24]. However, dSiPM technology is rather expensive and inflexible in scaling of the dSiPM dimensions and especially in producing arrays of dSiPMs due to large periphery occupied by electronics.

Grounds 3-4, Motivation to Combine Borowski and Spector: Vinogradov Does Not Support PO's Conclusion



Likewise, a given course of action often has simultaneous advantages and disadvantages, and this does not necessarily obviate motivation to combine. See [*Winner Int'l Royalty Corp. v. Wang*, 202 F.3d 1340 (Fed. Cir. 2000)] at 1349 n. 8 ("The fact that the motivating benefit comes at the expense of another benefit, however, should not nullify its use as a basis to modify the disclosure of one reference with the teachings of another. Instead, the benefits, both lost and gained, should be weighed against one another.").

Medichem, S.A. v. Rolabo, S.L., 437 F.3d 1157, 1165 (Fed. Cir. 2006)

Grounds 3-4, Motivation to Combine Hall and Borowski: Summary of Dispute

Petitioner's Arguments

The Petition provides multiple reasons why a POSITA would combine Hall and Borowski

PO's "teaching away" argument is legally incorrect

PO's vague concerns about noise does not render the references uncombinable

Patent Owner's Arguments

Hall teaches away from SPADs because it discloses APDs as photodetectors

A POSITA would not be motivated to use SPADs in Hall's system because Hall is "noisy"

Grounds 3-4, Motivation to Combine Hall and Borowski: Argument in the Petition

Second, a POSITA would have been motivated to modify Hall to incorporate SPAD arrays in view of Borowski. Ex. 1003 ¶¶189-190. Hall acknowledges that in existing LiDAR systems, the “detection of return signals includes significant sources of measurement noise that are exacerbated as measurement ranges are extended,” and that conventional solutions required “increasing laser pulse intensity.” Ex 1008, 2:27-33. Improvements are thus needed for “power management ... while maintaining sufficiently high levels of imaging resolution and range.” *Id.*, 2:46-48. Borowski teaches that SPADs can solve problems with light intensity because they “provide[] significant carrier amplification.” Ex. 1009, [0035]. Borowski further teaches that using a “cluster” of SPAD detector cells whose outputs are multiplexed and averaged is advantageous because the “programmed macro-cell ... acts as the equivalent of a single ‘perfect’ SPAD having no recovery time.” *Id.*, [0053]. A POSITA would have thus understood that using clusters of SPADs for LiDAR detection can improve detection at longer ranges and at lower light intensities. Ex. 1003 ¶¶189-190.

Hall expressly identifies a problem that Borowski’s SPAD arrays solve

Pet. 57; Ex. 1003 (Shanley Decl.) ¶¶ 189-190

Grounds 3-4, Motivation to Combine Hall and Borowski: Hall's Disclosure of APDs Does Not Teach Away from SPADs

Petitioner's argument that there is no motivation to combine because Hall discloses APDs is legally incorrect



Thus, the “mere disclosure of alternative designs does not teach away.” ... This court has further explained that just because better alternatives exist in the prior art does not mean that an inferior combination is inapt for obviousness purposes.

In re Mouttet, 686 F.3d 1322, 1332-33 (Fed. Cir. 2012)

Grounds 3-4, Motivation to Combine Hall and Borowski: Hall's Disclosure of APDs Does Not Teach Away from SPADs



When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try might show that it was obvious under § 103.

KSR Int'l Co. v. Teleflex Inc., 550 U.S. 398, 422 (2007)

Grounds 3-4, Motivation to Combine Hall and Borowski: PO's "Noise" Arguments Lack Support

PO's vague allusion to "noise" in Hall does not render Hall and Borowski "incompatible"

- No evidence that Hall's system is particularly noisy**
- No evidence that the amount of noise in Hall's system would render SPADs inoperable**
- No evidence that a POSITA would not be capable of mitigating noise**

Grounds 3-4, Motivation to Combine Hall and Borowski: Hall's Disclosure of "Noise":

Existing LIDAR systems employ a beam of light to interrogate a particular volume of the surrounding environment at any given time. The detection of return signals includes significant sources of measurement noise that are exacerbated as measurement ranges are extended. In many applications, the signal to noise ratio of measured signals is improved by increasing laser pulse intensity.

Grounds 3-4, Motivation to Combine Hall and Borowski: PO's "Noise" Arguments Lack Support

Dr. Shanley identifies numerous well-known techniques for mitigating noise in optical systems

53. Unwanted stray light can reduce the contrast of images and reduce the sensitivity of detection systems. There are a number of well-known ways to reduce the impact of stray light, including the following:

- Black paint: using black anodized surfaces or absorptive black paint on all optical mounting surfaces.
- Optical filters: filters that only allow light at certain wavelengths (*e.g.*, signal light from the transmitter) to pass through the system. Depending on system requirements, these can pass either a narrow- or wide-band width.
- Reduced apertures: limits the amount of light reaching the detector from surrounding reflections.
- Baffles: obstacles placed in the optical path that prevent light from propagating where it is not wanted.
- Absorptive filters: placed in front of the detectors to absorb unwanted stray light and can help to reduce the effects of scattered light, which can cause veiling glare.

56. Other than reducing the density of the SPAD array—which has the disadvantage of either increasing the size of the device, or reducing the number of SPADs (and thus the sensitivity/accuracy)—several techniques are known and employed to minimize optical cross-talk. These techniques are typically designed to reduce the likelihood that a photon from one channel or one SPAD will be detected at an adjacent channel or SPAD. For example, to prevent incoming light at one detector channel from bleeding into an adjacent channel, apertures may be provided on the surface of the device or the surface of the SPAD array, reducing the field of view of individual detectors so that light from adjacent channels is less likely to be received.

Grounds 3-4, Motivation to Combine Hall and Borowski: PO's "Noise" Arguments Lack Support

Hall, Spector, Borowski, and related references all disclose techniques for reducing noise at the photosensor

elements 113. In some embodiments, one or more of the optical elements of collection optics 116 is constructed from one or more materials that absorb light outside of a predetermined wavelength range that includes the wavelengths of light emitted by each of the array of light emitting elements 114. In one example, one or more of the lens elements are constructed from a plastic material that includes a colorant additive to absorb light having wavelengths less than infrared light generated by each of the array of light emitting elements 114. In one example, the colorant is Epolight 7276A available from Aako BV (The Netherlands). In general, any number of different colorants can be added to any of the plastic lens elements of collection optics 116 to filter out undesired spectra.

Ex. 1008 (Hall), 7:13-27

[0053] Local DSPs are integrated into clusters of several SPAD detector cells between neighboring SPAD detector cells. Such a cluster is programmed in size and shape to perform various operations mainly for multiplexing and averaging the detected events of the SPAD detector cells of the said programmed macro-cell that acts as the equivalent of a single "perfect" SPAD having no recovery time.

Ex. 1009 (Borowski), [0053]

By making use of a two dimensional array of isolated light spots and individual optical detection sites in one-to-one correspondence with those spots, cross-talk and multipath signal are advantageously reduced. Moreover, a much smaller scanning motion is required, thereby permitting the use of smaller and/or simpler and less expensive scanning mechanisms. To complete a scan of the scene, the arrayed micro-optic and the receiver optics only have to be scanned the distance between illumination spots.

Ex. 1005 (Spector), 6:11-20

[0205] In another embodiment of the present invention, the SPAD sensor array comprises means for applying a global blanking of light pulse reception within the detectors to extend the acquisition distances and to add noise mitigation capabilities. At least a first step of a progressive scanning is initiated first. The resulting knowledge of the approximate distance of the targets in the scene allows the correct selection of the optimal blanking period duration during non-landscape, non security measurement phase. During the period of the blanking, no external light or internal noise pulse could trigger an avalanche.

Ex. 1025 (Borowski-838), [0205]

Reply 24-25

Grounds 3-4, Motivation to Combine Hall and Borowski: PO's "Noise" Arguments Lack Support

Contemporaneous references demonstrate that SPADs may be used in LiDAR systems and are not rendered "inoperable" by noise

This paper presents a new SPAD structure to achieve a higher-performance, e.g., longer-range, higher-precision, and higher-measurement-rate, LIDAR system for future ADASs. In the proposed SPAD, two custom layers, p-SPAD and n-SPAD, are employed using the existing 0.18- μm CMOS technology. The doping concentrations of the customized layers are optimized to achieve a high electric field, while the p-type layer becomes fully depleted when the device is biased to operate in Geiger mode. This full-depletion layer enables the efficient collection of electrons generated by NIR light, without compromising the FF. Moreover, the p-epitaxial layer, which has a gradient doping profile, further enhances the NIR PDE.

In this study, various experiments are conducted to characterize the proposed SPAD. In SPAD PDE measurements, PDEs of 62.2% at 610 nm and 19.4% at 870 nm are attained. To the best of our knowledge, this is the highest PDE achieved for a CMOS SPAD under similar excess bias conditions, *i.e.*, 5 V. Moreover, the actual FF is measured by the special measurement system, and a high FF of 33.1% is obtained at 870 nm. Since SPAD sensitivity is characterized by the product of the PDE and FF, the proposed structure imparts the SPAD with higher NIR sensitivity, eliminating the PDE-FF tradeoff. The DCR levels of the proposed SPAD have only a small effect on the ranging performance, even when the worst SPAD among the test samples is used. The DCR measurement results at high temperature reveal new insight for actual vehicle installations. The ranging experiment demonstrates that target distances are successfully measured within an error of $\pm 2\%$. We believe that the proposed SPAD will pave the way for higher-performance LIDAR and ADAS systems.

Reply 25-26; Ex. 1032 (Takai), 8

Grounds 3-4, Motivation to Combine Hall and Borowski: PO's "Noise" Arguments Lack Support



Likewise, a given course of action often has simultaneous advantages and disadvantages, and this does not necessarily obviate motivation to combine. See [*Winner Int'l Royalty Corp. v. Wang*, 202 F.3d 1340 (Fed. Cir. 2000)] at 1349 n. 8 ("The fact that the motivating benefit comes at the expense of another benefit, however, should not nullify its use as a basis to modify the disclosure of one reference with the teachings of another. Instead, the benefits, both lost and gained, should be weighed against one another.").

Medichem, S.A. v. Rolabo, S.L., 437 F.3d 1157, 1165 (Fed. Cir. 2006)

Grounds 1-2, Cls. 21, 26 (“stop region”): Summary of Dispute

Petitioner’s Arguments

PO’s new claim construction improperly imports a limitation from an embodiment

Droz’s “absorbing layers” 368 and 378 provide a “stop region” even under PO’s construction

Patent Owner’s Arguments

“stop region” should be construed as “an optically non-transparent region that defines a field of view for a photosensor”

Droz’s “absorbing layers” are not a “stop region”

Grounds 1-2, Cls. 21, 26 (“stop region”): Claim Language

a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and an optical filter disposed between the bulk receiver optic and the plurality of photosensors and configured to allow a band of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the filter to the plurality of photosensors while blocking radiation outside the band from reaching the plurality of photosensors; and

Ex. 1001 ('405 Patent), cl. 21

a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and one or more optical filters disposed between the bulk receiver optic and the plurality of photosensors, each of the one or more optical filters configured to allow a set of wavelengths of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the one or more optical filters while blocking radiation outside that set; and

Ex. 1001 ('405 Patent), cl. 26

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect

Patent Owner’s Proposed Construction

“stop region” should be construed as “an optically non-transparent region that defines a field of view for a photosensor”

Additional language is drawn from an exemplary embodiment:

An input aperture layer 1740 including an optically transparent aperture 1744 and optically non-transparent stop region 1746 configured to define a narrow field of view when placed at the focal plane of an imaging optic such as bulk receiver optic 202 or 1008 (shown in FIGS. 2 and 10, respectively; not shown in FIG. 17). Aperture

Ex. 1001 ('405 patent), 37:17-23

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect



It is not enough for a patentee to simply disclose a single embodiment or use a word in the same manner in all embodiments, the patentee must “clearly express an intent” to redefine the term. ... It is likewise not enough that the only embodiments, or all of the embodiments, contain a particular limitation. We do not read limitations from the specification into claims; we do not redefine words.

Thorner v. Sony Comp. Entm’t Am. LLC, 669 F.3d 1362, 1365-66 (Fed. Cir. 2012)

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect

Numerous other embodiments disclose “stop regions” that are not limited to “defining a field of view”

FIG. 18A is a simplified cross-sectional view diagram of a different embodiment 1800 where aperture layer 1840 has two apertures 1844. Both the optically transparent apertures 1844 and corresponding optically non-transparent optical stop regions 1846 are supported on an optically transparent substrate 1845. Bottom aperture 1844 can be smaller and be

Ex. 1001 ('405 patent), 38:44-47

FIG. 18C is a simplified cross-sectional view diagram of an embodiment 1802 of aperture layer 1840 consisting of multiple optically non-transparent stop regions 1846 that are supported on optically transparent substrate 1845. These layers (stop regions 1846) follow the contour of marginal light rays (not shown, but similar to light rays 1733 in FIG. 17) to reduce stray light into the receiver channel. Optically

Ex. 1001 ('405 patent), 38:66-39:2

2055. Aperture 2049 defines the maximal cylinder of light desired to be passed into optical filter layer 2060 by optical filter 2061, and stop region 2063 an absorb or reflect any incident stray light outside the diameter of aperture 2049. Aperture 2054 defines the maximal cylinder of light desired to be passed out of optical filter layer 2060 and stop region 2055 absorbs or reflects any incident stray light outside the diameter of aperture 2054. Optical filters 2061 can be supported on an optically transparent substrate 2065.

Ex. 1001 ('405 patent), 40:56-63

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect

A stop region may prevent light from travelling between adjacent channels

FIG. 20D is a simplified cross-sectional view diagram of an embodiment 2003 of filter layer 2060 for a receiver channel, according to some embodiments of the present disclosure. Optical filter layer 2060 can include multiple optically transparent substrates 2065, and multiple optically non-transparent aperture layers between them in an alternating order. FIG. 20D shows an additional aperture 2049 and corresponding optically non-transparent stop region 2063 positioned on top of optical filter 2061 and supported by optically transparent substrates 2065. Aperture 2049 can define the maximal cylinder of light desired to be passed into optical filter layer 2060 by optical filter 2061, and stop region 2063 absorbs or reflects any incident stray light outside diameter of aperture 2049. FIG. 20D shows an additional aperture 2054 and corresponding optically non-transparent stop region 2055 positioned between optical filter layer 2060 and a photosensor layer (not shown, but similar to photosensor layer 1770 in FIG. 17). Aperture 2054 can define the maximal cylinder of light desired to be passed out of optical filter layer 2060 toward the photosensor, and stop region 2055 can absorb or reflect any incident stray light outside the diameter of aperture 2054. Collectively, these interleaved layers prevent stray light in one optical filter layer 2060 from traveling into an optical filter region of an adjacent receiver channel in a multi receiver channel system.

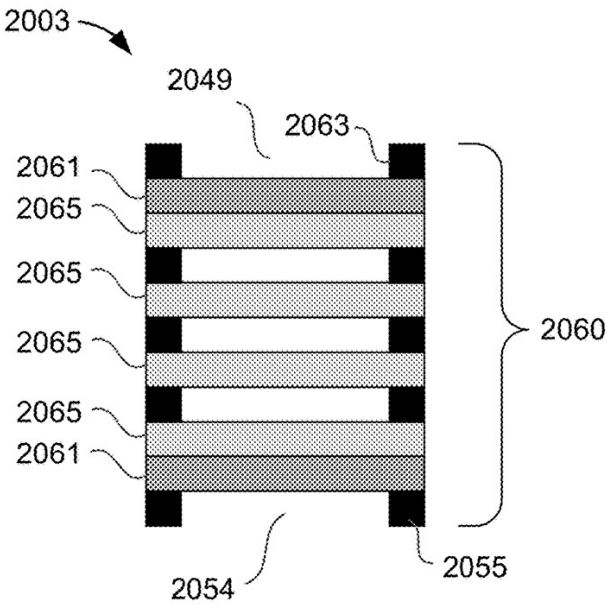
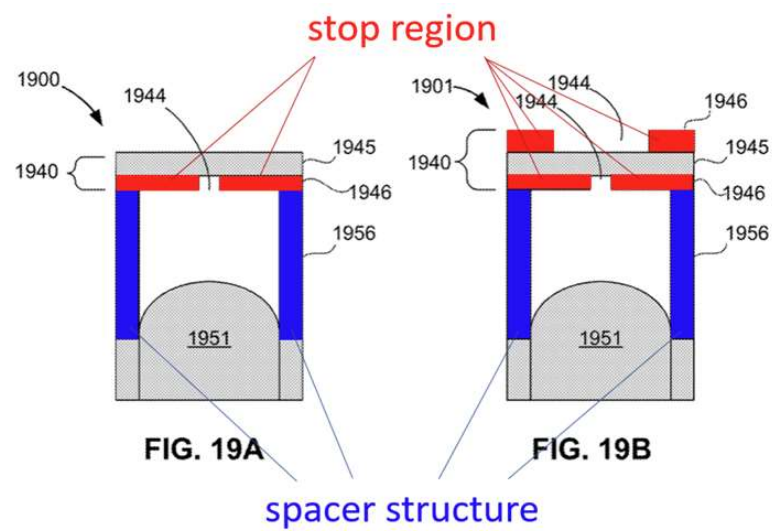


FIG. 20D

Reply 4; Ex. 1001 ('405 patent), 41:7-29, Fig. 20D

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect

PO's counterexamples are incorrect



The “spacer structures” are not stop regions because they are not in the aperture layer

Reply 4; POR 28-29; Ex. 1001 ('405 patent), Figs. 19A-19B

Grounds 1-2, Cls. 21, 26 (“stop region”): Claim Language

a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and an optical filter disposed between the bulk receiver optic and the plurality of photosensors and configured to allow a band of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the filter to the plurality of photosensors while blocking radiation outside the band from reaching the plurality of photosensors; and

Ex. 1001 ('405 Patent), cl. 21

a light sensing module coupled to the platform and comprising a bulk receiver optic, an aperture layer comprising a plurality of apertures separated by a stop region, a plurality of photosensors operable to detect photons emitted from the plurality of optical emitters and received through the bulk receiver optic after being reflected from surfaces within the field, and one or more optical filters disposed between the bulk receiver optic and the plurality of photosensors, each of the one or more optical filters configured to allow a set of wavelengths of radiation, including an operating wavelength of the plurality of optical emitters, to pass through the one or more optical filters while blocking radiation outside that set; and

Ex. 1001 ('405 Patent), cl. 26

Grounds 1-2, Cls. 21, 26 (“stop region”): PO’s Proposed Construction Is Incorrect

PO’s extrinsic evidence does not define the term “stop region”

2.2 Stops and Pupils

We begin with a discussion of an often neglected but vital aspect of optical systems, the concept of the *aperture stop*. In every optical system there is some feature, usually a diameter, which limits the size or diameter of the beam of rays which can pass through the system. If the system consists of just a single simple lens, the aperture stop is just the clear aperture of the lens. In a typical camera lens the iris diaphragm is the aperture stop. In a telescope the clear aperture of the objective lens (or that of the primary mirror) is ordinarily the aperture stop. Often the aperture stop is referred to simply as “the stop.”

Image Brightness: Aperture Stops and Pupils

Aperture Stop (AS) The *aperture stop* of an optical system is the actual physical component that limits the size of the *maximum cone* of rays—from an axial object point to a conjugate image point—that can be processed by the entire system. Thus it controls the brightness of the image. The diaphragm of a camera and the iris of the human eye are examples of aperture stops. Another example is found in the telescope, in which the first, or objective, lens determines how much light is accepted by the telescope to form a final image on the retina of the eye.

Reply 4-5; POR 30-31; Ex. 2013, 49; Ex. 2007, 21

Grounds 1-2, Cls. 21, 26 (“stop region”): Droz Discloses a Stop Region

No dispute that if PO’s proposed construction is rejected, Droz discloses the limitation

Each waveguide receives a portion of light 302 on an input side of the waveguide (side 360a) and guides the light toward and out of an output end of the waveguide (side 360b). *Id.*, 14:4-17. Light detectors (*e.g.*, light detector arrays 310, 316, and 318) are “positioned adjacent to the output end” of a waveguide “to intercept and detect” light guided through that waveguide. *Id.*, 14:11-17. “[E]ach respective input end of the waveguides in array 360 may correspond to a respective aperture of system 300.” *Id.*, 16:18-21. When applied to Pacala’s LiDAR device, Droz’s waveguide array would provide a plurality of apertures (the input ends of the waveguides). Ex. 1003 ¶¶150-151. Droz also teaches that a layer of light-absorbing material (*e.g.*, absorbing layers 368 and 378) is provided between waveguides to absorb leakage from one waveguide to an adjacent waveguide. Ex. 1006, 13:39-43, 14:47-60. The light-absorbing material comprises a stop region separating the apertures. Ex. 1003 ¶151.

**Grounds 1-2, Cls. 21, 26 (“stop region”):
Droz Discloses a Stop Region Under PO’s Construction**

Droz expressly discloses an “aperture” surrounded by “opaque material” that defines a field of view

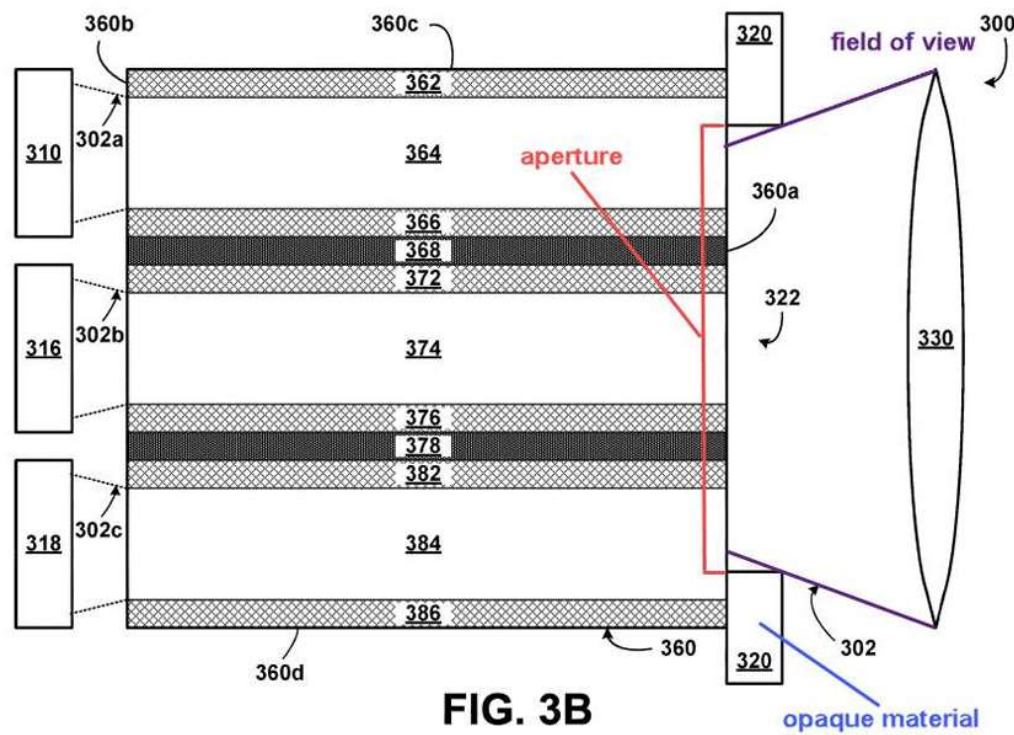


FIG. 3B

Reply 7; Ex. 1006 (Droz) 13:61-66, Fig. 3B

**Grounds 1-2, Cls. 21, 26 (“stop region”):
Droz Discloses a Stop Region Under PO’s Construction**

In a fourth embodiment, opaque material **320** can be omitted from system **300**. With this arrangement for instance, each respective input end of the waveguides in array **360** may correspond to a respective aperture of system **300**.

12 And so the total aperture is the cladding
13 layer plus that -- it's 272, 274, and 276. And now
14 part of the light's going to be reflected and guided
15 by the index of refraction chosen for that cladding
16 layer, so that the right, appropriate wavelengths will
17 go to the detector. And then part of it will be
18 directed so that it's absorbed by the black layer of
19 unwanted radiation.

Ex. 2017 (Shanley Reply Dep.), 13:12-19

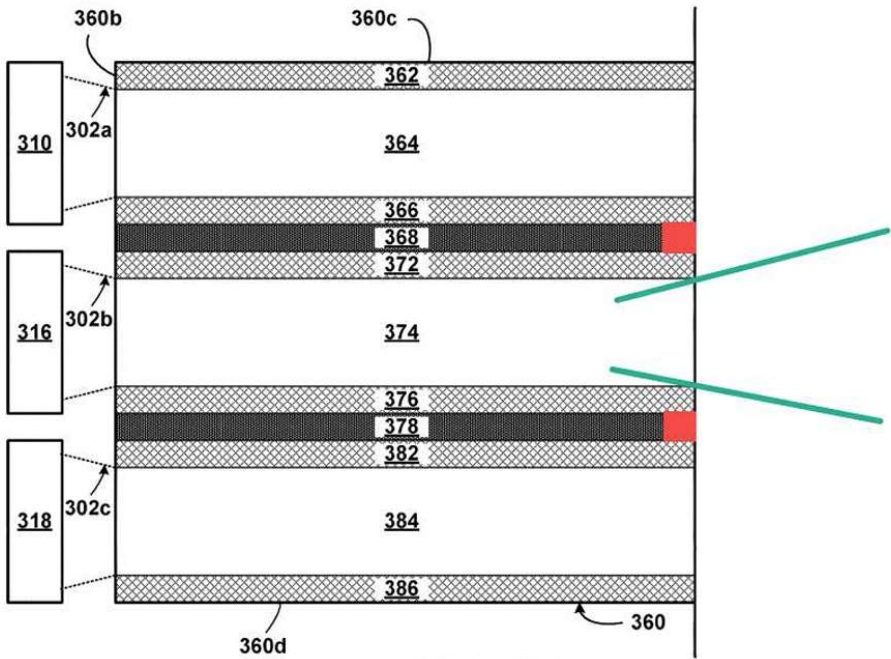


FIG. 3B

Reply 8; Ex. 1006 (Droz) 16:18-21, Fig. 3B (modified)

Grounds 1-2, Motivation to Combine Pacala and Droz: Summary of Dispute

Petitioner's Arguments

The Petition provides multiple reasons why a POSITA would combine Pacala and Droz

PO raises improper “bodily incorporation” arguments

PO misstates Dr. Shanley’s testimony

Patent Owner's Arguments

Droz’s waveguides are too large and heavy to incorporate in Pacala’s system

The combination is outside the level of skill of a POSITA

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Bodily Incorporation Argument is Legally Incorrect

PO's argument is premised on a flawed bodily incorporation theory

guide arrays. (Pet. at 18-20.) Petitioner and its expert have ignored the substantial differences between the Pacala and Droz systems and the potentially insurmountable challenge presented by attempting to incorporate the waveguides of Droz into the Pacala system. These problems, as explained below, refute any motivation to combine. *See Sound View Innovations, LLC v. Hulu, LLC*, 818 F. App'x 1009, 1013 n.3 (Fed. Cir. 2020) (“The impracticality of the prior art combination may be a factor in determining whether there would have been a motivation to combine.”).

Obviousness does not require Petitioner to establish how to “incorporate” one reference into another

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Bodily Incorporation Argument is Legally Incorrect



Contrary to Allied's position, “it is not necessary that [Caterpillar and Ogawa] be physically combinable to render obvious the ['489 patent].” ... “The test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference,” ... but rather whether “a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention.”

Allied Erecting & Dismantling Co. v. Genesis Attachments, 825 F.3d 1373, 1381 (Fed. Cir. 2016)

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Bodily Incorporation Argument is Legally Incorrect



Ultimately, however, it does not matter whether Okubo teaches cellular transmission or merely DGPS transmission, because Konishi undisputedly discloses a cellular network. "[I]t is not necessary that [two pieces of prior art] be physically combinable to render obvious" the asserted patent. ... Rather, the question is "whether the claimed inventions are rendered obvious by the teachings of the prior art as a whole." *In re Etter*, 756 F.2d 852, 859 (Fed. Cir. 1985) (noting that whether one prior art reference can be incorporated into another is "basically irrelevant.").

Uber Techs., Inc. v. X One, Inc., 957 F.3d 1334, 1341 (Fed. Cir. 2020)

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Bodily Incorporation Argument is Legally Incorrect



It is well-established that a determination of obviousness based on teachings from multiple references does not require an actual, physical substitution of elements. ... Rather, the test for obviousness is what the combined teachings of the references would have suggested to those having ordinary skill in the art. ... The Board properly found that an electrical engineer with several years of related industry experience would indeed have recognized that Falk's arithmetic processor could have been combined with Das's wired crossbar array to predictably yield Mouttet's claimed computing device.

In re Mouttet, 686 F.3d 1322, 1332-33 (Fed. Cir. 2012)

**Grounds 1-2, Motivation to Combine Pacala and Droz:
PO's Bodily Incorporation Argument is Legally Incorrect**

- **The claims do not require a particular size or weight**
- **The prior art is not limited to specific sizes or weights**
- **No evidence that Pacala must be small or that Droz must be large or heavy**

Petitioner is not required to describe how to build a real-world system in order to establish that the combination is obvious

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Misstates Dr. Shanley's Testimony

Dr. Shanley testified that a team would typically design a real world system

6 **A. They could do that analysis –**

7 Let me caveat that by saying: If they
8 came to me and said design this system, then the
9 answer is yes, I could do that analysis. Okay? And a
10 POSITA could do that, also.

11 But you have to remember that usually the
12 way these things are done is that there's a team of
13 people, and there's the system guy who sets all the
14 requirements, and he sort of runs the whole program.
15 And then there's the optics guy saying, "Well, you've
16 got to design optics for such-and-such a thing." And
17 the electrical engineering guy says, "Okay, this is
18 going to be my focal plane. This is going to be my
19 laser. These are my electronic requirements." And
20 then there's the mechanical guy, that says, "Okay, you
21 guys, give me all that stuff and then I'll wrap my
22 metal around it and design all the housing and stuff

1 like that."

2 So each of these areas in the team would
3 understand the overall systems part of it and then how
4 to craft this into a unique operating, functioning
5 system.

Reply 12-13; Ex. 2011 (Shanley Dep.), 57:6-58:5

Grounds 1-2, Motivation to Combine Pacala and Droz: PO's Misstates Dr. Shanley's Testimony

An engineer fresh out of school could use a CAD system to combine Pacala and Droz

4 A. Oh. Yeah. Oh, yeah. I mean, myself, today,
5 I myself can run the CAD programs and top-level. But
6 a mechanical engineer out of school or an optical
7 engineer or an electrical engineer, they all can run
8 these programs that does it.

9 And basically, between the optical CAD and
10 the mechanical CAD, it talks about how you wrap metal
11 around these objects once you've done your optical
12 design. It gives you the whole list of materials and
13 all the parameters associated with the materials and
14 the optics. And then the same thing happens with the
15 CAD programs. And then there's interfaces that marry
16 the two. And you can get all this information, just
17 drops out.

18 So you'll get the form, fit, and function,
19 including weight and all this right out of those
20 systems.

Reply 12-13; Ex. 2011 (Shanley Dep.), 56:4-20

Secondary Considerations of Nonobviousness: Summary of Dispute

Patent Owner's Arguments

There was industry skepticism about using SPADs in LiDAR devices

Others failed to incorporate SPADs into LiDAR devices

Petitioner's Arguments

PO offers no evidence of “industry skepticism” regarding SPADs, and the evidence contradicts PO's assertion

Numerous papers demonstrated that SPADs could be used in LiDAR systems before the '405 patent

Secondary Considerations of Nonobviousness: Industry Skepticism

PO's only evidence of “industry” skepticism is a design choice Petitioner's expert made in 2008

Dr. Shanley testified that while he was aware of SPADs as of the 1990s, he never incorporated them into a system, including any of the LIDAR systems he worked on. (EX2011 (Shanley depo transcript), 12:18-22, 14:13-15:4.) For example, Dr. Shanley testified that for one LIDAR system he worked on, he specifically recalls considering using SPADs as the photodetectors in the system—but he ultimately chose to use photodiodes instead of SPADs. (*Id.*, 16:20-17:1.) Dr. Shanley testified that his team rejected SPADs because “[w]e didn’t have the volume and the power required at that point, and we wanted a simple system.” (*Id.*, 17:2-5.) Additionally, Dr. Shanley testified that his team need a photodetector that was “very simple” and “very fast and very quick and very reliable”—and SPADs did not fit the brief. (*Id.*, 18:10-15.) Dr. Shanley testified that his team chose photodiodes instead, because they were “cheap” and an “off-the-shelf array.” (*Id.*, 17:6-12.) In other words, Dr. Shanley testified that though he and his team knew about SPADs prior to the '405 patent, they did not use SPADs in LIDAR systems due to concerns about their disadvantages, including size requirements, power requirements, complexity, cost, lack of ease of use, lack of reliability, and lack of availability. This is clear evidence that there was significant industry skepticism about the use of SPADs in a LIDAR system, which the challenged claims of the '405 patent require.

Secondary Considerations of Nonobviousness: Industry Skepticism

Petitioner presented extensive evidence that others actively pursued the use of SPADs in LiDAR systems for years before the '405 patent

MIT Lincoln Laboratory is developing laser and detector technologies that make it possible to build a three-dimensional laser radar (3D ladar) with several attractive features, including capture of an entire 3D image on a single laser pulse, tens of thousands of pixels, high frame rate, few-centimeter range resolution, and small size.¹⁻⁶ The laser technology is based on diode-pumped solid-state microchip lasers that are passively Q-switched.⁵ The detector technology is based on arrays of avalanche photodiodes (APDs) operating in Geiger mode, with integrated timing circuitry for each pixel.⁷⁻⁹

■ABSTRACT■ We are developing automotive light detection and ranging (LIDAR) sensing technologies based on both CMOS single-photon avalanche diodes (SPADs) and optical scanning systems. CMOS SPADs are highly sensitive detectors that can detect single photons and can form dense pixel arrays. These characteristics offer significant benefits for high-resolution detection. However, SPADs have the disadvantage of being oversensitive to background light due to their digital binary output. An attempt was made to overcome the adverse effect of beam thinning when the reflected reduce background light by detecting only for a limited time and area. scanning system with a one-dimensional SPAD array, pedestrians can be e 50 m. To the best of our knowledge, this is the first real-time CMOS SP existence. We are also developing a MEMS mirror-scanned LIDAR using

Ex. 1029 (Matsubara), 1

Ex. 1028 (Marino), 2

This paper presents a new SPAD structure to achieve a higher-performance, e.g., longer-range, higher-precision, and higher-measurement-rate, LIDAR system for future ADASs. In the proposed SPAD, two custom layers, p-SPAD and n-SPAD, are employed using the existing 0.18-μm CMOS technology. The doping concentrations of the customized layers are optimized to achieve a high electric field, while the p-type layer becomes fully depleted when the device is biased to operate in Geiger mode. This full-depletion layer enables the efficient collection of electrons generated by NIR light, without compromising the FF. Moreover, the p-epitaxial layer, which has a gradient doping profile, further enhances the NIR PDE.

Ex. 1032 (Takai), 8

Reply 27-28

Secondary Considerations of Nonobviousness: Failure of Others

PO relies exclusively on Vinogradov's lack of awareness of SPAD-based LiDAR receivers

Therefore, to the best of the author's knowledge, there are no attempts either to implement SPAD arrays or dSiPMs as a single photon number resolving LIDAR receiver or to combine an array of SPAD arrays or dSiPMs as a focal plane array of photon number resolving detectors in 3D imaging LIDARs. In this situation, detailed analysis of the SPAD-based receivers is out of the scope of this paper.

Secondary Considerations of Nonobviousness: Failure of Others

37. Second, the Vinogradov paper does not claim to have performed a comprehensive survey of the literature or the field in order to determine whether or not the use of SPADs in LiDAR devices was successful. The paper only discusses two projects: the MiSPiA project, citing to papers published in the 2013-2015 time frame, and a project undertaken by Philips, citing to papers published in 2009 and 2012. Ex. 2014 (Vinogradov paper) at 3. Based on these two examples, the author concludes that “to the best of [his] knowledge, there are not attempts either to implement SPAD arrays or dSiPMs as a single photon number resolving LIDAR receiver or to combine an array of SPAD arrays or dSiPMs as a focal plane array of photon number resolving detectors in 3D imaging LIDARs.” Ex. 2014 (Vinogradov Paper) at 4. The paper does not discuss any other research relating to SPADs and LiDAR systems, including the research and inventions discussed in Droz (Ex. 1006), Borowski (Ex. 1009), Marino (Ex. 1028), Matsubara (Ex. 1029), or Takai (Ex. 1032). Indeed, the paper acknowledges that a “detailed analysis of the SPAD-based receivers is *out of the scope of this paper*.” Ex. 2014 (Vinogradov Paper) at 4.

Reply 28-29; Ex. 1033 (Shanley Reply Decl.) ¶137