

## **DOCUMENT MADE AVAILABLE UNDER THE PATENT COOPERATION TREATY (PCT)**

International application number:	<b>PCT/US2020/025042</b>
International filing date:	<b>26 March 2020 (26.03.2020)</b>
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Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-bis)

1064139



**THE UNITED STATES OF AMERICA**

**TO ALL TO WHOM THESE PRESENTS SHALL COME:**

**UNITED STATES DEPARTMENT OF COMMERCE**

United States Patent and Trademark Office

*May 17, 2020*

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.**

**APPLICATION NUMBER: 62/849,807**

**FILING DATE: *May 17, 2019***

**RELATED PCT APPLICATION NUMBER: *PCT/US20/25042***

**THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/849,807***



Certified by

Under Secretary of Commerce  
for Intellectual Property  
and Director of the United States  
Patent and Trademark Office

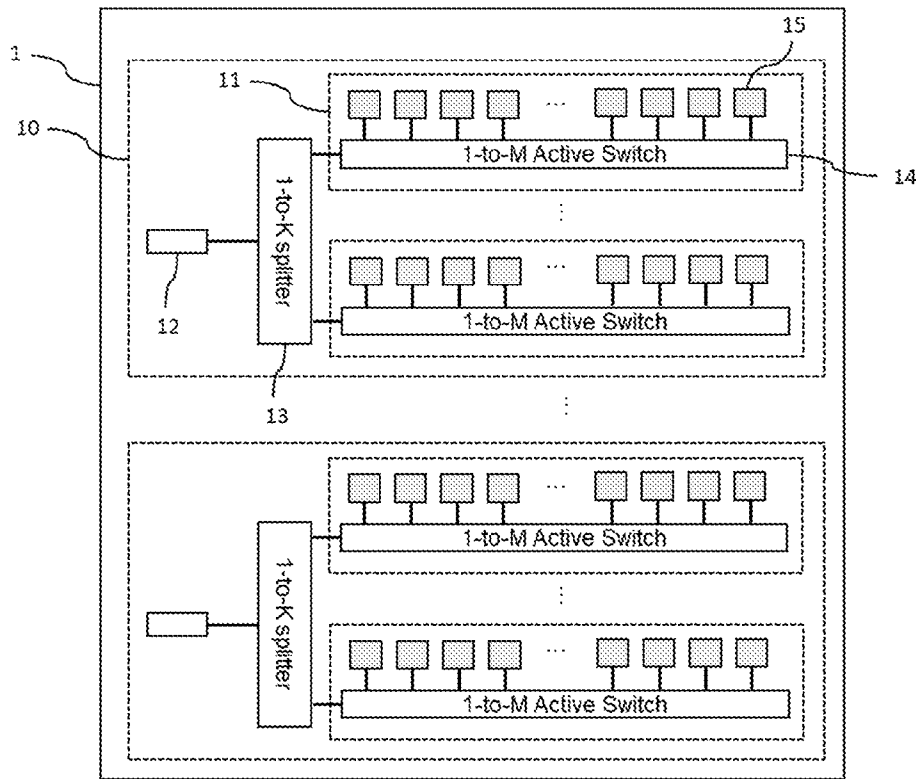


Figure 1

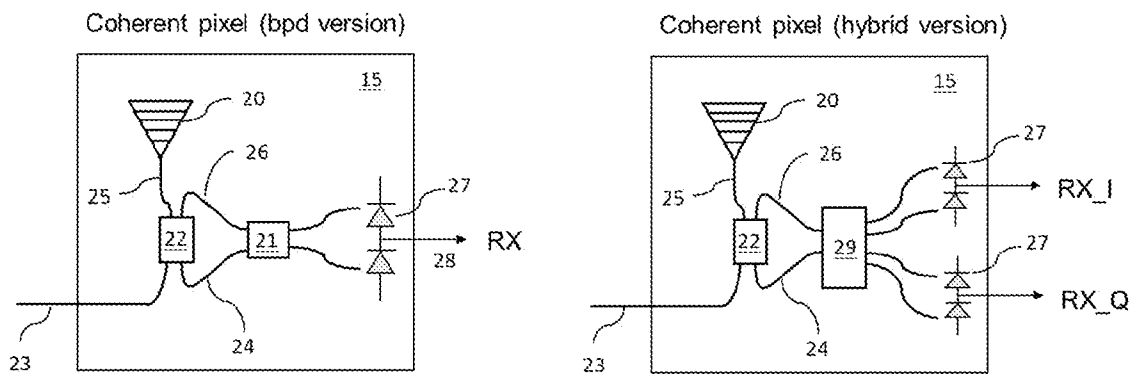


Figure 2

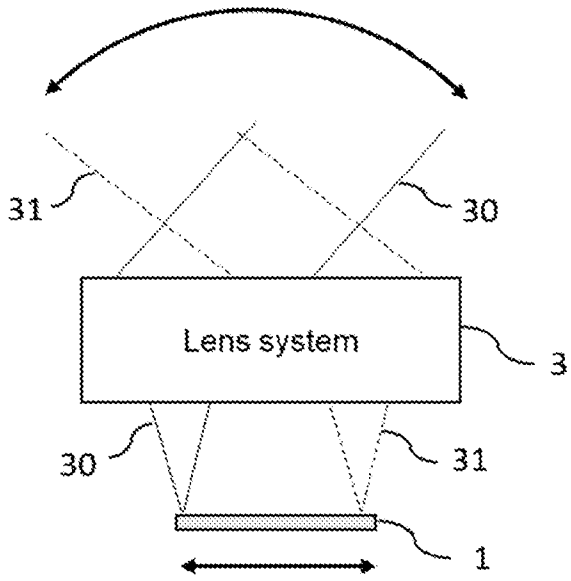


Figure 3

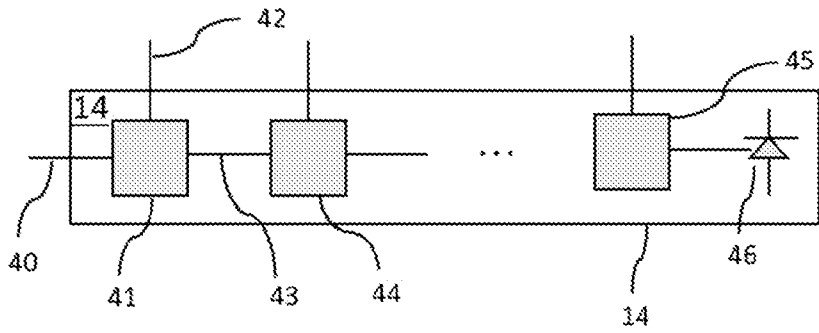


Figure 4

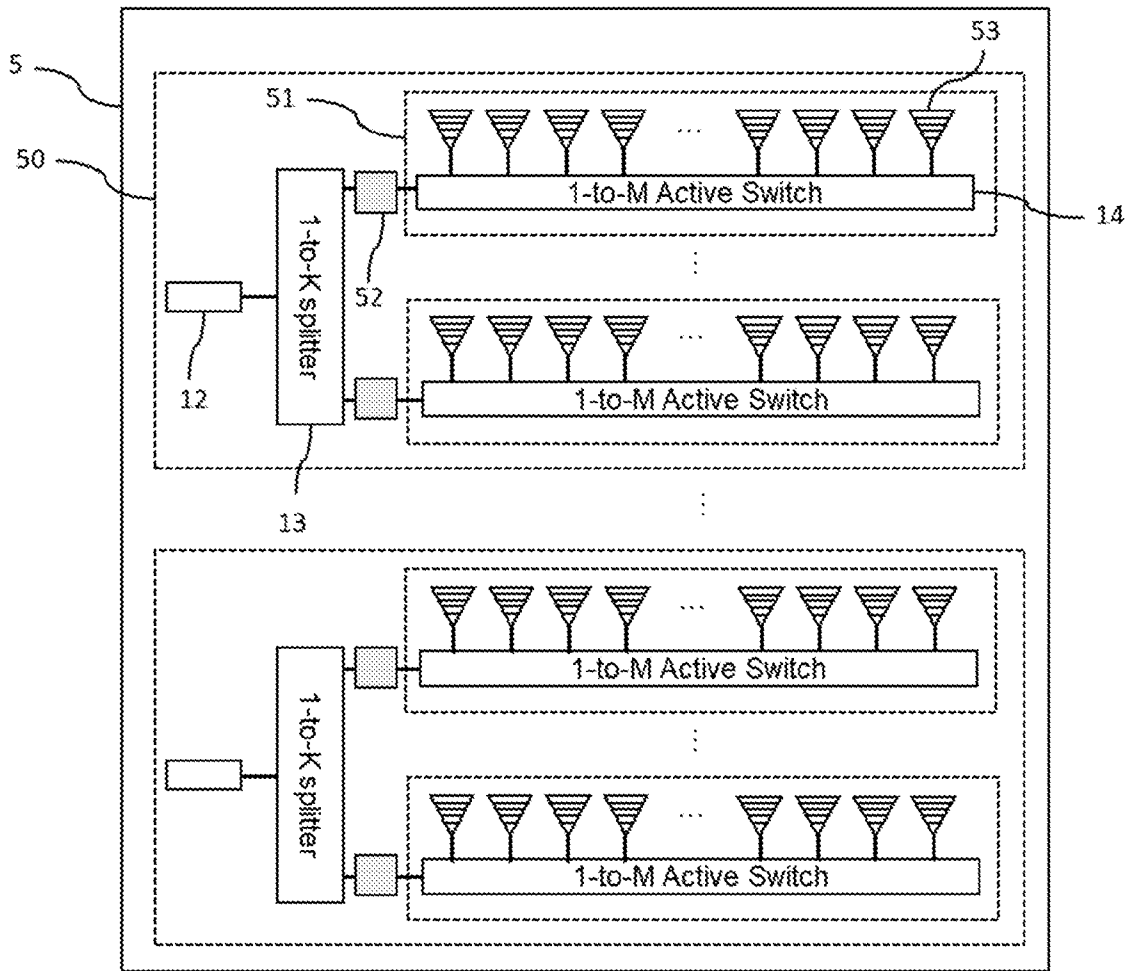
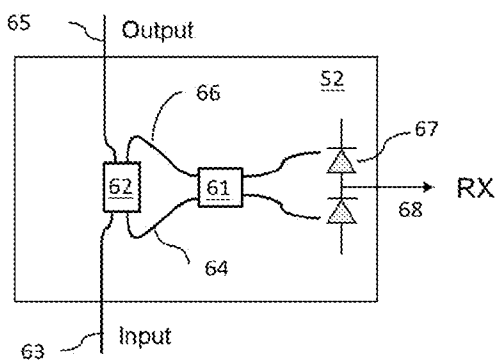


Figure 5

Coherent receiver (bpd version)



Coherent receiver (hybrid version)

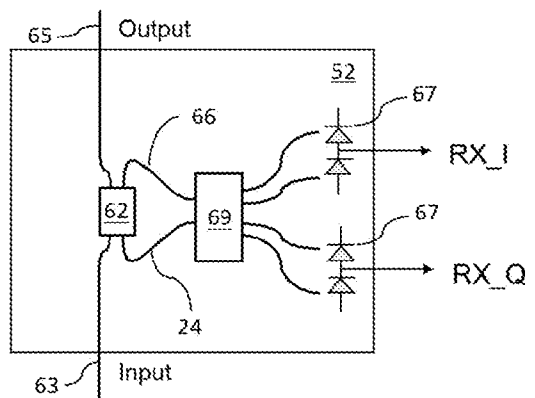
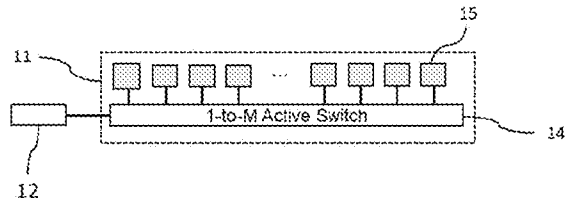


Figure 6

Type C: one-dimensional array of Coherent Pixels



Type D: one-dimensional array of Optical Antennas

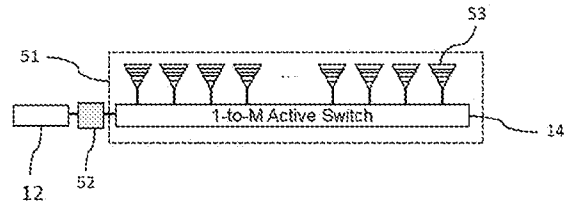


Figure 7

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<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	35703-xxx/US
		Application Number	
Title of Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

**Secrecy Order 37 CFR 5.2:**

<input type="checkbox"/>	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--------------------------	---

**Inventor Information:**

Inventor 1					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Amir		Hosseini		
Residence Information (Select One) <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service					
City	San Jose	State/Province	CA	Country of Residence	US

**Mailing Address of Inventor:**

Address 1	OURS Technology Inc.				
Address 2	4701 Patrick Henry Dr #18				
City	Santa Clara	State/Province	CA		
Postal Code	95054	Country i	US		

Inventor 2					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Sen		Lin		
Residence Information (Select One) <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service					
City	Mountain View	State/Province	CA	Country of Residence	US

**Mailing Address of Inventor:**

Address 1	OURS Technology Inc.				
Address 2	4701 Patrick Henry Dr #18				
City	Santa Clara	State/Province	CA		
Postal Code	95054	Country i	US		

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.

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**Correspondence Information:**

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
	Application Number	
Title of Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS	

 An Address is being provided for the correspondence information of this application.

Customer Number	00758		
Email Address	ptoc@fenwick.com	<input type="button" value="Add Email"/>	<input type="button" value="Remove Email"/>

### Application Information:

Title of the Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS		
Attorney Docket Number	35703-xxx/US	Small Entity Status Claimed	<input checked="" type="checkbox"/>
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	4	Suggested Figure for Publication (if any)	

### Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

### Publication Information:

 Request Early Publication (Fee required at time of Request 37 CFR 1.219)

**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

### Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer number will be used for the Representative Information during processing.

Please Select One:	<input checked="" type="radio"/> Customer Number	<input type="radio"/> US Patent Practitioner	<input type="radio"/> Limited Recognition (37 CFR 11.9)
Customer Number	00758		



Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
	Application Number	
Title of Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS	

### Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	<input type="text"/>	<input type="button" value="Remove"/>
Application Number	Continuity Type	Prior Application Number
<input type="text"/>	<input type="text"/>	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> button.		<input type="button" value="Add"/>

### Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country <sup>i</sup>	Filing Date (YYYY-MM-DD)	Access Code <sup>i</sup> (if applicable)	<input type="button" value="Remove"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>		
Additional Foreign Priority Data may be generated within this form by selecting the <b>Add</b> button.				<input type="button" value="Add"/>

### Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

- This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
- NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
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## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
	Application Number	
Title of Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS	

**Applicant Information:**

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

<b>Applicant</b> 1	<input type="button" value="Remove"/>			
<p>If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.</p>				
<input type="button" value="Clear"/>				
Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor		
Person to whom the inventor is obligated to assign.		Person who shows sufficient proprietary interest		
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:				
<div style="border: 1px solid black; height: 20px; width: 100%;"></div>				
Name of the Deceased or Legally Incapacitated Inventor: <input style="width: 90%;" type="text"/>				
If the Applicant is an Organization check here. <input type="checkbox"/>				
Prefix	Given Name	Middle Name	Family Name	Suffix
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<b>Mailing Address Information For Applicant:</b>				
Address 1		<input type="text"/>		
Address 2		<input type="text"/>		
City		State/Province	<input type="text"/>	
Country	<input type="text"/>	Postal Code	<input type="text"/>	
Phone Number	<input type="text"/>	Fax Number	<input type="text"/>	
Email Address		<input type="text"/>		
Additional Applicant Data may be generated within this form by selecting the Add button.				<input type="button" value="Add"/>

**Assignee Information including Non-Applicant Assignee Information:**

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
	Application Number	
Title of Invention	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS	

<b>Assignee</b>	1
-----------------	---

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here.

Prefix	Given Name	Middle Name	Family Name	Suffix

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

Address 1				
Address 2				
City		State/Province		
Country <sup>i</sup>		Postal Code		
Phone Number		Fax Number		
Email Address				

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Add

**Signature:**

Remove

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Michael W. Farn/		Date (YYYY-MM-DD)	2019-05-17	
First Name	Michael W.	Last Name	Farn	Registration Number	41,015

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<b>Application Data Sheet 37 CFR 1.76</b>	Attorney Docket Number	35703-xxx/US
	Application Number	
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This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

## Electronic Acknowledgement Receipt

<b>EFS ID:</b>	36050568
<b>Application Number:</b>	62849807
<b>International Application Number:</b>	
<b>Confirmation Number:</b>	1888
<b>Title of Invention:</b>	FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS
<b>First Named Inventor/Applicant Name:</b>	Amir Hosseini
<b>Customer Number:</b>	758
<b>Filer:</b>	Michael Wayne Farn
<b>Filer Authorized By:</b>	
<b>Attorney Docket Number:</b>	35703-xxx/US
<b>Receipt Date:</b>	17-MAY-2019
<b>Filing Date:</b>	
<b>Time Stamp:</b>	21:19:15
<b>Application Type:</b>	Provisional

### Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$140
RAM confirmation Number	052019INTEFSW00005952192555
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

<b>File Listing:</b>					
<b>Document Number</b>	<b>Document Description</b>	<b>File Name</b>	<b>File Size(Bytes)/ Message Digest</b>	<b>Multi Part /.zip</b>	<b>Pages (if appl.)</b>
1	Specification	xxx_provisional.pdf	117533	no	5
			7c45a07845d8f01d7799e8041c861fd5b4e d2cea		
<b>Warnings:</b>					
<b>Information:</b>					
2	Drawings-other than black and white line drawings	xxx_drawings.pdf	1054048	no	4
			accdc<4f18ea7a9ab51<86736b671d4d532 63a2c		
<b>Warnings:</b>					
<b>Information:</b>					
3	Application Data Sheet	xxx_ADS.PDF	1255852	no	8
			94ca3b4f7cc0726dc21c0f416600f73e9c75 7f2		
<b>Warnings:</b>					
<b>Information:</b>					
4	Fee Worksheet (SB06)	fee-info.pdf	29717	no	2
			1fa4cf79afc2ad688f0ab21f78c146182396a 90b		
<b>Warnings:</b>					
<b>Information:</b>					
<b>Total Files Size (in bytes):</b>			2457150		



**This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.**

**New Applications Under 35 U.S.C. 111**

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

**New International Application Filed with the USPTO as a Receiving Office**

**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

## SCORE Placeholder Sheet for IFW Content

Application Number: 62849807

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# FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING MICRO-ELECTRO-MECHANICAL SWITCHED FOCAL PLANE ARRAYS

## BACKGROUND OF THE INVENTION

**[0001]** The present invention is in the technical field of solid-state LIDAR.

**[0002]** Conventional LIDAR systems require mechanical moving parts to steer the laser beam and scan the field of view. They are considered bulky, costly and unreliable for a large range of applications, such as automotive and robotics.

**[0003]** Solid-state LIDARs overcome these issues by eliminating fast mechanically moving parts required to steer the optical beam for LIDAR operation. A Focal Plane Array (FPA), which maps the direction of the incoming beam into the position of the focused spot, and vice versa, can be used to realize solid-state beam steering, hence enabling solid-state LIDARs.

**[0004]** Frequency Modulated Continuous Wave (FMCW) lidars measure range and velocity of an object by directing a frequency modulated, collimated light beam at the object. The light that is reflected from the object is mixed with a tapped version of the beam, resulting in a Radio Frequency (RF) beat tone.

**[0005]** The frequency of the resulting beat tone is proportional to the distance of the object from the LIDAR system once corrected for the doppler shift which may require a second measurement. The two measurements, which may or may not be performed at the same time, provide both range and velocity information.

**[0006]** Lidar systems for automotive applications, where the laser beam used for detection and ranging can enter human eyes, must meet the eye safety criteria under the 21 Code of Federal Regulations (CFR) Part 1040 in the US and IEC 60825 internationally. According to the Laser Institute of America (LIA), the safest category of lasers and laser systems, which can be operated in public without the risk of damaging human eye or skin, is referred to as Class 1. This class includes all lasers or laser systems which cannot emit levels of optical radiation above the exposure limits for the eye under any exposure conditions.

## SUMMARY OF THE INVENTION

**[0007]** One aspect of the present invention is a solid-state LIDAR system based on an FPA-on-chip. At any given time, a set of several parallel channels shoot beams at different directions at the same time. The measurement time is prolonged by a factor equal to the number of parallel

channels. Thus the Signal to Noise Ratio (SNR) of the received beat tone is increased by the same factor, enabling long distance (>200m) detection range. Once the measurement is completed for the currently selected channels, a different set of parallel channels are switched on until the entire field of view is scanned.

**[0008]** The present invention enables meeting the eye-safety requirements of Class 1 lasers and laser systems in two ways: 1) the enhancement of the SNR in multichannel FPA-based lidars allows for lowering the optical intensity of the laser beam needed for long range detection 2) directions at which parallel channels emit light at the same time are maximally spaced out in the field of view, enabling safe exposure pattern by minimizing the number of optical beams that can simultaneously be received by human eye outside of an enforced stand-off region.

**[0009]** Switching among different sets of parallel channels is done through integrated optical switches, which form optical switch networks on the photonic chip. Micro Electromechanical (MEMS) based optical switches in 1D or 2D configurations provide a low optical loss, reliable, and easy to control switching solution.

**[0010]** Due to the lack of thermal or electrical cross-talk that large optical switch networks, such as those based on thermal optical switches on chip, suffer from, MEMS based switches enable large optical switch networks required for on-chip FPAs to function without lengthy calibration at the beginning of life or real-time and in-the-field calibration.

**[0011]** This disclosure describes four types of MEMS optical switch based FPAs (A) two-dimensional (2D) array of Coherent Pixels (CP) switched using MEMS optical switch arrays, (B) two-dimensional array of optical antennas switched using MEMS optical switch arrays, (C) one-dimensional array of CPs switched using a 1D MEMS optical switch array for optical beam steering in one dimension, while a slow rotating mirror or other mechanism scans the optical beam in the 2<sup>nd</sup> dimension for a full 2D scanning of the field of view, (D) one-dimensional array of optical antennas switched using a 1D MEMS optical switch array for optical beam steering in one dimension, while a slow rotating mirror or other mechanism scans the optical beam in the 2<sup>nd</sup> dimension for a full 2D scanning of the field of view.

**[0012]** Type (A) and Type (B) are fully solid-state scanning lidars whereas Type (C) and Type (D) are hybrid solid state scanning and mechanical scanning lidars. The hybrid system benefits from the fast beam steering enabled by the 1D solid state scanner. The required speed of the mechanically moving parts is reduced by a factor equal to the number of channels on the FPA

chip. The elimination of the fast-moving parts significantly increases the lifetime, reliability and reduces the design constraints on the mirrors hence enabling low cost LIDAR systems.

#### BRIEF DESCRIPTION OF THE DRAWING

**[0013]** Figure 1 shows a schematic of the Type (A) System on Chip (SoC) design of the FPA chip, 1. The chip is divided into N subsets 10. Each subset, 10, includes an optical I/O port, 12, and a 1-to-K passive optical splitter, 13. Each of the optical I/Os is fed by a frequency modulated laser light provided by an off-chip or on-chip laser. Each output of the 1-to-K optical splitters feeds M CPs, 15. A 1D MEMS optical switch network, 14, selects one out of the M CPs to send and receive Frequency Modulated (FM) light and generate RF beat tone.

**[0014]** Figure 2 shows two versions of the CP. Light from the MEMS switch network, 14, is provided to the optical input of the CP, 23. A bi-directional 2x2 splitter, 22, splits the light into 2 outputs, referred two as Signal, 25, and Local Oscillator, LO, 26. Signal, 25, is sent out of the chip using an optical antenna, 20. The antenna is reciprocal and collects the reflected beam from the object under measurement and sends it back to the bi-directional 2x2 splitter, which in turn splits it between ports 24 and 23. The received signal out of port 24 and LO 26, are mixed either using a balanced 2x2 optical combiner, 21, in the version on the left or using an optical hybrid, 29, in the version on the right. Finally, a pair of Photodiodes (PDs), 27, in the version on the left and four PDs in the version on right convert the optical signal into electrical signal for beat tone detection. We refer to the version on the left as the Balanced Photo Diode (BPD) CP version and the version on the right is the optical hybrid CP version. The optical hybrid version provides in-phase and quadrature outputs, which are used to determine the sign of the velocity of the object from the doppler shift in the beat tone.

**[0015]** Figure 3 illustrates optical beam steering using FPA. The photonic chip, 1, is placed at the focal distance of a lens system, 3, that maps the physical location of each CPs, into a unique direction out of the lens system. The optical antenna on the left-most CP, 30, sends and receives light along the solid line, while the right-most CP, 31, sends and receives light along the dashed line. All of the CPs in between steer the light into a direction in between these 2 lines and hence, a discrete optical beam scanning is achieved.

**[0016]** Figure 4 shows a 1D MEMS based optical switch array, 14. The MEMS based optical switch used here is a 1x2 switch and can route the input light into the one of the two output ports. We refer to the output port with the smaller insertion loss as the “through” port and the other one

as the “drop” port. Input light from the optical input, 40, enters the first optical MEMS switch stage, 41, which selects whether to route the light out to its “drop” port, 42, or delivers it to the next optical MEMS switch stage, 44, via its “through” port, 43. This process continues until the last (Mth stage) optical MEMS switch stage, 45, where the “through” port is monitored using a PD, 46.

**[0017]** Figure 5 shows a schematic of the Type (B) System on Chip (SoC) design of the FPA chip, 5. The chip is divided into N subsets. Each subset, 50, includes an optical I/O port, 12, and a 1-to-K passive optical splitter, 13. Each of the optical I/Os is fed by a frequency modulated laser light provided by an off-chip or on-chip laser. Each output of the 1-to-K optical splitters is connected into one of the two optical ports of a Coherent Receiver (CR), 52. The other CR optical port is connected to M optical antennas, 53, through a 1D MEMS optical switch network, 14, which selects one out of the M optical antennas to send and receive Frequency Modulated (FM) light for ranging and detection.

**[0018]** Figure 6 shows two versions of CR, 52. Light from the 1-to-K splitter, 13, is provided to the optical input of the CR, 63. A 2x2, bi-directional splitter, 62, splits the light into two outputs 65 and 66. The optical power 65 is sent out of the chip using one of the M actively switched antenna at a time. The antenna is reciprocal and collects the reflected beam from the object and sends it back to the CR through the same line 65. The bi-directional 2x2 splitter splits the returned signal between ports 64 and 63. The returned Signal, 64, and LO, 66, are mixed either using a balanced 2x2, 61 in the version on the left or using an optical hybrid, 69, in the version on the right. Finally, a pair of Photodiodes (PDs), 67, in version on the left and 4 PDs in the version on right convert the optical signal into electrical signal for beat tone detection. We refer to the version on the left as the Balanced Photo Diode (BPD) CR version and the version on the right is the optical hybrid CR version. The optical hybrid version provides in-phase and quadrature outputs, which are used to determine the sign of the velocity from the doppler shift in the measured beat tone.

**[0019]** Figure 7 illustrates, Type (C) and Type (D) 1D FPA-on-chip systems. Type (C) and Type (D) are subsets of the Type (A) and Type (B) systems, respectively, and can steer the optical beam only along one direction. In order to achieve 2D scanning of the field of view, a slow rotating mirror scans the optical beam along a direction perpendicular to that of the FPA.

## CLAIMS

What is claimed is:

1. A method comprising any process in any disclosure herein, performed by any component in any disclosure herein.
2. An apparatus comprising any component in any disclosure herein, configured to perform any process in any disclosure herein.