Based on the distance to the peripheral surface of the copper sample 10 expressed by the distance signal, position of the moving table 14 expressed by the table position signal ST, rotational position of the rotating plate 30 expressed by the rotation position signal SR, and the dimension R [from] the center line of rotation of the rotary plate 30 to the laser measurement device 40 that has been set in advance, it measures the peripheral shape of the copper sample 10 and displays its peripheral shape by outputting a display signal DD to a display unit 48.

The operation of the peripheral shape measurement device configured in the above manner shall now be described.

First, the copper sample 10 is fixed into position at the center line of rotation of the rotating plate 30 by means of a holding device (not shown in the figures), and while the rotating plate 30 is made to rotate continuously in one direction by the drive motor 34, the moving table 14 is moved linearly by the drive motor 16. Because the axis of the copper sample 10 is aligned with the center line of rotation of the rotating plate 30 and the direction of motion of the moving table 14 is made parallel to the center line of rotation of the rotating plate 30, the rotating plate 30 rotates concentrically with the axis of the copper sample 10 and is moved in its axial direction. In addition, because laser measurement devices 40 are mounted onto the rotating plate on the shared circumference centering on its center line of rotation, the laser measurement devices 40 also rotate concentrically with the axis of the copper sample 10 while also moving in its axial direction.

Next, distance signals SD that express the distance to the peripheral surface of the copper sample 10 are output from said laser measurement devices 40. If one defines the distance expressed by these distance signals SD as d, the radius 10 of the copper sample 10 is obtained by the difference (R - d) between the aforementioned dimension R and that distance d. Accordingly, the previously described microcomputer 46 is provided with those distance signals SD and computes that difference (R - d), and in accordance with the rotation position of the rotating plate 30 expressed by the rotation position signal SR, it outputs a display signal DD that expresses that difference (R - d), and causes a graph like that shown, for example, in Figure 6 to be displayed on said display unit 48.

Figure 6 displays the radius over the entire circumference (2 [illegible]) at an arbitrary location in the axial direction of the copper sample 10. Because four laser measurement devices 40 are mounted on the rotating plate 30 at 90° intervals, the peripheral shape at a single location on the copper sample 10 is measured with each quarter rotation of the rotating plate 30. In addition, if the radius, as shown by the solid line, is constant across the entire circumference, then the cross sectional shape of the copper sample 10 in that region will be a perfect circle, indicating that no surface flaws or the like are present. However, in cases where, as shown for example in Figure 5, surface flaws 50 are present, then because the light reflection point of the reflected light will be offset, then the distance signal SD that expresses a distance (d + Δd) that includes the depth of the flaw Δd will be provided from the laser measurement device 40. Consequently, at circumferential positions where surface flaws 50 do exist, then as shown by the dash-dot line in Figure 6, the radius will be smaller, and the location of the flaw in the circumferential direction and the flaw depth Δd will be recognized based on that graph.

Now, as the above-described graph shown in Figure 6 is displayed for each quarter rotation of the rotating plate 30, then based on the position of the moving table 14 expressed by the table position signal ST, the position of the copper sample 10 in the axial direction will be expressed in each graph. Consequently, the peripheral shape of the copper sample 10 will be sequentially measured in the axial direction, and changes in the diameter together with the position and length of surface flaws 50 in the axial direction will be recognized.

In this way, with the peripheral shape measurement device of the present embodiment, because the peripheral shape of the copper sample 10 is measured by obtaining the distances up to the surface of the copper sample 10, it is possible to perform such measurements even in cases where unevenness is present on its surface, and not only is it possible to obtain the diameter of the copper sample 10, but one may also accurately measure the position and depth of said surface flaws 50.

Moreover, in the example above, a copper sample 10 serving as an object to be measured was disposed at a fixed position, and measurements of the peripheral shape in the axial direction of the copper sample 10 were performed by moving laser measurement devices 40 in a direction that was parallel with its center line of rotation. However, it would also be possible to move the object to be measured along the center line of rotation of the laser measurement devices 40. In that case, the rotating plate 30 that holds the above-described laser measurement devices 40 would be continuously rotated in one direction around its center line of rotation, and it could therefore be rotated at high speeds on the order of, for example, 3000 - 5000 rpm. In addition, because four laser measurement devices 40 would be provided on the rotating plate 30

Quanergy Systems EX1004 Page 4

and the outer shape could be measured at each quarter rotation, then even in cases where the object to be measured was moved at a high speed of, for example, several meters per second (m/s), it would still be possible to measure its peripheral shape with high resolution. In addition, in the present embodiment, because a rotary transformer 42 was used as a signal transmission means, then even if the rotating plate 30 is rotated at high speed as described above, noise will not be introduced into said distance signals SD, and this has the benefit of making it possible to measure with high precision.

In addition, the display method of the above-described embodiment was merely an example [of the possibilities], as one could display the cross-sectional shape of the copper sample 10 as is, display it stereoscopically in three dimensions, or record it on a chart or the like. Moreover, rather than performing such display, one could apply a coating material at locations where surface flaws 50 are present, or send a signal that shows the positions and depths of flaws to a separate[ly provided] flaw removal device.

In addition, in the above-described embodiment, because four laser measurement devices 40 were mounted at 90° intervals on the rotating plate 30, the microcomputer 46 serving as the signal processing device may detect misalignment or the like between the axis of the copper sample 10 and the center line of rotation of the laser measurement devices 40 and then correct the peripheral shape [accordingly]. It can also measure the cross sectional shape of the object to be measured by applying differential amplification to the distance signals SD output from the laser measurement devices 40 at oppositely disposed positions. Moreover, so long the object of the present invention is achieved, the number laser measurement devices 40 may be [as low as] 1 or 2, and their number can be appropriately determined in accordance with the measurement requirements.

In addition, in the above-described embodiment, a table position signal ST and rotation position signal SR were provided to the microcomputer 46 from the rotary encoders 22 and 38, but in cases where the drive motors 16 and 34 provide rotational drive at a constant speed, such signals are not necessarily required.

Further still, a description was given of a case where the diameter of a cylindrically shaped copper sample 10 serving as the object to be measured was measured along with the positions and depths of flaws [thereon], but the peripheral shape measurement device of the present invention could be advantageously applied to peripheral shape measurements of objects to be measured having various shapes, such as L-shaped or H-shaped copper samples, resin products, or objects whose cross-sectional shape changes in the axial direction.

Furthermore, in the above-described embodiment, a rotary transformer 42 was employed as the signal transmission means, but it would also be possible to use a slip ring or the like.

Other embodiments shall not be illustrated [herein], but the present invention could be implemented using various embodiments to which modifications or improvements have been applied based on expertise of those skilled in the art.

4. Brief Description of the Figures

Figure 1 is a front view of a peripheral shape measurement device constituting an embodiment of the present invention. Figure 2 is a side view wherein a portion of the device of Figure 1 has been cut out. Figure 3 is a diagram that shows an enlarged cutout of a portion of Figure 2. Figure 4 is a block diagram of the measurement circuit that is provided to the device of Figure 1. Figure 5 is a diagram that describes the measurement principles [employed] when measuring the peripheral shape using the device of Figure 1. Figure 6 is a diagram that shows an example of the measurement results that are displayed on the display unit of the device of Figure 1.

10: copper sample (object to be measured)
14: moving table
16: drive motor (moving device)
24: frame (support member)
30: rotating plate (rotating member)
34: drive motor (drive means)
40: laser measurement device (light-reflection-based distance measurement device)
42: rotary transformer (signal transmission means)
46: microcomputer (signal processing device)
SD: distance signal

Applicant Daido Steel Co. Ltd.
Attorneys Haruyuki Ikeda (and two others)

/6

Figure 1
Figure 2
Figure 3

Figure 4
28 rotary encoder
38 rotary encoder
40 laser measurement device
40 laser measurement device
40 laser measurement device
40 laser measurement device
44 interface
44 interface
44 interface
44 interface
46 microcomputer

/7

Figure 5

Figure 6

Quanergy Systems EX1004 Page 5

Figure 1

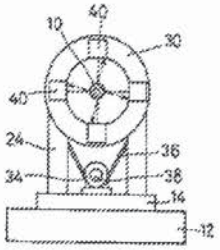


Figure 2

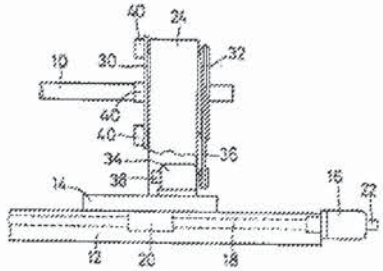


Figure 3

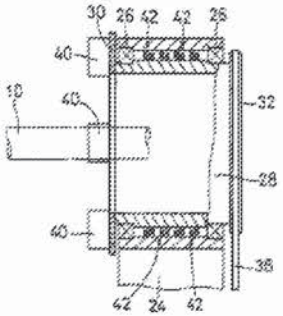


Figure 4
[text in image below illegible]

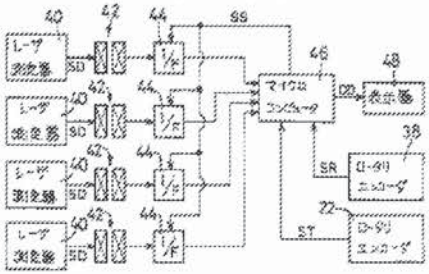


Figure 5

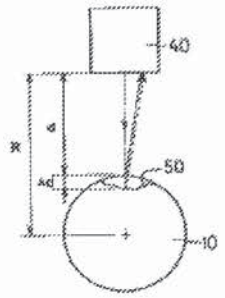
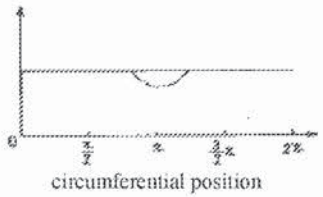


Figure 6

Figure radius
(R - d)



Chevy Chase, Maryland

I, Daniel Child, hereby certify that I translated document "**3_006407_cert**" and that this translation is a true and accurate translation from Japanese into English. All statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true. These statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

Daniel Child

Sworn to before me this
Thursday, September ~~28~~ 29, 2017

Signature, Notary Public

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My Commission Expires 8/30/2019

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審査請求　未請求　請求項の数 1　（全7頁）

㊹発明の名称　外周形状測定装置

㉑特　願　平1−141899

㉒出　願　平1(1989)6月3日

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明　細　書

1．発明の名称

外周形状測定装置

2．特許請求の範囲

被測定物の外周形状を測定する装置であって、

光を出射するとともに該光の反射光を受光して反射位置までの距離を測定し、該距離に対応する距離信号を出力する光反射型距離測定器と、

一中心線まわりの回転可能に設けられ、前記光が該一中心線に向かって出射される姿勢で前記光反射型距離測定器を保持する回転部材と、

該回転部材を前記一中心線まわりにおける一方向へ連続回転させる駆動手段と、

前記一中心線上に前記被測定物が略位置する状態で、該一中心線と平行な方向へ該被測定物と前記回転部材とを相対移動させる移動装置と、

前記回転部材と該回転部材を支持する支持部材との間に設けられ、前記光反射型距離測定器から出力された距離信号を該回転部材側から該支持部材側に伝達する信号伝達手段と、

該信号伝達手段を介して伝送される距離信号に基づいて、前記光反射型距離測定器と前記被測定物の外周面との間の距離から該被測定物の前記一中心線まわりにおける外周形状を該一中心線方向に沿って順次求める信号処理装置と

を有することを特徴とする外周形状測定装置。

3．発明の詳細な説明

産業上の利用分野

本発明は被測定物の外周形状を測定する装置に係り、特に、光反射型距離測定器を利用して外周形状を測定する装置に関するものである。

従来の技術

被測定物の外周形状を測定するための装置として、従来から光走査式測定装置が知られている。これは、細い光ビームを被測定物と交差する方向へ走査するとともに、被測定物を挟んで反対側に設けられたイメージセンサ等の受光器によりその光ビームを検出し、被測定物によって光が遮断された部分の寸法を測定するものであり、その状態で測定装置を被測定物のまわりに回転させること

Quanergy Systems EX1004 Page 9

により、被測定物の横断面形状や直径寸法，幅寸法等の外周形状が測定される。また、被測定物と測定装置とを上記回転中心線と平行な方向へ相対移動させることにより、被測定物全体の外周形状を測定できる。

発明が解決しようとする課題

しかしながら、このような従来の外周形状測定装置は被測定物の影を測定するものであるため、例えば被測定物に凹みが存在してもそれを測定し得ず、被測定物の外周形状を必ずしも正確に測定することはできなかったのである。

本発明は以上の事情に鑑みて為されたもので、その目的とするところは、被測定物に凹み等が存在してもそれを正しく測定できる外周形状測定装置を提供することにある。

課題を解決するための手段

かかる目的を達成するために、本発明は、被測定物の外周形状を測定する装置であって、(a)光を出射するとともにその光の反射光を受光して反射位置までの距離を測定し、その距離に対応する距離信号を出力する光反射型距離測定器と、(b)一中心線まわりの回転可能に設けられ、前記光がその一中心線に向かって出射される姿勢で前記光反射型距離測定器を保持する回転部材と、(c)その回転部材を前記一中心線まわりにおける一方向へ連続回転させる駆動手段と、(d)前記一中心線上に前記被測定物が略位置する状態で、その一中心線と平行な方向へその被測定物と前記回転部材とを相対移動させる移動装置と、(e)前記回転部材とその回転部材を支持する支持部材との間に設けられ、前記光反射型距離測定器から出力された距離信号をその回転部材側からその支持部材側に伝達する信号伝達手段と、(f)その信号伝達手段を介して伝達される距離信号に基づいて、前記光反射型距離測定器と前記被測定物の外周面との間の距離からその被測定物の前記一中心線まわりにおける外周形状をその一中心線方向に沿って順次求める信号処理装置とを有することを特徴とする。

作用および発明の効果

このような外周形状測定装置においては、回転

部材が回転駆動される一中心線上に被測定物を配置した状態において、駆動手段によりその回転部材をその一中心線まわりに連続回転させるとともに、移動装置によって回転部材と被測定物とを一中心線と平行な方向へ相対移動させる。これにより、上記一中心線に向かって光を出射する姿勢で回転部材に保持された光反射型距離測定器は、その一中心線上に配置された被測定物の外周面で反射される反射光を受光してその外周面との間の距離を測定しつつ、上記一中心線まわりに回転させられ且つその一中心線と平行な方向へ被測定物に対して相対移動させられる。

そして、かかる光反射型距離測定器から出力される上記外周面との間の距離に対応する距離信号は、信号伝達手段を介して回転部材側から支持部材側に伝達され、更に信号処理装置に供給される。信号処理装置では、上記距離信号が表す被測定物の外周面と光反射型距離測定器との間の距離から、例えば光反射型距離測定器と一中心線との間の距離，駆動手段による回転部材の回転速度，移動装置による相対移動速度等に基づいて、被測定物の横断面形状や大きさ等の外周形状が求められる。

ここで、かかる本発明の表面形状測定装置は、光反射型距離測定器を用いて被測定物の表面までの距離を測定するようになっているため、その表面に凹凸等が存在する場合でもその測定が可能で、例えば外周面に凹みや底がある被測定物の横断面形状や底位置等を正確に測定したり、断面がL字形状やH字形状等の被測定物の外周形状を測定したりすることができるのである。

また、回転部材は駆動手段によって一中心線まわりにおける一方向へ連続回転させられるため、これを高速回転させることにより被測定物の外周形状を高分解能で能率良く測定できるとともに、例えば被測定物が上記一中心線上を高速移動させられる場合でも外周面形状を高い精度で測定することが可能なのである。この場合に、前記光反射型距離測定器を上記回転部材に等角度間隔で複数設けておけば、一層高い分解能で測定を行うことができる。

Quanergy Systems EX1004 Page 10

実施例

以下、本発明の一実施例を図面に基づいて詳細に説明する。

第１図および第２図は、それぞれ本発明の一実施例である外周形状測定装置の正面図および側面図で、被測定物としての円柱形状を成す鋼材１０の径寸法や表面疵等を検査するためのものである。かかる測定装置において、略水平な基台１２上には移動テーブル１４が配設されており、その移動テーブル１４は、駆動モータ１６により送りねじ１８およびボールナット２０を介して第２図における左右方向へ直線往復移動させられる。駆動モータ１６にはロータリエンコーダ２２が取り付けられており、そのロータリエンコーダ２２からは、駆動モータ１６の回転量に対応して移動させられる移動テーブル１４の位置を表すテーブル位置信号ＳＴが出力される。上記移動テーブル１４および駆動モータ１６等により移動装置が構成されている。

移動テーブル１４上には支持部材としてのフレーム２４が固設されている。フレーム２４の上部は、第３図からも明らかなように、移動テーブル１４の移動方向と平行な円筒形状を成しており、その円筒内には一対のベアリング２６を介して回転筒２８が回転可能に保持されている。回転筒２８の一端部にはリング形状の回転板３０が同心に固設されている一方、回転筒２８の他端部にはプーリ３２が固設され、移動テーブル１４上に設けられた駆動モータ３４によりベルト３６を介して一方向へ連続回転させられるようになっている。駆動モータ３４にはロータリエンコーダ３８が取り付けられており、そのロータリエンコーダ３８からは、駆動モータ３４の回転量に対応して回転させられる回転板３０の回転位置を表す回転位置信号ＳＲが出力される。上記回転板３０は回転部材に相当するもので、その回転中心線は一中心線に相当する。また、駆動モータ３４はその回転部材を連続回転させる駆動手段に相当する。

上記回転板３０には、その回転中心線を中心とする共通の一円周上に９０° 間隔で４個のレーザ測定器４０が設けられている。このレーザ測定器４０は、レーザ光を出射するとともにそのレーザ光の反射光をポジションセンサやイメージセンサ等にて受光し、その受光位置に基づいてレーザ測定器４０から反射位置までの距離を測定する光反射型の距離測定器であって、何れもそのレーザ光を回転板３０の回転中心線に向かって出射する姿勢で取り付けられている。前記鋼材１０は、その軸心が回転板３０の回転中心線と一致する姿勢で図示しない保持装置によって位置固定に保持されるようになっており、上記レーザ測定器４０は、回転板３０の回転中心線に向かってレーザ光を出射することによりその鋼材１０の外周面までの距離を測定し、その距離を表す距離信号ＳＤをそれぞれ出力することとなる。なお、このレーザ測定器４０の動力源は、回転板３０に電池等を取り付けたり、フレーム２４に磁石を固定するとともに回転筒２８にコイルを設けて発電機を形成したり、スリップリングを介してフレーム２４側から回転筒２８側へ電力を通電したりするなど、種々の態様で構成され得る。

一方、かかる外周形状測定装置は、第４図に示されている測定回路を備えており、前記４個のレーザ測定器４０から出力された距離信号ＳＤは、図示しないＡ／Ｄ変換器によってディジタル信号に変換された後、回転筒２８とフレーム２４との間に相対抗して設けられた一対のコイルから成る回転トランス４２を介してそれぞれフレーム２４側へ伝達される。この回転トランス４２は信号伝達手段に相当する。また、このようにしてフレーム２４側へ伝達された距離信号ＳＤは、それぞれインタフェース４４を介してサンプル信号ＳＳに従ってマイクロコンピュータ４６に取り込まれる。マイクロコンピュータ４６には、前記ロータリエンコーダ２２および３８からテーブル位置信号ＳＴおよび回転位置信号ＳＲが供給されるようになっている。

上記マイクロコンピュータ４６は信号処理装置に相当するもので、ＲＡＭの一時記憶機能を利用しつつＲＯＭに予め記憶されたプログラムに従っ

Quanergy Systems EX1004 Page 11

て信号処理を行い、距離信号ＳＤが表す鋼材１０の外周面までの距離，テーブル位置信号ＳＴが表す移動テーブル１４の位置，回転位置信号ＳＲが表す回転板３０の回転位置，および予め設定されたレーザ測定器４０と回転板３０の回転中心線までの寸法Ｒに基づいて、鋼材１０の外周形状を測定するとともに、表示信号ＤＤを表示器４８に出力してその外周形状を表示させる。

次に、以上のように構成された外周形状測定装置の作動を説明する。

先ず、図示しない保持装置により鋼材１０を回転板３０の回転中心線上に位置固定に配置し、駆動モータ３４により回転板３０を一方向へ連続回転させるとともに、駆動モータ１６により移動テーブル１４を直線移動させる。鋼材１０の軸心は回転板３０の回転中心線と一致させられており、且つ移動テーブル１４の移動方向と回転板３０の回転中心線は平行とされているため、回転板３０は鋼材１０の軸心を中心として回転させられるとともにその軸心方向へ移動させられる。また、かかる回転板３０には、その回転中心線を中心として共通の一円周上にレーザ測定器４０が取り付けられているため、このレーザ測定器４０も、鋼材１０の軸心を中心として回転させられるとともにその軸心方向へ移動させられることとなる。

そして、上記レーザ測定器４０からは鋼材１０の外周面までの距離を表す距離信号ＳＤが出力され、その距離信号ＳＤが表す距離をｄとすると、第５図から明らかなように、その距離ｄと前記寸法Ｒとの差（Ｒ－ｄ）により鋼材１０の半径が求められる。したがって、その距離信号ＳＤが供給される前記マイクロコンピュータ４６においては、その差（Ｒ－ｄ）を算出するとともに、回転位置信号ＳＲが表す回転板３０の回転位置に対応させてその差（Ｒ－ｄ）を表す表示信号ＤＤを出力し、前記表示器４８に例えば第６図に示されるようなグラフを表示させる。

第６図は鋼材１０の軸方向の任意の１箇所での全周（２π）における半径を表示したものであるが、回転板３０には９０°間隔で４個のレーザ測

１１　　１２

定器４０が取り付けられているため、回転板３０の１／４回転で鋼材１０の１箇所における外周形状が測定される。また、第６図において実線で示されているように半径が全周において一定であれば、その部分での鋼材１０の横断面形状は完全な円で表面疵等は存在しないこととなるが、例えば第５図に示されているように表面疵５０が存在する場合には、反射光の受光位置がずれて疵深さΔｄを含む距離（ｄ＋Δｄ）を表す距離信号ＳＤがレーザ測定器４０から供給されるため、その表面疵５０が存在する周方向位置では第６図において一点鎖線で示されているように半径が小さくなり、このグラフから疵深さΔｄおよび周方向における疵位置が認識される。

一方、上記第６図に示すグラフは回転板３０の１／４回転毎に表示され、各グラフにはテーブル位置信号ＳＴが表す移動テーブル１４の位置に基づいて、鋼材１０の軸方向位置が表示されるようになっている。したがって、鋼材１０の外周形状が軸方向に順次測定されることとなり、軸方向における径寸法の変化や表面疵５０の位置，長さが認識される。

このように、本実施例の外周形状測定装置においては、鋼材１０の表面までの距離を測定してその鋼材１０の外周形状を測定するようになっているため、その表面に凹凸等が存在する場合でもその測定が可能で、鋼材１０の径寸法のみならず前記表面疵５０の疵深さや疵位置をも正確に測定することができるのである。

なお、上例では被測定物としての鋼材１０を位置固定に配置し、レーザ測定器４０をその回転中心線と平行な方向へ移動させて鋼材１０の軸心方向に向かって外周形状の測定を行うようになっているが、被測定物をレーザ測定器４０の回転中心線に沿って移動させることも可能である。その場合に、上記レーザ測定器４０を保持している回転板３０はその回転中心線まわりの一方向へ連続回転させられるため、例えば３０００～５０００ｒｐｍ程度で高速回転させることが可能であり、しかもその回転板３０には４個のレーザ測定器４０

１３　　１４

Quanergy Systems EX1004 Page 12

が設けられて１／４回転で一外周形状を測定できるようになっているため、被測定物が例えば数m／秒程度の高速で移動する場合でも、その外周形状を高分解能で測定することができるのである。また、この実施例では信号伝達手段として回転トランス４２が用いられているため、上記のように回転板３０が高速回転させられても前記距離信号ＳＤにノイズが混入することがなく、高い精度で測定できる利点がある。

また、前記実施例の表示方法はあくまでも一例で、鋼材１０の横断面形状をそのまま表示させるようにしたり、三次元で立体的に表示させるようにしたり、チャート等に記録させたりすることも可能である。更に、そのような表示を行うことなく、表面疵５９の位置に塗料を付けるようにしたり、別の疵取り装置等に疵位置や疵深さを表す信号を送るようにしたりすることもできる。

また、前記実施例では回転板３０に９０°間隔で４個のレーザ測定器４０が取り付けられているため、信号処理装置としてのマイクロコンピュータ４６においては、レーザ測定器４０の回転中心線と鋼材１０の軸心との芯ずれ等を検出して外周形状を補正するようにしたり、相対向する位置のレーザ測定器４０から出力される距離信号ＳＤを差動増幅して被測定物の断面形状を測定したりすることもできる。なお、本発明の目的を達成する上においては、レーザ測定器４０の数は１個或いは２個等であっても差支えなく、測定条件に応じて適宜定めることができる。

また、前記実施例ではロータリエンコーダ２２，３８からテーブル位置信号ＳＴおよび回転位置信号ＳＲがマイクロコンピュータ４６に供給されるようになっているが、駆動モータ１６，３４が予め定められた一定の速度で回転駆動される場合には、それ等の信号は必ずしも必要ない。

また、前記実施例では被測定物として円柱形状の鋼材１０の径寸法や疵位置，疵深さを測定する場合について説明したが、Ｌ字形状やＨ形状の鋼材，樹脂製品，或いは軸方向において横断面形状が変化するものなど、本発明の外周形状測定装置

は種々の形状を成す被測定物の外周形状測定に利用され得る。

また、前記実施例では信号伝達手段として回転トランス４２が用いられているが、スリップリング等を利用することも可能である。

その他一々例示はしないが、本発明は当業者の知識に基づいて種々の変更，改良を加えた態様で実施できる。

４．図面の簡単な説明

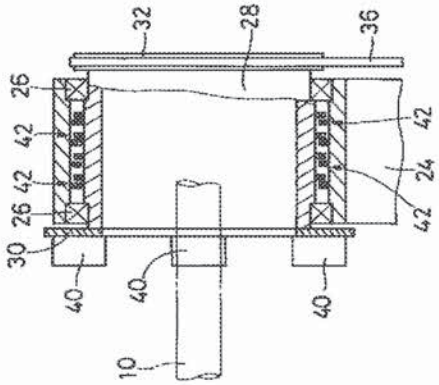
第１図は本発明の一実施例である外周形状測定装置の正面図である。第２図は第１図の装置の一部を切り欠いた側面図である。第３図は第２図の一部を拡大するとともに切り欠いて示した図である。第４図は第１図の装置に備えられている測定回路のブロック図である。第５図は第１図の装置によって外周形状を測定する際の測定原理を説明するための図である。第６図は第１図の装置の表示器に表示される測定結果の一例を示す図である。

１０：鋼材（被測定物）
１４：移動テーブル
１６：駆動モータ　（移動装置）
２４：フレーム（支持部材）
３０：回転板（回転部材）
３４：駆動モータ（駆動手段）
４０：レーザ測定器（光反射型距離測定器）
４２：回転トランス（信号伝達手段）
４６：マイクロコンピュータ（信号処理装置）
ＳＤ：距離信号

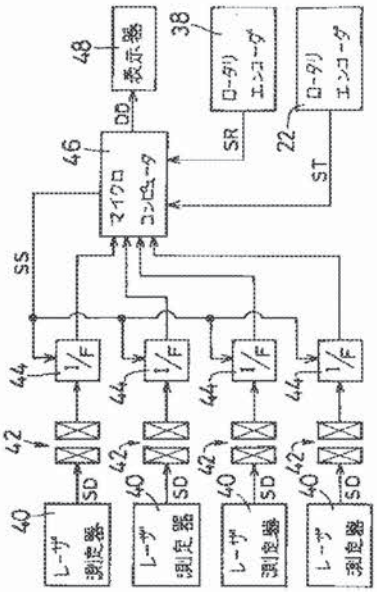
出願人　大同特殊鋼株式会社
代理人　弁理士　池　田　治　幸
（ほか２名）

Quanergy Systems EX1004 Page 13

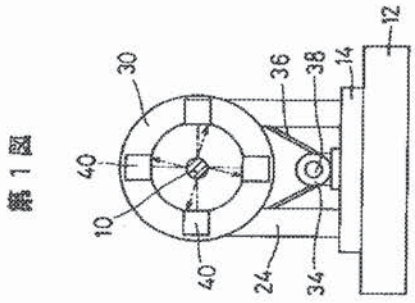
第3図



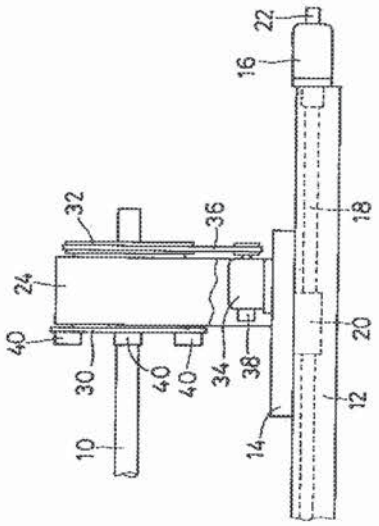
第4図



第1図

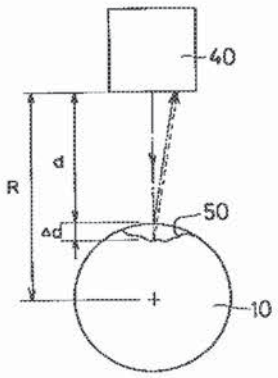


第2図

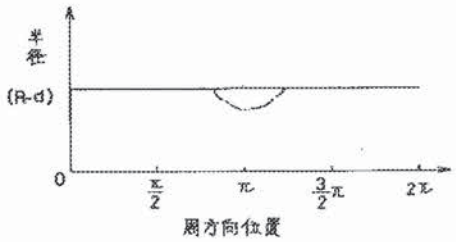


Quanergy Systems EX1004 Page 14

第 5 図



第 6 図



Quanergy Systems EX1004 Page 15

ABSTRACT EP3002548

The invention relates to an illumination device for generating an illumination field for an optoelectronic sensor, having at least one light source (9) and an adjustable optical beam shaping element (10), wherein the beam shaping element (10) engages a pressure element (16). In an illumination device which is simple to manufacture, the light source (9) and the beam shaping element (10) directly adjoin one another and form a compact unit (8).

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H04N 13/04 *(2006.01)*

(54) **Beleuchtungseinrichtung und Verfahren zum Erzeugen eines Beleuchtungsfeldes**

Illumination device and method for generating an illumination field

Dispositif d'éclairage et procédé destiné à la production d'une zone d'éclairage

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US-A- 5 864 128
US-A1- 2008 204 548

Anmerkung: Innerhalb von neun Monaten nach Bekanntmachung des Hinweises auf die Erteilung des europäischen Patents im Europäischen Patentblatt kann jedermann nach Maßgabe der Ausführungsordnung beim Europäischen Patentamt gegen dieses Patent Einspruch einlegen. Der Einspruch gilt erst als eingelegt, wenn die Einspruchsgebühr entrichtet worden ist. (Art. 99(1) Europäisches Patentübereinkommen).

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Beschreibung

[0001] Die Erfindung betrifft eine Beleuchtungseinrichtung zum Erzeugen eines Beleuchtungsfeldes nach dem Oberbegriff von Anspruch 1.

[0002] Für die Inspektion oder Vermessung von Objekten werden häufig Kamerasysteme eingesetzt, welche auch zum Lesen von Barcodes weite Verbreitung gefunden haben. Dabei werden Bilder des Objektes erfasst und entsprechend der Aufgabe durch Bildverarbeitungsverfahren ausgewertet. Eine weitere Anwendung von Kameras ist das Lesen von Codes. Derartige kamerabasierte Codeleser lösen die noch weit verbreiteten Barcode-Scanner zunehmend ab. Mit Hilfe eines Bildsensors werden Objekte mit den darauf befindlichen Codes aufgenommen, in den Bildern die Codebereiche identifiziert und dann decodiert. Kamerabasierte Codeleser kommen problemlos auch mit anderen Codearten als eindimensionalen Strichcodes zurecht, die wie ein Matrixcode auch zweidimensional aufgebaut sind und mehr Informationen zur Verfügung stellen.

[0003] Alle diese Anwendungen haben gemein, dass sie eine Beleuchtung benötigen, um den zu lesenden Barcode bzw. die zu inspizierenden und zu vermessenden Objekte unabhängig vom Umgebungs- oder Fremdlicht zu erfassen. Zu diesem Zweck weisen diese Kamerasysteme Lichtquellen auf, die häufig als LEDs ausgebildet sind. Im Vergleich zu den ebenfalls gelegentlich verwendeten Laserlichtquellen haben LEDs meist eine divergentere Abstrahlungscharakteristik und größere Abstrahlflächen.

[0004] Darüber hinaus ist bekannt, Vergusslinsen zur Strahlfokussierung direkt auf ein LED-Gehäuse aufzubringen.

[0005] In der DE 602 15 093 T2 ist eine steuerbare flüssige Mikrolinse offenbart, welche aus einer Isolierschicht und einem Tröpfchen einer transparenten leitenden Flüssigkeit besteht, die auf einem Trägermaterial angeordnet ist. Die Mikrolinse enthält mehrere Elektroden, wobei sich die Position der Mikrolinse durch die, an den Elektroden jeweilig angelegten Spannungen verändern lässt.

[0006] Aus dem Stand der Technik ist weiterhin eine Beleuchtungsvorrichtung bekannt, bei welcher eine LED ein Strahlführungselement in Form einer festen TIR-Linse (Total Internal Reflection) beleuchtet und welche zur effizienten Projektion des Lichtes in die Szene eingesetzt wird. An das Strahlführungselement schließt sich ein Mikrolinsenarray aus Silikon an, auf welchem eine Deckplatte aus Glas aufliegt. Durch eine Krafteinwirkung wird die Deckplatte an das elastische Mikrolinsenarray gedrückt und somit das Mikrolinsenarray deformiert. Durch die Deformation des Mikrolinsenarrays wird das Beleuchtungsfeld geformt.

[0007] Aus der WO2009/034511 A2 ist eine Beleuchtungseinrichtung nach dem Oberbegriff bekannt.

[0008] Es ist die Aufgabe der Erfindung, eine Beleuchtungseinrichtung zur Erzeugung eines Beleuchtungsfeldes für einen optoelektronischen Sensor anzugeben, der konstruktiv einfach herstellbar ist.

[0009] Diese Aufgabe wird durch eine Beleuchtungseinrichtung nach Anspruch 1 gelöst. Dabei geht die Erfindung von dem Grundgedanken aus, dass das optische Strahlformungselement direkt auf der Lichtquelle aufliegt und durch einen, an dem Strahlformungselement angreifenden Druck dieses Strahlformungselement zur Lichtformung deformiert wird. Das Strahlformungselement bildet dabei mit der Lichtquelle eine einfach zu betätigende kompakte Einheit. Auf ein Strahlführungselement kann dabei verzichtet werden.

[0010] In einem Strahlengang hinter dem Strahlformungselement, der Lichtquelle abgewandt, ist ein Mikrolinsen aufweisendes Mustererzeugungselement angeordnet, welches einen Erfassungsbereich des optoelektronischen Sensors durch ein Beleuchtungsmuster sichtbar macht. Ein solches Mustererzeugungselement erlaubt die Einstellung der Größe bzw. der Art der Zielgeometrie des optoelektronischen Sensors.

[0011] Das Mustererzeugungselement ist als adaptiver, Mikrolinsen aufweisender Punktmustergenerator ausgebildet, welcher bei einer mechanischen Druckbeanspruchung der elastisch ausgebildeten Mikrolinsen durch die aus einem festen Material bestehenden Deckplatte in Abhängigkeit der vertikal angreifenden Druckkraft ein Beleuchtungsmuster mit variierendem Punktdurchmesser erzeugt. Mittels einer solchen adaptiven Punktmusterbeleuchtung ist eine Umschaltung zwischen einem Punktlichtmuster und einer homogenen Beleuchtung, was ein Beleuchtungsmuster ohne Struktur darstellt, einfach möglich. Hierbei wird die homogene Beleuchtung der Szene verwendet, um neben der 3D-Information (mit strukturierter Beleuchtung) Grauwertbilder aufzunehmen. Diese zusätzliche Information kann zur reinen Darstellung oder algorithmischen Auswertung des Erfassungsbereiches des optoelektronischen Sensors verwendet werden.

[0012] Um beispielsweise bei einem Objektivwechsel des Kamerasystems des optoelektronischen Sensors die Zielgeometrie an den Sichtbereich des Objektivs anzupassen, bestehen die Mikrolinsen aus einem elastischen oder festen Material und sind auf einem festen Trägermaterial angeordnet, wobei eine beweglich gelagerte, vorzugsweise lateral verschiebliche, aus einem festen oder elastischen Material bestehende, transparente Abdeckung auf den Mikrolinsen aufliegt. Die Druckbeaufschlagung der Mikrolinsen bewirkt eine Vergrößerung der Krümmungsradien bzw. der Brennweiten der Mikrolinsen. Dies hat eine Verringerung der Strahldivergenz und somit eine Verkleinerung des Lichtmusters im Erfassungsbereich des optoelektronischen Sensors zur Folge. Die optische Strahlformung im deformierten bzw. undeformierten Zustand der Mikrolinsen kann durch eine asphärische oder frei geformte oder sphärische Linsenoberfläche und/oder Oberfläche der Deckplatte verändert werden. Die Mikrolinsen können dabei auch ein Mikrolinsenarray bilden. Anstelle eines elastischen Mikrolin-

senarrays und einer festen transparenten Deckplatte können ein festes Mikrolinsenarray und eine elastische Deckplatte verwendet werden.

[0013] Das Mustererzeugungselement besteht bevorzugt aus zwei gekreuzten, vorzugsweise senkrecht zueinander stehenden, elastischen Mikrolinsenarrays, die durch eine Trennplatte voneinander beabstandet sind, wobei jedes Mikrolinsenarray mit je einer festen Deckplatte abgedeckt ist und die Deckplatten unabhängig voneinander lateral und/oder vertikal beweglich ausgebildet sind. Durch die jeweilige Bewegung einer der Deckplatten in lateraler Richtung entsteht eine Scherung des jeweiligen Mikrolinsenarrays, was zu einer nicht rotationssymmetrischen Deformation der Mikrolinsen führt. Dadurch wird das Beleuchtungsmuster im Erfassungsbereich des optoelektronischen Sensors lateral verschoben. Dies hat den Vorteil, dass die Position des Beleuchtungsmusters an den Sichtbereich der Kamera angepasst werden kann, wenn diese Kamera ein neues Objektiv erhält oder wenn das Beleuchtungsmustermuster an eine bevorzugte Stelle im Kamerasichtbereich positioniert werden soll. Die gekreuzte Ausführung der Mikrolinsenarrays ermöglicht darüber hinaus eine individuelle Einstellung der zwei Dimensionen des Beleuchtungsmusters.

[0014] Besonders einfach ist es möglich, von einem strukturierten auf ein homogenes Lichtmuster umzuschalten, wenn der Punktmustergenerator bei einer lateralen Deformation des Mikrolinsenarrays durch die Deckplatte ein Beleuchtungsmuster erzeugt, welches lateral im Erfassungsbereich verschoben ist. Durch diese laterale Verschiebung der festen Deckplatte entsteht eine Scherung des Mikrolinsenarrays, was zu einer nicht rotationssymmetrischen Deformation der Mikrolinsen führt. Dies hat zur Folge, dass das Punktmuster lateral verschoben wird und auf diese Weise die Position des Punktmusters an die zu betrachtende Szene angepasst wird.

[0015] Für alle beschriebenen Ausführungsbeispiele gilt alternativ, dass anstelle der elastisch ausgebildeten Mikrolinsen auch feste Mikrolinsen verwendet werden können, wobei eine elastische Deckplatte an den Mikrolinsen angreift.

[0016] Die Erfindung wird nachstehend auch hinsichtlich weiterer Merkmale und Vorteile beispielhaft anhand von Ausführungsformen und unter Bezug auf die beigefügte Zeichnung näher erläutert. Die Abbildungen der Zeichnung zeigen in:

Fig. 1 eine schematische Schnittdarstellung einer optoelektronischen Kamera mit einer Beleuchtungseinrichtung,

Fig. 2 ein Ausführungsbeispiel einer erfindungsgemäßen Beleuchtungseinrichtung,

Fig.3 ein erstes Ausführungsbeispiel der Funktionsweise der erfindungsgemäßen Beleuchtungseinrichtung nach Fig. 2,

Fig.4 ein weiteres Ausführungsbeispiel der Funktionsweise der erfindungsgemäßen Beleuchtungseinrichtung nach Fig. 2,

Fig.5 ein weiteres Ausführungsbeispiel der Funktionsweise der erfindungsgemäßen Beleuchtungseinrichtung nach Fig. 2,

Fig. 6 eine simulierte Oberflächengeometrie einer deformierten sphärischen Mikrolinse,

Fig.7 ein erstes Ausführungsbeispiel einer Funktionsweise eines adaptiven Mustererzeugungselementes,

Fig.8 ein zweites Ausführungsbeispiel der Funktionsweise eines adaptiven Mustererzeugungselementes,

Fig.9 ein weiteres Ausführungsbeispiel der Funktionsweise eines adaptiven Mustererzeugungselementes,

Fig. 10 ein Ausführungsbeispiel zur Funktionsweise eines Punktmustergenerators,

Fig. 11 ein weiteres Ausführungsbeispiel zur Funktionsweise eines Punktmustergenerators.

[0017] Fig. 1 zeigt eine schematische Darstellung eines optoelektronischen Sensors 1. Der optoelektronische Sensor 1 ist beispielsweise ein kamerabasierter Codeleser, kann aber ebenso ein anderer optoelektronischer Sensor sein, dessen Erfassungsbereich 2 ausgerichtet werden soll und deshalb von einer Visualisierung mittels einer Zieleinrichtung profitiert.

[0018] Der optoelektronische Sensor 1 empfängt Licht aus dem Erfassungsbereich 2. Im Falle eines Codelesers können sich dort beispielsweise Objekte mit zu lesenden Codes befinden. Das Licht aus dem Erfassungsbereich 2 wird durch ein Aufnahmeobjektiv oder eine Empfangsoptik empfangen, die vereinfacht durch eine Linse 3 dargestellt ist. Ein Lichtempfänger 4 wandelt das Empfangslicht in ein elektrisches Signal um. Bei dem Lichtempfänger 4 handelt es sich beispielsweise um eine Photodiode oder, wie bei einem kamerabasierten Codeleser, um einen CCD- oder CMOS-Chip mit einer Vielzahl von zu einer Zeile oder einer Matrix angeordneten Pixelelementen.

[0019] Das elektrische Signal des Lichtempfängers 4 wird einer Auswerteeinheit 5 zugeführt, die daraus Objektinformationen des Erfassungsbereiches 2 gewinnt. Im Beispiel des Codelesers enthält das elektrische Signal Bilddaten aus einem Lesefeld in dem Erfassungsbereich 2. In diesen Bilddaten werden Codebereiche gesucht und die Codeinformationen innerhalb von Codebereichen

werden decodiert. Das Ergebnis der Auswertung wird an einem Ausgang 6 bereitgestellt.

[0020] Der optoelektronische Sensor 1 umfasst weiterhin eine Beleuchtungseinrichtung 7, welche eine kompakte Einheit 8 umfasst, bestehend aus einer Lichtquelle 9, beispielsweise eine Halbleiterlichtquelle, wie eine LED, eine Laserdiode oder eine VC-SEL, und einem Strahlformungselement 10. Weiterhin ist in der Beleuchtungseinrichtung 7 ein Mustererzeugungselement 11 angeordnet. In dem Erfassungsbereich 2 wird damit ein Beleuchtungsmuster erzeugt, um die Lage des Erfassungsbereiches 2 sichtbar zu machen und somit den optoelektronischen Sensor 1 auf einen gewünschten Erfassungsbereich 2 richten zu können.

[0021] In Fig. 2 ist ein erstes Ausführungsbeispiel der kompakten Einheit 8 der Beleuchtungseinrichtung 7 dargestellt, welche dabei als deformierbares LED-Vergusslinsen-Array 12 ausgebildet ist. Bei einem solchen LED-Vergusslinsen-Array 12 sind auf einer Trägerplatte 13 mehrere LEDs 14 befestigt, wobei jede einzelne LED 14 mit einer sphärisch ausgebildeten Vergusslinse 15 aus einem elastischen Material verspritzt ist, so dass die LED 14 und die Vergusslinse 15 die kompakte Einheit 8 bilden. Dabei wird in einem Spritzgussprozess die Vergusslinse 15 aus einem Polymer hergestellt und mit der LED 14 zu einer Beleuchtung assembliert. Ein solches LED-Vergusslinsenarray 12 wird mit einer transparenten, aus einem festen Material bestehenden Deckplatte 16, welche in vorliegenden Fall eine inhomogene Dicke aufweist, zusammengedrückt, wobei das so betätigte deformierte LED-Vergusslinsen-Array 12 zur adaptiven Strahlformung des von den LEDs 14 ausgestrahlten Lichtes genutzt wird.

[0022] Ein Ausführungsbeispiel einer Funktionsweise einer einzelnen, mit einer LED 14 vergossenen Vergusslinse 15, die eine sphärische Linsenoberfläche aufweist, ist in Fig. 3 ersichtlich. Dabei wird durch die feste Deckplatte 16 eine Kraft F1 auf die elastische Vergusslinse 15 ausgeübt (Fig. 3A). Wird die anliegende homogene Kraft F2 gegenüber der Kraft F1 verstärkt, wird die elastische Vergusslinse 15 zusammengedrückt und deformiert (Fig. 3B). Die Abflachung der sphärischen Linsenform im inneren Bereich führt zu einer optischen Strahlformung. Infolge der Deformation der elastischen Vergusslinse 15 wird das von der LED 14 ausgegebene Licht divergent beeinflusst. Alternativ zu der beschriebenen sphärischen Linsenform ist aber auch eine asphärische oder frei geformte Linsenoberfläche einsetzbar.

[0023] Wie aus Fig. 4 ersichtlich, funktioniert ein solches Strahlformungselement 10 aber auch dann, wenn die Vergusslinse 15 fest ausgebildet ist und die Deckplatte 16 aus einem elastischen Material besteht. Dabei verformt sich, wie aus Fig. 4 ersichtlich, die Deckplatte 16, was ebenfalls zu einer Strahlformung des von der LED 14 abgegebenen Lichtstrahles führt.

[0024] Somit sind unterschiedliche Materialkombinationen für Deckplatte 16 und Vergusslinse 15 möglich. Besteht die Vergusslinse 15 aus einem elastischen Material wie beispielsweise Silikon, so kann die Deckplatte 16 aus einem festen Material wie Glas oder Polymer ausgebildet sein. Alternativ kann die Vergusslinse 15 aber auch aus einem festen Material wie Glas und die Deckplatte 16 aus dem elastischen Material wie Silikon bestehen. In einer weiteren Alternative können sowohl Vergusslinse 15 als auch Deckplatte 16 aus einem voll- oder teilelastischen Material hergestellt sein.

[0025] In Fig. 5 ist auf der Oberfläche der sphärisch ausgebildeten Vergusslinse 15 eine Noppe 17 ausgebildet. Diese Noppe 17 ist insbesondere in dem Bereich der Oberfläche der Vergusslinse 15 ausgebildet, wo die Linsenoberfläche zuerst die Deckplatte 16 berührt. Diese Noppe 17 im Kontaktbereich zwischen elastischer Vergusslinse 15 und fester Deckplatte 16 hat den Vorteil, dass eine Hysterese der Beleuchtungsdivergenz unterbunden wird, indem die Kontaktfläche zwischen elastischer Vergusslinse 15 und fester Deckplatte 16 minimiert wird. Dieser Effekt kann verbessert werden, wenn auf der Oberfläche der Vergusslinse 15 in vorgegebenen Abständen mehrere Noppen 17 ausgebildet sind.

[0026] In Fig. 6 ist eine simulierte Oberflächengeometrie der beschriebenen deformierten sphärischen Vergusslinse 15 dargestellt, woraus hervorgeht, dass bei einem auf die Vergusslinse 15 wirkenden Druck infolge der homogenen Kraft die Abflachung der sphärischen Linsenform im inneren Bereich der Vergusslinse 15 erfolgt.

[0027] Fig. 7 zeigt ein Mustererzeugungselement 11 der Beleuchtungseinrichtung 7, welche ebenfalls als Mikrolinsenarray 18 ausgebildet ist, bei dem eine vorgegebene Anzahl aus elastischen Mikrolinsen 19 auf einem festen Trägermaterial 20 positioniert sind. Ein solches Mustererzeugungselement 11 wird bei einer Neujustierung des optoelektronischen Sensors 1 benötigt. Über den Mikrolinsen 19 ist eine transparente, aus festem Material bestehende Deckplatte 21 angeordnet, die in Fig. 7A ohne eine weitere Krafteinwirkung auf den Mikrolinsen 19 aufliegt. Das Ergebnis ist, dass das, von dem Mikrolinsenarray 18 im Erfassungsbereich 2 des optoelektronischen Sensors 1 erzeugte Beleuchtungsmuster ein Zielkreuz 22 darstellt. Wird auf die Deckplatte 21 mit einer homogenen Kraft F2, welche größer ist als F1, gegen die elastischen Mikrolinsen 19 gedrückt, so bewirkt diese Druckbeaufschlagung der Mikrolinsen 19 eine Vergrößerung der Krümmungsradien und somit der Brennweiten der Mikrolinsen 19. Dies hat eine Verringerung der Strahldivergenz und somit eine Verkleinerung der Dimension des Zielkreuzes 22 zur Folge, wie es in Fig. 7B dargestellt ist. Auch hier können anstelle eines elastischen Mikrolinsenarrays und einer festen transparenten Deckplatte ein festes Mikrolinsenarray und eine elastische Deckplatte verwendet werden.

[0028] Im druckbeaufschlagtem Zustand (F>0) des elastischen Mikrolinsenarrays 18 besteht die Möglichkeit, dieses lateral zu deformieren, wie aus Fig. 8 hervorgeht. Dabei befindet sich das Zielkreuz 22 im unbelasteten Zustand in der Mitte des Erfassungsbereiches 2 (Fig.8A). Durch die laterale Verschiebung der festen

transparenten Deckplatte 21 und der gleichzeitigen Druckbeaufschlagung der Mikrolinsen 19 entsteht eine Scherung des Mikrolinsenarrays 18, was zu einer nicht rotationssymmetrischen Deformation der Mikrolinsen 19 führt, wie in Fig. 8B dargestellt. Dies hat zur Folge, dass das Zielkreuz 22 im Erfassungsbereich 2 lateral verschoben wird. Auf diese Weise kann die Position des Zielkreuzes 22 in dem Erfassungsbereich des optoelektronischen Sensors 1 angepasst oder an einer bestimmten bevorzugten Stelle im Erfassungsbereich 2 positioniert werden.

[0029] Es besteht auch die Möglichkeit, die zwei Dimensionen des Zielkreuzes 28 individuell voneinander einzustellen. Zu diesem Zweck besteht das Mustererzeugungselement 23 aus zwei gekreuzten elastischen Mikrolinsenarrays 24, 25. Die Orientierung von Mikrolinsenarray 24 ist senkrecht zur Orientierung vom Mikrolinsenarray 25, wobei die beiden Mikrolinsenarrays 24, 25 zu beiden Seiten eines Trägerelementes angeordnet sind. Im vorgegebenen Beispiel wird das erste Mikrolinsenarray 24 von einer ersten Deckplatte 26 aus einem festen transparenten Material abgedeckt, während das zweite Mikrolinsenarray 25 von einer zweiten Deckplatte 27 überdeckt wird. Wird keinerlei Kraft auf das erste und das zweite Mikrolinsenarray 24, 25 durch die Deckplatten 26, 27 ausgeübt, so ergibt sich ein Zielkreuz 28 wie es in Fig. 9A gezeigt ist. Durch die individuelle Druckbeaufschlagung des Mikrolinsenelementes 24 über die erste Deckplatte 26 und des zweiten Mikrolinsenarrays 25 durch die zweite Deckplatte 27 verschiebt sich die Dimension des Zielkreuzes 28 in beiden Richtungen unabhängig voneinander. So verkürzt sich der waagerechte Strich 29 des Zielkreuzes 28, wenn nur die Deckplatte 26 mit einer vorgegebenen konstanten Kraft F>0 auf das erste Mikrolinsenarray 24 drückt. Wird dem zweiten Mikrolinsenarray 25 keine Kraft zugeführt, so bleibt der vertikale Strich 30 des Zielkreuzes 28 unverändert (Fig. 9B). In einer Alternative, welche in Fig. 9C dargestellt ist, wird das zweite Mikrolinsenarray 25 durch die zweite Deckplatte 27 mit einer vorgegebenen Kraft F>0 beaufschlagt, wodurch sich der vertikale Strich 30 des Zielkreuzes 28 verkürzt. Da in diesem Fall das erste Mikrolinsenarray 24 druckunbeaufschlagt ist, bleibt der waagerechte Strich 29 des Zielkreuzes 28 unverändert.

[0030] Insbesondere bei der Verwendung eines optoelektronischen Sensors 1, der als 3D-Kamerasensor zur Entfernungsmessung ausgebildet ist, basiert das Detektionsprinzip auf Triangulation unter Zuhilfenahme einer aktiven Musterbeleuchtung. In Stereosystemen wird die Beleuchtung zur Generierung eines künstlichen Kontrastes eingesetzt, um dichte Tiefenkanten zu erzeugen und die Abstandswerte periodischer Objekte in der zu betrachtenden Szene eindeutig zu bestimmen. In diesem Fall ist das Mustererzeugungselement als Punktmustergenerator 31 auf der Basis eines Mikrolinsenarrays 32 ausgebildet. Die auf dem Mikrolinsenarray 32 angeordneten Mikrolinsen 33 bestehen aus einem elastischen Material, beispielsweise aus Silikon. Die elastischen Mikrolinsen 33 sind auf einem festen Trägermaterial 34 angeordnet und, wie im Zusammenhang mit Fig. 1 erläutert, ist dieses so geformte Mustererzeugungselement Bestandteil der Beleuchtungseinrichtung 7.

[0031] Ein Ausführungsbeispiel für die Funktionsweise eines solchen Punktmustergenerators 31 ist in Fig. 10 dargestellt. Das Mikrolinsenarray 32 des Punktmustergenerators 31 wird von dem Lichtstrahl der Lichtquelle 9 durchleuchtet, wobei, wie aus Fig. 10A ersichtlich, der Lichtstrahl konvergiert. Dies ist immer dann der Fall, wenn keine Kraft auf das Mikrolinsenarray 32 ausgeübt wird. Ohne diese mechanische Druckbeanspruchung bilden die Mikrolinsen 33 des Mikrolinsenarrays 32 in der Fokusebene des Projektionsobjektivs kleine Brennpunkte aus, dessen Lichtmuster zu einem Beleuchtungsmuster mit kleinen Punktdurchmessern führt. Wird gemäß Fig. 10B eine Kraft F2>0 durch die transparente Deckplatte 35 auf das Mikrolinsenarray 32 ausgeübt, deformieren sich die Mikrolinsen 33, wie im Zusammenhang mit Fig. 5 erläutert. Die Deformation führt zu einer Abflachung des Linsenkrümmungsradius in der Linsenmitte, was wiederum zur Verschiebung des Brennpunktes führt. Die Verschiebung des Brennpunktes in der Fokusebene des Projektionsobjektivs führt zur Vergrößerung des Punktdurchmessers des in der Fokusebene des Projektionsobjektivs dargestellten Beleuchtungsmusters.

[0032] Wird weiterhin der Druck (F>>0) auf das elastische Mikrolinsenarray 32 erhöht (Fig. 10C), verschwindet die gekrümmte Linsenform vollständig. Übrig bleiben zwei parallele Glasplatten in Form der transparenten Deckplatte 35 und des transparenten Trägermaterials 34 mit einem elastischen Material dazwischen. Bei dieser Position der Mikrolinsen 33 erlischt deren Strahlformungseffekt vollständig. In diesem Zustand wird die Fokusebene des Projektionsobjektivs homogen beleuchtet, was zu einer homogenen Beleuchtung der Szene führt.

[0033] Wird in einem druckbeaufschlagten Zustand des elastischen Mikrolinsenarrays 32 dieses lateral deformiert, wie in Fig. 11 dargestellt, indem eine laterale Verschiebung der Deckplatte 34 vorgenommen wird, entsteht eine Scherung des Mikrolinsenarrays 32, was zu einer nicht rotationssymmetrischen Deformation der Mikrolinsen 33 führt. Dies hat zur Folge, dass das Punktmuster in der Fokusebene des Projektionsobjektivs in Richtung der Verschiebung der Deckplatte 34 verschoben wird (Fig. 11 B). Im Vergleich dazu befindet sich das Punktmuster immer dann, wenn das Mikrolinsenarray 32 frei von einer Druckbeaufschlagung ist, im Zentrum der Fokusebene des Projektionsobjektivs (Fig. 11A). Aufgrund der Verwendung eines solchen Punktmuster-Erzeugungselementes in einer 3D-Stereokamera, lassen sich die Beleuchtungsmuster adaptiv an die Gegebenheiten der zu beleuchtenden Szene anpassen, wobei das Beleuchtungsmuster zwischen strukturiert und homogen adaptiv umgeschaltet werden kann. Dieses Umschalten ermöglicht neben den 3D-Tiefendaten auch die Aufnahme von Grauwertbildern.

[0034] Es besteht ebenfalls die Möglichkeit, die Ver-

änderung bzw. Verschiebung des Punktmusters für sichere Stereokameras einzusetzen. In der Sicherheitstechnik muss sichergestellt werden, dass die Bildaufnahme immer zuverlässig funktioniert. Die Funktionalität der Bildsensoren wird dabei mit einem dynamischen Bildsensortest (Hell- und Dunkelbildern) in den Pausen der Stereobildaufnahme mit einer internen Beleuchtungs-LED überprüft. Der Bildsensortest mit interner Beleuchtungs-LED kann eingespart werden, wenn sich das Beleuchtungsmuster

[0035] (Position und Größe der Punkte) von Zeit zu Zeit ändert, um die dynamische Funktion der Bildsensoren mit den Grauwertbildern der beiden Kameramodule aus der Szene zu verifizieren.

Patentansprüche

1. Beleuchtungseinrichtung zum Erzeugen eines Beleuchtungsfeldes für einen optoelektronischen Sensor, die mindestens eine Lichtquelle (9), ein anpassbares optisches Strahlformungselement (10) und ein Druckelement aufweist, wobei das Druckelement an das Strahlformungselement (10) (16) angreift, und zur Lichtformung deformiert, und wobei die Lichtquelle (9) und das Strahlformungselement (10) direkt aneinander grenzen und eine kompakte Einheit (8) bilden, **dadurch gekennzeichnet, dass** im Strahlengang hinter dem Strahlformungselement (10), der Lichtquelle (9) abgewandt, ein Mikrolinsen (19) aufweisendes Mustererzeugungselement (11) angeordnet ist, welches einen Erfassungsbereich (2) des optoelektronischen Sensors (1) durch ein Beleuchtungsmuster (22, 28) sichtbar macht, dass das Mustererzeugungselement (11) als adaptiver, Mikrolinsen (33) umfassender Punktmustergenerator (31) ausgebildet ist, welcher bei einer mechanischen Druckbeanspruchung der elastisch ausgebildeten Mikrolinsen (33) durch die aus einem festen Material bestehenden Deckplatte (35) in Abhängigkeit der senkrecht an den Mikrolinsen (33) angreifenden Druckkraft das Beleuchtungsmuster mit variierendem Punktdurchmesser erzeugt.

2. Beleuchtungseinrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Punktmustergenerator (31) bei einer lateralen Deformation der Mikrolinsen (33) durch die Deckplatte (35) ein Beleuchtungsmuster erzeugt, welches lateral im Erfassungsbereich (2) verschoben ist.

Claims

1. An illumination device for producing an illumination field for an optoelectronic sensor which has at least one light source (9), an adaptable optical beam shaping element (10) and a pressure element, wherein the pressure element (16) engages at the beam shaping element (10) and deforms it for light shaping; and wherein the light source (9) and the beam shaping element (10) are directly adjacent to one another and form a compact unit (8), **characterized in that** a pattern generating element (11) having microlenses (19) is arranged in the optical path behind the beam shaping element (10) and facing away from the light source (9), said pattern generating element making a detection zone (2) of the optoelectronic sensor (1) visible by an illumination pattern (22, 28); **in that** the pattern generating element (11) is configured as an adaptive point pattern generator (31) which comprises microlenses (33) and which produces the illumination pattern with a varying point diameter on a mechanical pressure exertion on the elastic microlenses (33) by the top plate (35) comprising a solid material in dependence on the perpendicular pressure force engaging at the microlenses (33).

2. An illumination device in accordance with claim 1, **characterized in that** the point pattern generator (31) produces an illumination pattern, which is displaced laterally in the detection zone (2), on a lateral deformation of the microlenses (33) by the top plate (35).

Revendications

1. Dispositif d'éclairage destiné à la production d'une zone d'éclairage pour un capteur optoélectronique, qui comprend au moins une source de lumière (9) et un élément de formage de rayon (10) optique adaptable et un élément de compression, l'élément de compression attaquant l'élément de formage de rayon (10) et le déformant pour le formage de la lumière, et dans lequel la source de lumière (9) et l'élément de formage de rayon (10) sont directement adjacents l'un à l'autre et forment une unité compacte (8), **caractérisé en ce qu'**en arrière de l'élément de formage de rayon (10) dans le chemin optique, un élément de génération de motif (11) comprenant des microlentilles (19) est agencé en étant détourné de la source de lumière (9), qui rend visible une zone de détection (2) du capteur optoélectronique (1) par un motif d'éclairage (22, 28), **en ce que** l'élément de génération de motif (11) est réalisé sous forme de générateur de motif de points (31) adaptatif comprenant des microlentilles (33), qui, lors d'une sollicitation mécanique par pression des microlentilles (33) réalisées élastiques, génère le motif d'éclairage avec variation du diamètre des points par la plaque de couverture (35) constituée en un matériau solide, en fonction de la force de compression attaquant verticalement les microlentilles (33).

2. Dispositif d'éclairage selon la revendication 1, **caractérisé en ce que** lors de la déformation latérale des microlentilles (33) par la plaque de couverture (35), le générateur de motif de points (31) génère un motif d'éclairage qui est décalé latéralement dans la zone de détection (2).

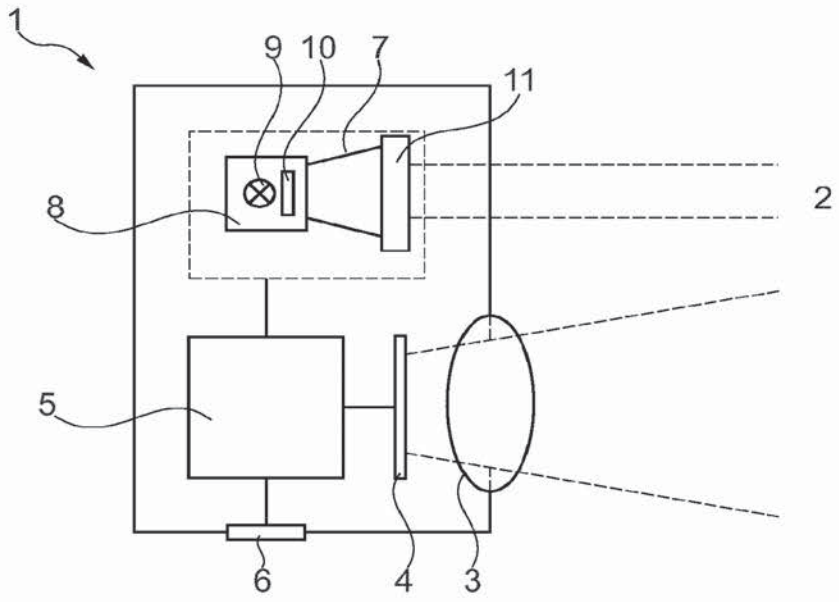


Fig. 1

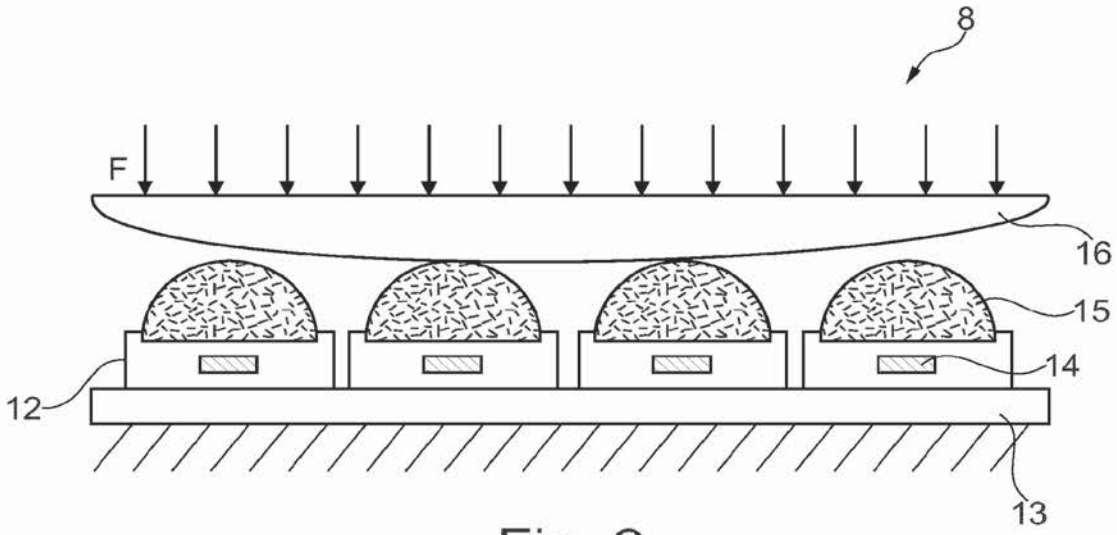


Fig. 2

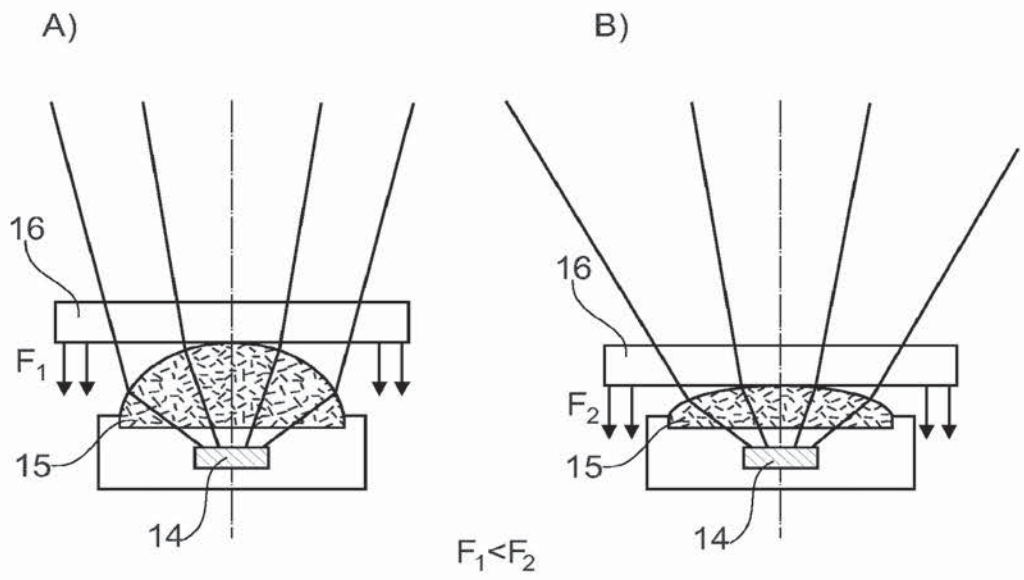


Fig. 3

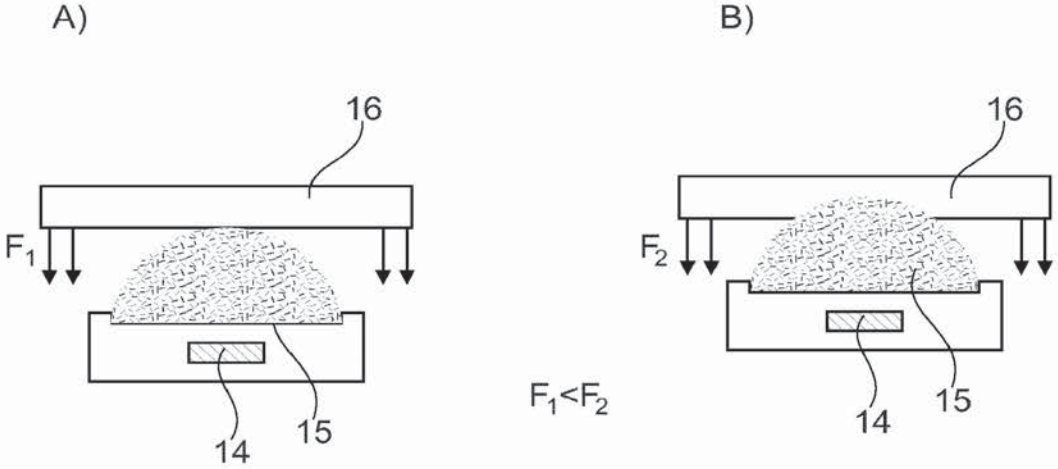


Fig. 4

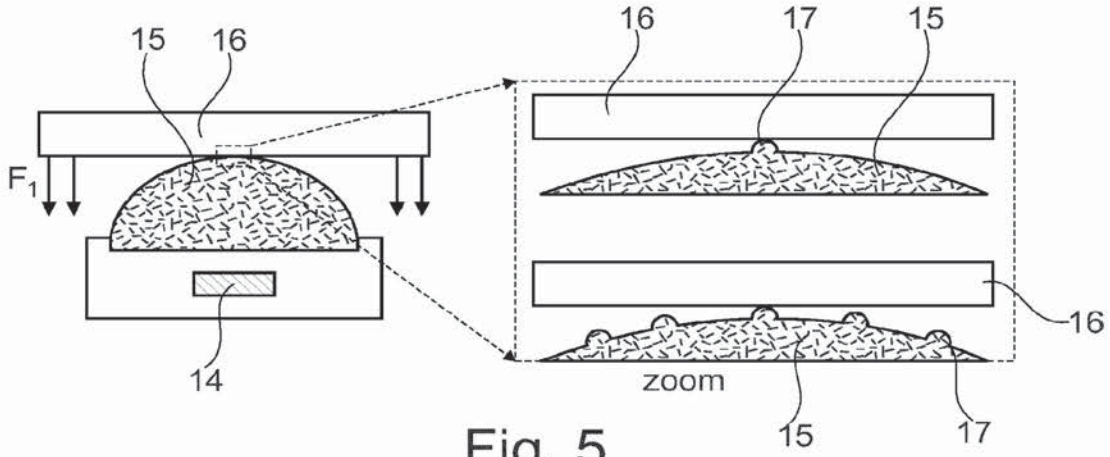

15
16
F1
14
16
17
15
16
zoom
15
17

Fig. 5

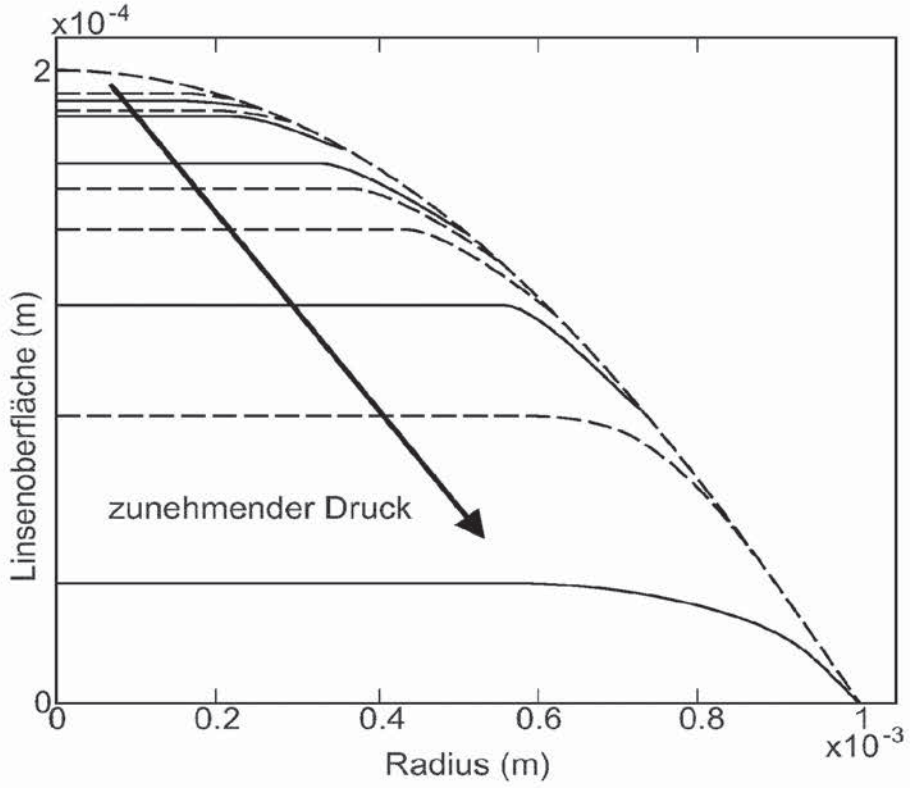

x10-4
2
0
Linsenoberfläche (m)
zunehmender Druck
0
0.2
0.4
0.6
0.8
1
x10-3
Radius (m)

Fig. 6

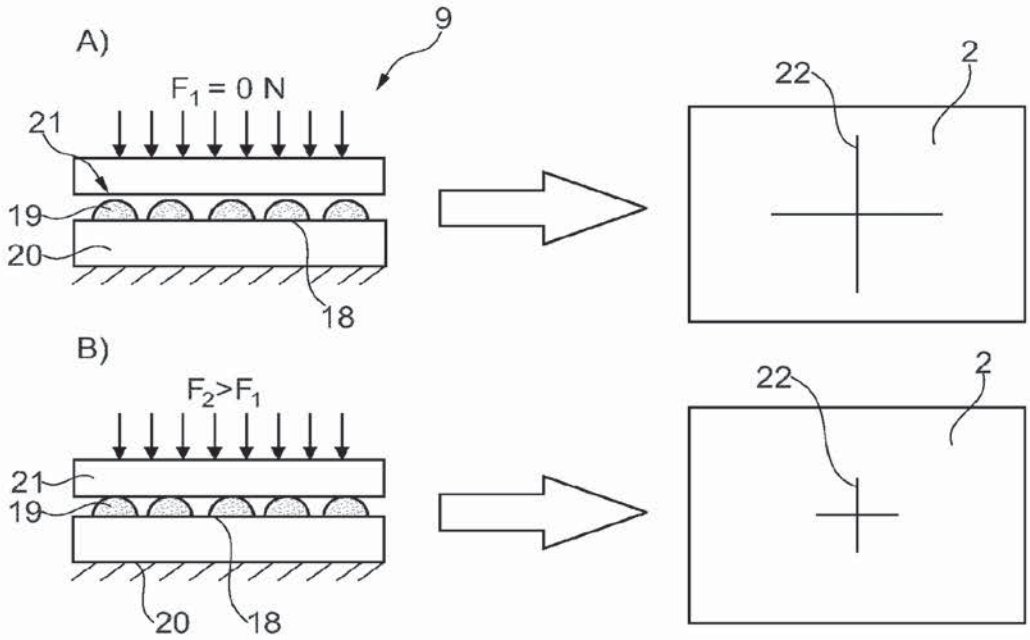

A)
9
F_1 = 0 N
21
19
20
18
22
2
B)
F_2>F_1
21
19
20
18
22
2

Fig. 7

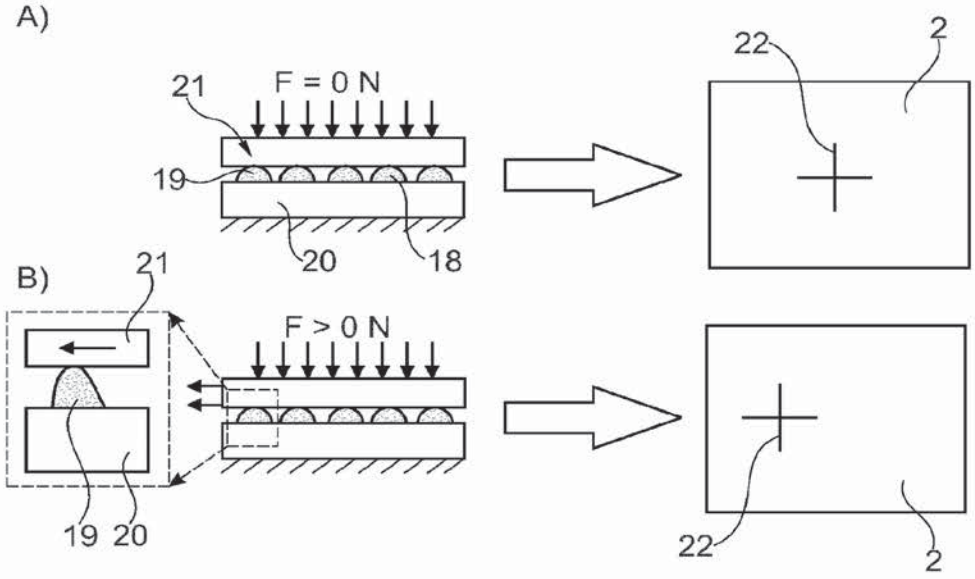

A)
21
F = 0 N
19
20
18
22
2
B)
21
F > 0 N
19
20
22
2

Fig. 8

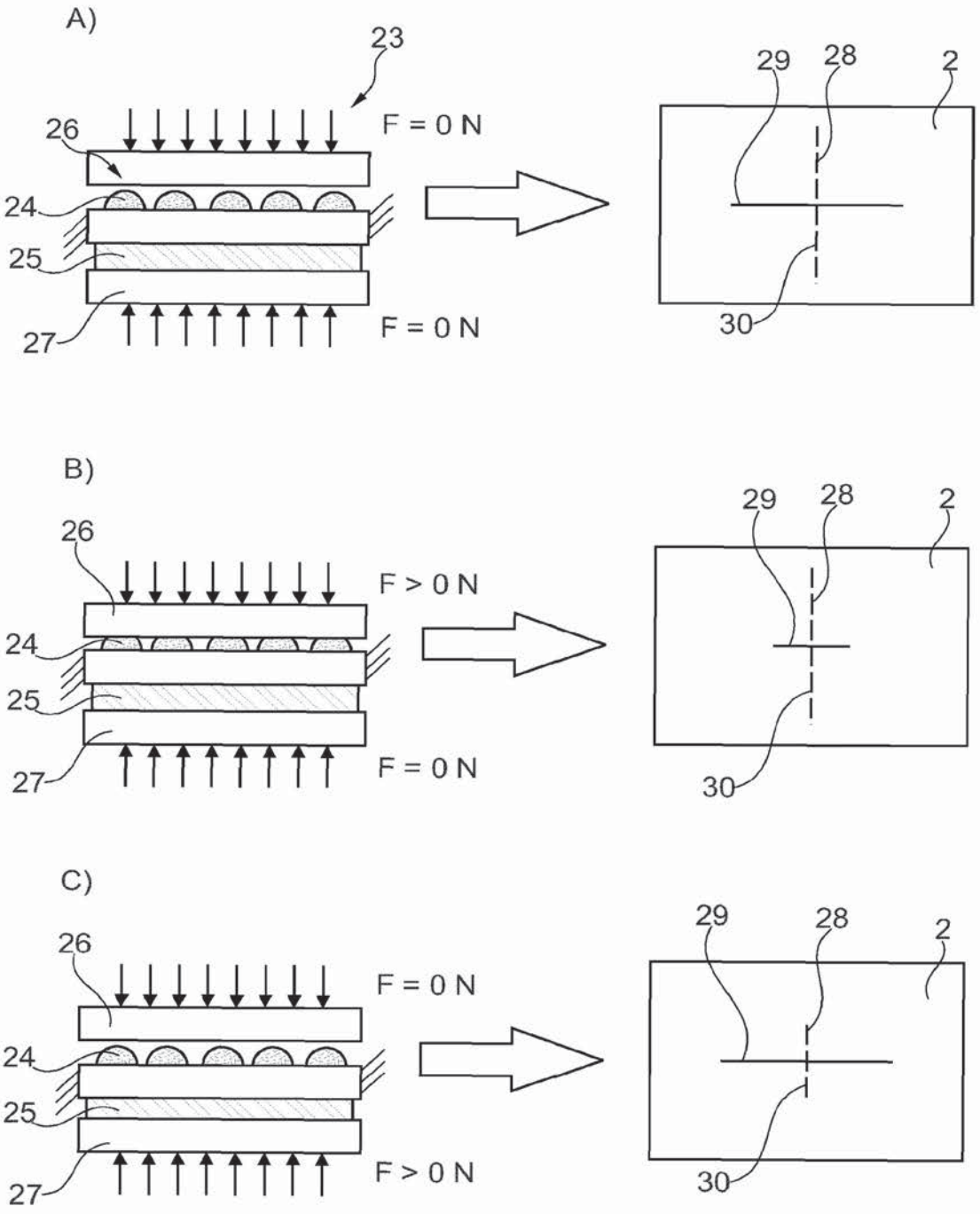

A)
23
26
F = 0 N
24
25
27
F = 0 N
29
28
2
30
B)
26
F > 0 N
24
25
27
F = 0 N
29
28
2
30
C)
26
F = 0 N
24
25
27
F > 0 N
29
28
2
30

Fig. 9

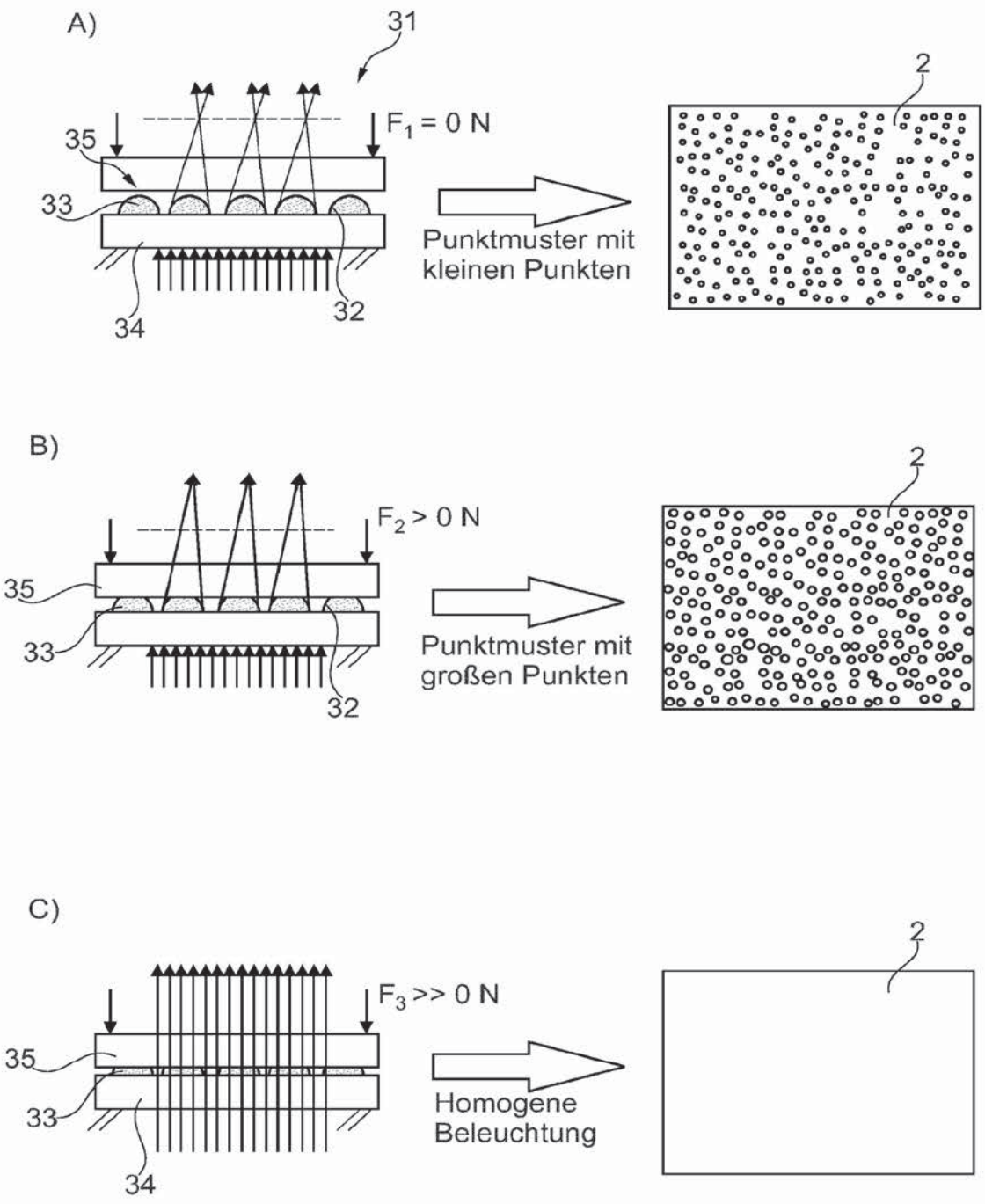

A)
31
35
F_1 = 0 N
33
34
32
Punktmuster mit kleinen Punkten
2
B)
F_2 > 0 N
35
33
32
Punktmuster mit großen Punkten
2
C)
F_3 >> 0 N
35
33
34
Homogene Beleuchtung
2

Fig. 10

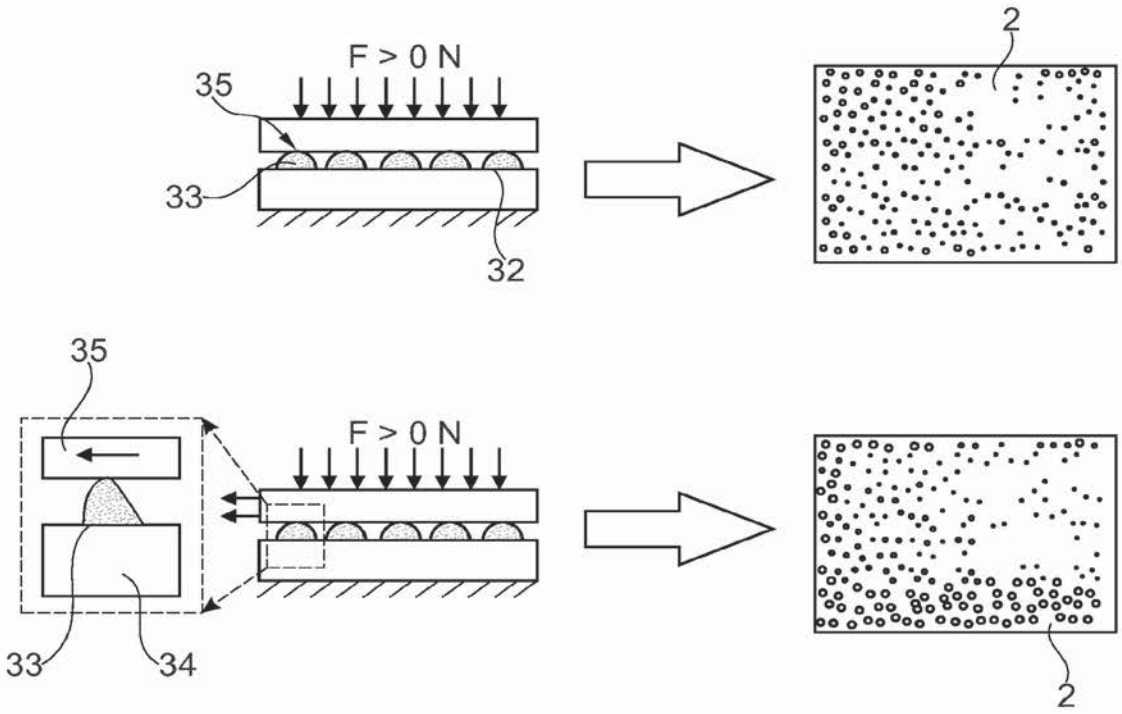


Fig. 11

IN DER BESCHREIBUNG AUFGEFÜHRTE DOKUMENTE

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) Title: MONOLITHIC LED ARRAYS FOR UNIFORM AND HIGH-BRIGHTNESS LIGHT SOURCES

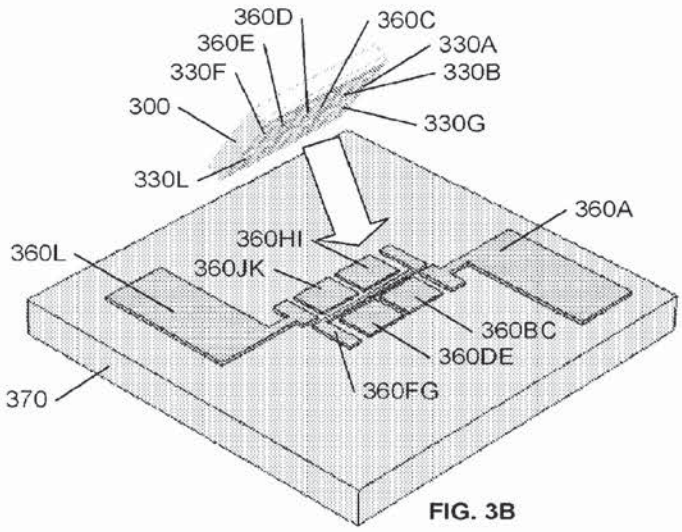


FIG. 3B

(57) Abstract: A wafer of light emitting elements is sliced/diced to create monolithic arrays of individual light emitting elements. To increase the light output intensity, more light emitting elements are included within the monolithic array. Accordingly, the light output intensity is determined by the number of light emitting elements that are included in the array. Because each light emitting element is the same, regardless of the number of elements in the array, the differently sized arrays need not be individually characterized. In like manner, because the light emitting elements in each array are fabricated on the same wafer, under the same environmental conditions, all of the light emitting elements in the array will exhibit common light output characteristics.

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MONOLITHIC LED ARRAYS FOR UNIFORM AND HIGH-BRIGHTNESS LIGHT SOURCES

FIELD OF THE INVENTION

This invention relates to the field of light emitting devices, and in particular to a light source comprising a monolithic array of light emitting elements.

BACKGROUND OF THE INVENTION

The ever expanding use of semiconductor light emitting devices has produced a highly competitive market for these devices. In this market, performance and price are often significant for providing product distinction among vendors.

Light emitting elements are typically grown on a wafer ('growth substrate') and include an active light emitting material sandwiched between an N-type semiconductor and a P-type semiconductor. Hundreds or thousands of light emitting elements may be grown simultaneously on the growth substrate, with 'lanes' or 'streets' separating each of the light emitting elements. The light emitting elements are singulated into individual light emitting 'chips' by slicing/dicing along these dividing streets and removing the growth substrate. One or more of these singulated chips may be mounted on a submount that provides structural support to the light emitting chips and provides a means for connecting the chip to an external source of power.

The light output intensity is dependent upon the current that flows through the light emitting element; however, the heat produced within the light emitting element is also dependent upon this current, and thus the maximum current, and therefore light output, is limited by the allowable junction temperature (typically 125°C). In addition, the LED efficacy drops with increased junction temperature and with increased current density due to the "droop" effect.

In order to address these issues one way is to increase the surface area of the LED. This allows to decrease the current density of the LED and improve its efficacy, and at the same time decrease its thermal resistance and lower the junction temperature. This comes at the expense of cost, reliability (larger size LEDs are usually more fragile) footprint, and source size (etendue). Larger LED source size impacts the secondary optics size which are usually needed in LED lamps. This in turn leads to additional cost increases and to larger lamp volume and weight. Additionally, to prevent, for example, localized bright regions and dim regions across larger surface areas, more sophisticated fabrication techniques may be required. Each different fabrication technique will generally require different layout techniques, perhaps different processing techniques, and so on. In addition to the design and testing overhead associated with each differently sized design, the more sophisticated processes required for larger surface area light emitting elements increase the per-unit-area fabrication costs. That is, convention fabrication techniques for light emitting elements are not directly 'scalable' for increasing light output intensity by increasing surface area, per se.

Another technique for improving the performance of a light emitting device is to increase the light output intensity from the device, often by packaging multiple light emitting chips within the device. A plurality of the aforementioned submounted chips may be placed on a larger mount, such as a printed circuit board, suitable for packaging as a single light emitting device. Wavelength conversion material, such as phosphor may be added, to either each individual chip on a submount, or to a plurality of the chips on the larger mount.

The larger mount may include circuit traces that serve to interconnect the chips on the submounts in a desired manner, often as a series connection of light emitting chips of the same color. The circuit traces may also include contact pads or other structures for providing external power to the light emitting device.

The light emitting device may also include an optical element, such as a collimating lens, that serves to provide a desired light output pattern. The optical element may include features that serve to direct the light from each submount chip in a desired orientation relative to the light from the other submounted chips.

Recent advances have allowed for eliminating the submount by providing self-supporting light emitting elements. As disclosed in copending U.S. patent application 61/568,297, "FORMING THICK METAL LAYERS ON A SEMICONDUCTOR LIGHT EMITTING DEVICE", filed 8 December 2011 for Alexander Nickel, Jim Lei, Anneli Munkholm, Grigoriy Basin, Sal Akram, and Stefano Schiaffino (Attorney Docket 2011P00972), and incorporated by reference herein, thick metal layers are added to each of the N-layer and P-layer contacts, separated by an insulating material. These metal layers provide the structural support to the light emitting element, and form contact pads for the light emitting element when used in a 'flip-chip' configuration.

Copending U.S. patent application 61/656,691, "CHIP SCALE LIGHT EMITTING DEVICE WITH METAL PILLARS IN A MOLDING COMPOUND FORMED AT WAFER LEVEL", filed 7 June 2012, for Jipu Lei, Stefano Schiaffino, Alexander Nickel, Mooi Guan Ng, Grigoriy Basin, and Sal Akram, (Attorney docket 2012PF00450) and incorporated by reference herein, discloses providing a multiple pillars upon the N-type and P-type contacts pads and embedding these pillars in a molding compound. The pillars provide the mechanical support and conductivity, while the molding compound prevents distortions in the pillar structure.

In like manner, techniques have been developed that allow the light emitting element to remain on the growth substrate, the growth substrate providing the structural support for the singulated light emitting elements. In such an embodiment, after singulation, the light emitting element emits light into the remaining (transparent) substrate, and the light is emitted from the opposite surface, or the sides, of the substrate. A Patterned Sapphire Substrate (PSS) may be used as the growth substrate, the pattern on the substrate serving to enhance light extraction into the substrate by reducing the likelihood of total internal reflection at the interface between the light emitting element and the sapphire substrate.

By providing a self-supporting light emitting chip, conventional 'pick and place' manufacturing techniques may be used to place these self-supporting chips directly upon the aforementioned larger mount, such as a printed circuit board.

A disadvantage of placing multiple light emitting elements within a light emitting device, however, is that different light emitting elements, and particularly light emitting elements from different fabrication wafers may exhibit different light output characteristics, and this variance may render some of the devices unsuitable for their intended purpose.

SUMMARY OF THE INVENTION

It would be advantageous to provide a technique for increasing light output intensity that is easily scalable. It would also be advantageous to provide a scalable increase in light output intensity that does not necessarily impose a need to re-characterize differently scaled light emitting elements. It would also be advantageous to provide a scalable increase in light output intensity that provides a uniformity in light output characteristics.

To better address one or more of these concerns, in an embodiment of this invention, a wafer of light emitting elements is sliced/diced to create monolithic arrays of individual light emitting elements, with minimal gaps between the light emitting elements. To increase the light output intensity, more light emitting elements are included within the monolithic array. Accordingly, the light output intensity is determined by the number of light emitting elements that are included in the array. Because each light emitting element is the same, regardless of the number of elements in the array, the differently sized arrays need not be individually characterized. In like manner, because the light emitting elements in each array are fabricated on the same wafer, under the same environmental conditions, all of the light emitting elements in the array will exhibit common light output characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

FIGs. 1A-1C illustrate an example fabrication and singulation of prior art light emitting elements.

FIGs. 2A-2B illustrate an example fabrication and singulation of an array of light emitting elements.

FIGs. 3A-3B illustrate an example mounting of an array of light emitting elements upon a printed circuit board mount.

FIG. 4 illustrates an example printed circuit board that provides a plurality of printed circuit board mounts.

FIGS. 5A-5C illustrate an example fabrication of a light emitting device with an array of light emitting elements on a printed circuit board mount.

Throughout the drawings, the same reference numerals indicate similar or corresponding features or functions. The drawings are included for illustrative purposes and are not intended to limit the scope of the invention.

DETAILED DESCRIPTION

In the following description, for purposes of explanation rather than limitation, specific details are set forth such as the particular architecture, interfaces, techniques, etc., in order to provide a thorough understanding of the concepts of the invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments, which depart from these specific details. In like manner, the text of this description is directed to the example embodiments as illustrated in the Figures, and is not intended to limit the claimed invention beyond the limits expressly included in the claims. For purposes of simplicity and clarity, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

FIGs. 1A-1C illustrate an example fabrication and singulation of prior art light emitting devices 100, which is a portion of a wafer. FIG. 1A illustrates a side view of the wafer and FIG. 1B illustrates a top view of a wafer including a substrate 110 upon which many semiconductor light emitting elements 120 are formed. FIG. 1C illustrates an individual light emitting device 100 which includes a portion of substrate 110, a single light emitting element 120 and two contacts 130A, 130B. The substrate 110 may be a transparent material, such as sapphire, through which the light from the light emitting elements 120 is transmitted. The light emitting elements 120 typically includes multiple layers in including an active light emitting region sandwiched between an N-type and P-type semiconductors. Contact pads 130 (130A-130B in FIG. 1B) allow for coupling of external power to each of the N-type and P-type semiconductors.

Hundreds, or thousands, of light emitting elements 120 may be formed on the substrate 110. Upon completion of the fabrication of these elements 120 on the substrate 110, the substrate 110 is sliced/diced as illustrated by the cutting lines 150, to 'singulate' each light emitting device 100, as illustrated in FIG. 1C.

FIGs. 2A-2B illustrate an example fabrication and singulation of an array 200 of light emitting elements 120. In this example embodiment, the individual light emitting elements 120 may be formed on the substrate 110 using conventional fabrication techniques. To form an array 200 of light emitting elements 120, the substrate 110 is sliced/diced along cutting lines 250, leaving multiple light emitting elements 120 physically connected to each other.

The individual light emitting elements 120 are delineated in FIG. 2A by the dashed lines, although there may not be a visible delineation between these elements. For example, a layer of the light emitting elements 120 closest to the contact pads 230 may be a dielectric layer that extends into the unused regions ('streets') between the light emitting devices 200.

In this example embodiment, the cutting lines 250 result in four light emitting elements 120 within each array 200. Of particular note, each array 200 is monolithic, in that all of the elements 120 within each array 200 are produced concurrently using the same process and are integrally connected, physically. Electrically, however, each of these light emitting elements 120 is independent of the other light emitting elements, and operates as an individual light emitting element 120. Accordingly, each of the light emitting elements 120 can be expected to exhibit the same performance and reliability characteristics as the light emitting element 120 in the conventional light emitting device 100 of FIG. 1C.

Each array 200 of light emitting elements 120 includes the two contact pads for coupling to each of the N-type and P-type semiconductors of each light emitting element 120, illustrated as contacts 230A through 230H in FIG. 2A. That is, contact pads 230A-230B are coupled to one light emitting element 120; contact pads 230C-230D are coupled to another; and so on. The illumination of the array 200 may be controlled by providing a selective control of each light emitting element 120, or by providing a single source of power to all of the light emitting elements 120 in the array 200. For example, each of the light emitting elements 120 may subsequently be connected in series, allowing for a single pair of contacts for external control of the array 200 of light emitting elements 120.

In the example of FIGs. 2A-2B, all of the light emitting elements 120 are uniformly disposed on the substrate 110, and differently arranged arrays may be formed by slicing along the appropriate streets between the arrays. For example, a 4x2 array of light emitting elements may be provided by eliminating the cuts 250A, 250C. In this manner, the choice of the number and shape of light emitting elements 120 within a particular array can be made as a last step in the process, and the wafer that provides these uniformly disposed light emitting elements can be fabricated without regard to the eventually slicing to provide a particularly sized or shaped array.

One of skill in the art will recognize, however, that if the size and shape of the array is known a priori, the light emitting elements 120 may be laid out on the substrate 110 to optimize the production of the particular array. For example, the width of select streets between the light emitting elements 120 may be reduced if that street is not included in the pattern of cutting lines for the array. That is, in FIG. 2A, the streets identified by dotted lines can be narrower than the streets identified but cutting lines 250 if it is known a priori that the arrays will be 2x2 arrays (or multiples thereof), because the narrower streets do not need to accommodate the width of the kerf of the slicing process at cutting lines 250.

One of skill in the art will also recognize that custom layouts based on an a priori definition of the size and shape of the array may also allow for the use of predefined connections between the light emitting elements. For example, if the wafer of FIG. 2A, which includes many 2x2 arrays 200, is expected to have the light emitting elements 120 within the array 200 connected in a particular fashion (series, parallel, series-parallel, etc.), the layout of this a priori defined array configuration on the substrate 110 may include the appropriate interconnections among the light emitting elements to effect the intended connection pattern.

Alternatively, the interconnection of the light emitting elements within the array may be effected via the submount upon which the array is mounted.

FIGs. 3A-3B illustrate an example mounting of an array 300 of light emitting elements 120 upon a printed circuit board mount 370. In this example embodiment, the array 300 is a 3x2 array of light emitting elements 120, with six pair of contacts, 330A through 330L. As illustrated in FIG. 3B, the array 300 is 'flip-chip' mounted on the mount 370, such that the contacts 330A-330L are on the 'lower' surface of the array 300, and the substrate 110 through which light is emitted is the 'upper' surface of the array 300.

The printed circuit board mount 370 includes a pattern of circuit traces 360A-360L that are arranged to couple the six light emitting elements 120 in series with each other. A first trace 360A provides for an external coupling to contact 330A of a first light emitting element of the array 300. A second trace 360BC provides for an external coupling from contact 330B of the first light emitting element to contact 330C of a second light emitting element in the array 300, placing the second light emitting element in series with the first light emitting element. In like manner, 360DE provides coupling from contact 330D of the second light emitting element to contact 330E of a third light emitting element, and so on. Circuit trace 360L provides for an external coupling to contact 330L of the last light emitting

element. Providing power to circuit traces 360A and 360L will provide a current to each of the six light emitting elements 120 in the array 300 in series.

One of skill in the art will recognize that although a series connection is illustrated, the circuit traces 360 may be arranged to provide alternative interconnections between the contacts 330A-330L as desired.

The mount 370 may also include other components 390, such as ESD protection devices, temperature sensing devices, driving circuits, and the like. Although illustrated as a single component 390 (in FIG. 4) that is coupled in parallel with the series arrangement of the array 300 of light emitting elements 120, one of skill in the art will recognize that additional components may be included on each mount, with circuit traces to provide the desired circuit arrangement.

In like manner, one of skill in the art will recognize that the mount 370 is not limited to a printed circuit board, per se. The circuit traces 360, and optional components 390 may be situated within a lamp structure, on a flexible circuit substrate, and so on, as the situation warrants, each of which may be referred to as a 'mount' for the purposes of this disclosure and claims.

One of skill in the art will also recognize that although the circuit traces 360 that serve to couple the individual light emitting elements 120 are situated on a separate mount 370, the interconnecting circuitry may be applied as a final metal layer upon the light emitting elements 120, interconnecting the contact pads of one light emitting element 120 to another light emitting element 120 in the array 300. Because such interconnections may be provided as a final step in the fabrication process, the basic characteristics of the light emitting elements 120 are unchanged, and only the final mask layers need be customized to form each array 300 of interconnected light emitting elements 120.

In an example embodiment, the printed circuit mount 370 may be a larger printed circuit board that includes a plurality of sets of traces 360, as illustrated in FIG. 4. In this embodiment, a plurality of arrays 300 of light emitting elements 120 are mounted on the larger mount 370, using, for example, a pick and place process, then coupled/soldered to the traces 360 in a single process. In like manner, additional processing of multiple arrays 300 may be performed on the larger mount 370, such as the addition of wavelength conversion material or optical lenses to each array before the larger mount 370 is sliced/diced to provide singulated light emitting devices, each device comprising an array 300 of well matched light emitting elements 120.

FIGS. 5A-5C illustrate an example fabrication of a light emitting device with an array 500 of light emitting elements 120 on a printed circuit board mount 570. In this example embodiment, the array 500 is a 6x6 array of light emitting elements 120 on a substrate 110, as illustrated in FIG. 5A.

FIG. 5B illustrates a printed circuit mount 570 that provides traces 560A, 560Z for external coupling to the array 500, and a pattern of traces 560 that arrange the 6x6 array of light emitting elements 120 in series between these traces 560A, 560Z. The printed circuit mount 570 may include other traces for interconnecting other devices, such as one or more ESD protection devices, temperature sensing devices, driver circuits, and the like.

FIG. 5C illustrates a completed light emitting device that includes an array 500 of light emitting elements 120, a mount 570 with traces 560A, 560Z that provide for external coupling to the array 500, and a lens 550 that protects the array 500. The lens 550 may be shaped to provide a desired light output pattern, and a wavelength conversion material may be included within the lens 550.

A wavelength conversion material (not illustrated), such as one or more phosphors, may also be applied to the array of light emitting elements 120, before the application of the lens 550, or in lieu of this lens 550. The wavelength conversion material may include a wavelength conversion film that is laminated to the array of light emitting elements 120. In one embodiment, a thermally efficient transfer tape is used to laminate the wavelength conversion film to the array of light emitting elements 120 before the mounting of the array on the submount 510. Alternatively, the wavelength conversion material may be applied to the light emitting elements 120 as a silicone, or other coating that is subsequently cured, or as a material that is sprayed or printed upon the array 500 of the light emitting elements 120 before application of the lens 550. The application of this material may include the use of a "dam and fill" process, common in the art.

It is significant to note that each of the example arrays 200, 300, 500 use the same basic light emitting element 120. Accordingly, these arrays 200, 300, 500 can be assumed to have the same basic characteristics of this light emitting element 120, and further characterization tests are not required. However, even though these arrays may have the same basic characteristics, array 200 can be expected to provide four times the light output intensity as the single light emitting device 100 of FIG. 1C; array 300 can be expected to provide six times the light output intensity; and array 500 can be expected to provide thirty-six times the light output intensity.

Additionally, each of these arrays 200, 300, 500 were formed by selectively slicing/dicing the substrate 110 to form the arrays, and the additional design time for these different arrays is merely the layout time for forming the appropriate circuit traces on the circuit board mounts. Some additional design time may be required to provide sufficient heat dissipation, particularly for the larger arrays, but the basic design of the light emitting element 120 is unchanged, regardless of the size of the array.

Although the example embodiments of this disclosure include an array of light emitting elements 120 on a substrate 110, one of skill in the art will recognize that the substrate 110 may be removed from the light emitting element 120. If the light emitting element 120 is self-supporting without the substrate 110, the substrate 110 may be removed before singulating the arrays; otherwise, the substrate 110 may be removed after mounting the array on the circuit board mount.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A light emitting device comprising:

a monolithic array of light emitting elements, each light emitting element being adjacent to at least one other light emitting element that is concurrently and integrally formed on a common substrate.

2. The device of claim 1, wherein each of the light emitting elements in the array is substantially identical to the other light emitting elements.

3. The device of claim 1, including a mount upon which the array is situated, the mount providing circuit traces that facilitate coupling the array to an external power source.

4. The device of claim 3, wherein the mount includes other circuit traces that electrically couple the light emitting elements in the array together.

5. The device of claim 4, wherein the other circuit traces couple the light emitting elements in the array in a series connection.

6. The device of claim 3, including an optical element for transmitting light from the array of light emitting elements.

7. The device of claim 3, wherein the array is situated on the mount in a 'flip-chip' configuration.

8. The device of claim 3, including one or more other, non-light-emitting components situated on the submount and coupled to one or more of the circuit traces.

9. The device of claim 1, wherein the array includes at least four light emitting elements.

10. The device of claim 1, including the common substrate, wherein the common substrate is substantially transparent to the light emitted by the light emitting element.

11. The device of claim 1, including a wavelength conversion material that receives light of a first wavelength from the array of light emitting elements and emits light of a second wavelength.

12. A printed circuit board comprising:

a plurality of sets of circuit traces, each set of circuit traces being situated on the board to receive a monolithic array of light emitting elements and to provide for coupling the array of light emitting elements to a source of external power.

13. The printed circuit board of claim 12, wherein each set of circuit traces include circuit traces that interconnect the light emitting elements of each array when the array is coupled to the set of circuit traces.

14. The printed circuit board of claim 13, including each array of light emitting elements coupled to a corresponding set of circuit traces.

15. The printed circuit board of claim 14, including an optical element that is coupled to a light emitting surface of the array of light emitting elements.

16. The printed circuit board of claim 14, including a wavelength conversion material that receives light of a first wavelength from the array of light emitting elements and emits light of a second wavelength.

17. The printed circuit board of claim 14, including a plurality of sets of one or more other non-light-emitting components that are correspondingly coupled to the each array of light emitting elements.

18. A method comprising:

providing a plurality of light emitting elements upon a common growth substrate, and

slicing the substrate to form monolithic arrays of light emitting elements, each array including adjacent light emitting elements that are formed on the common growth substrate.

19. The method of claim 17, including mounting the formed monolithic arrays of light emitting elements on a corresponding plurality of sets of circuit traces on a mount, and slicing the mount to form a plurality of submounts, each submount including one of the monolithic arrays.

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20. The method of claim 18, including covering a light emitting surface of each of the monolithic arrays with at least one of: an optical element and a wavelength conversion material.



FIG. 1A

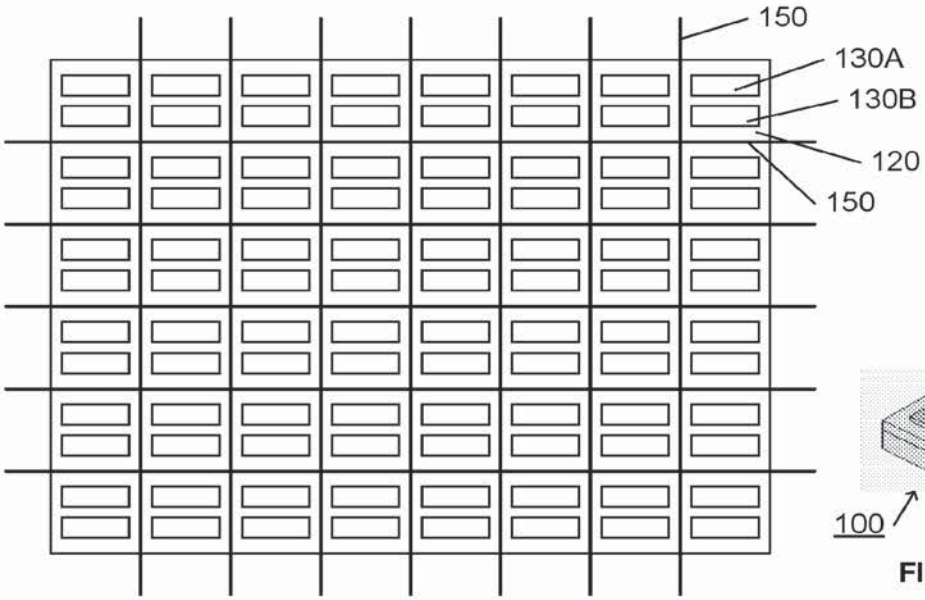


FIG. 1B

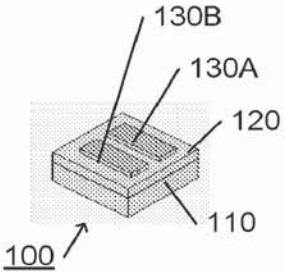


FIG. 1C

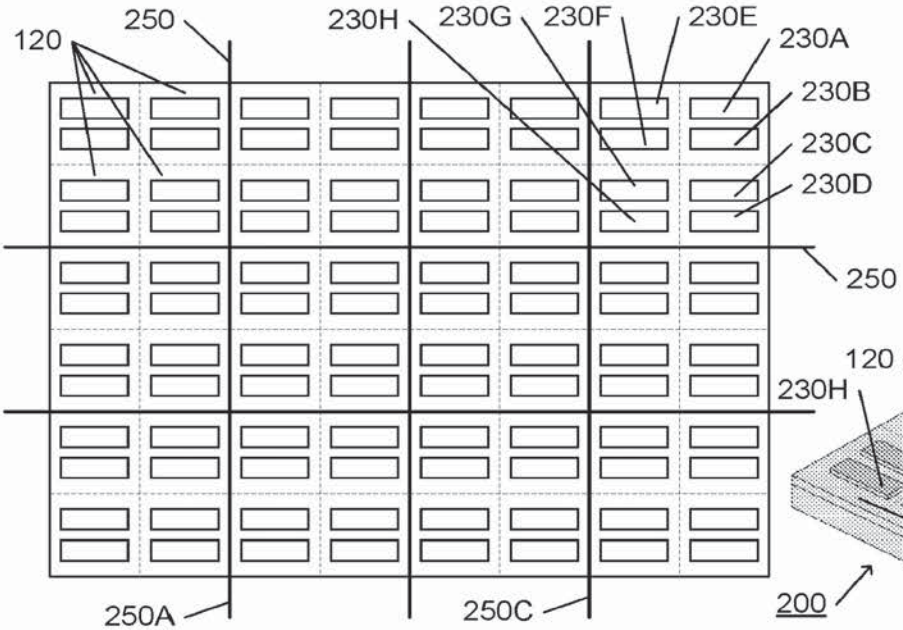


FIG. 2A

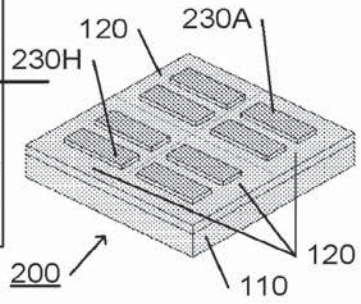


FIG. 2B

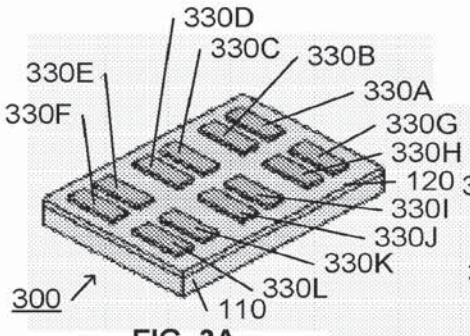


FIG. 3A

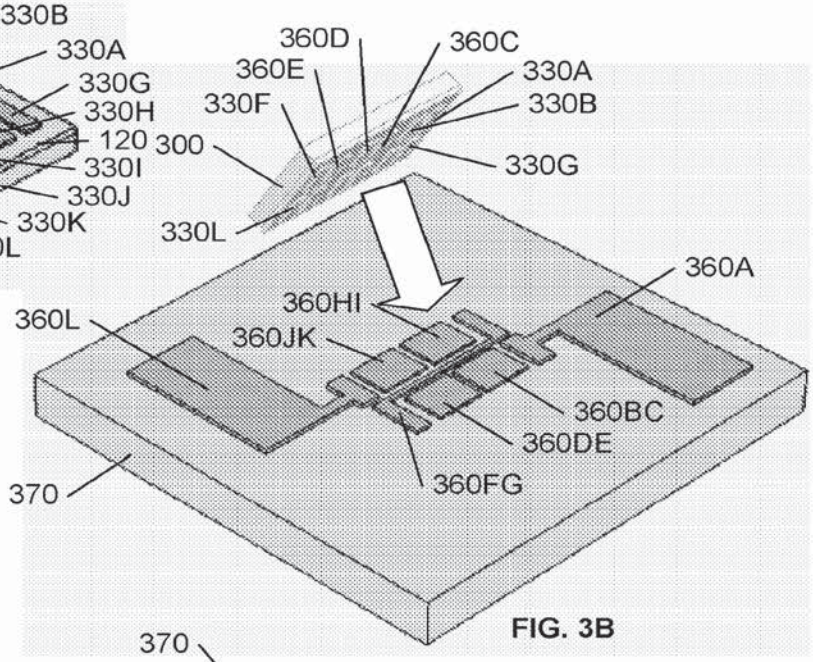


FIG. 3B

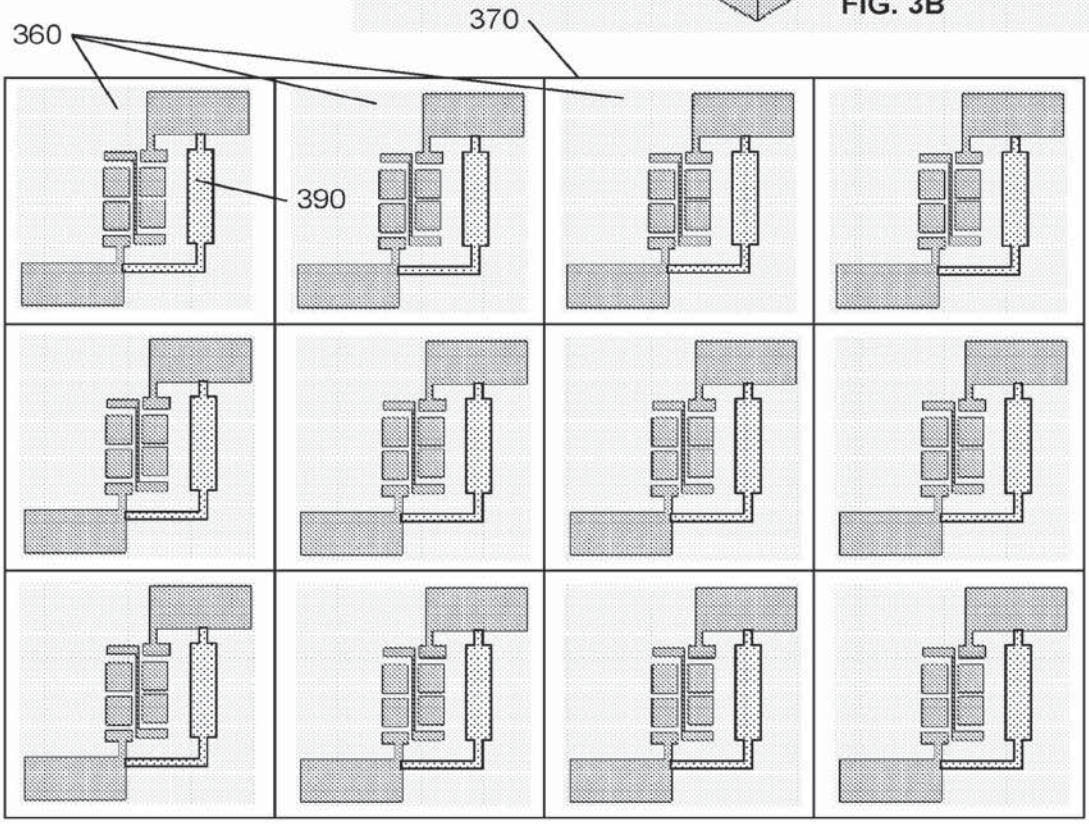


FIG. 4

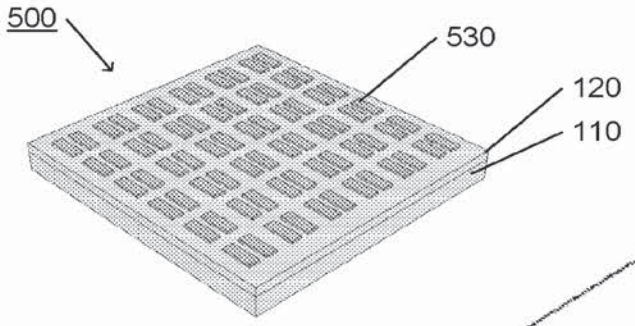


FIG. 5A

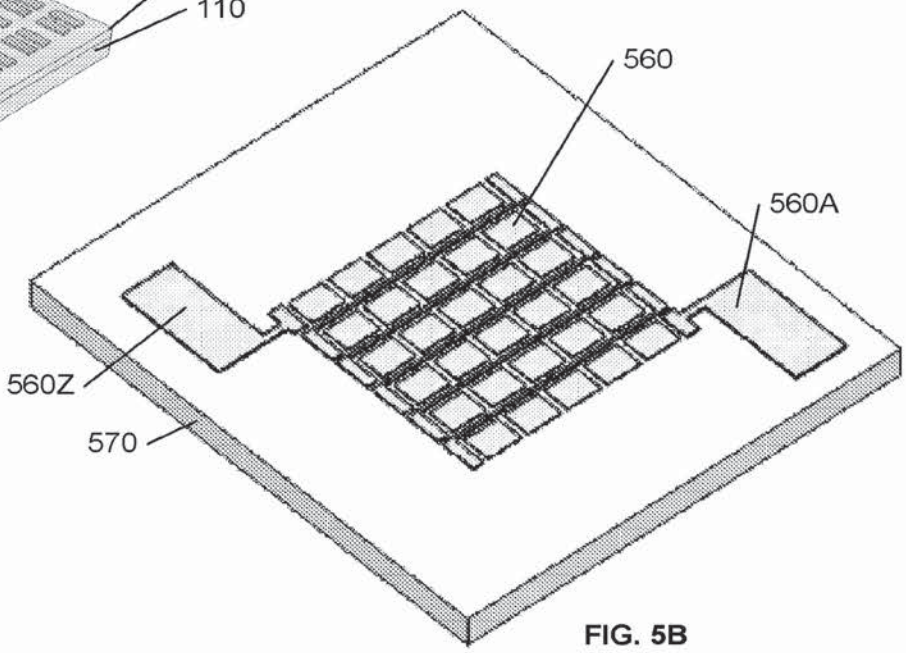


FIG. 5B

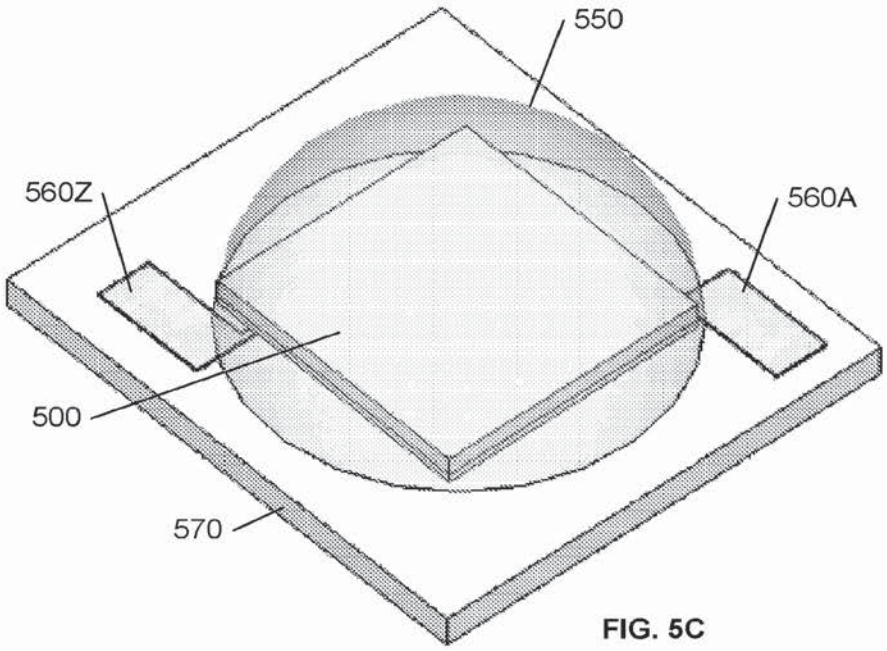


FIG. 5C

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/064941

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L27/15
ADD. H01L25/16 H01L33/54 H01L33/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009 111099 A (MITSUBISHI CHEM CORP) 21 May 2009 (2009-05-21) paragraphs [[0882]], [[0883]]; claims; figures	1-20
X	US 2009/108269 A1 (NEGLEY GERALD H [US] ET AL) 30 April 2009 (2009-04-30) figure 9	1,11,12, 16,18,20
X	US 2011/285284 A1 (ZHOU YUGANG [CN] ET AL) 24 November 2011 (2011-11-24) figures 5,6	1,8,12, 17,18
X	US 2010/308347 A1 (YEH WEN-YUNG [TW] ET AL) 9 December 2010 (2010-12-09) figures 10-15	1,8,12, 17,18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 January 2015	22/01/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ott, Andrē

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/064941

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2009111099 A	21-05-2009	NONE	
US 2009108269 A1	30-04-2009	CN 101836297 A	15-09-2010
		EP 2203938 A1	07-07-2010
		JP 2011501466 A	06-01-2011
		KR 20100101572 A	17-09-2010
		TW 200919696 A	01-05-2009
		US 2009108269 A1	30-04-2009
		WO 2009055079 A1	30-04-2009
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		EP 2390918 A2	30-11-2011
		JP 5636251 B2	03-12-2014
		JP 2011249755 A	08-12-2011
		US 2011285284 A1	24-11-2011
		WO 2011147063 A1	01-12-2011
US 2010308347 A1	09-12-2010	CN 101908534 A	08-12-2010
		TW 201044557 A	16-12-2010
		US 2010308347 A1	09-12-2010

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(74) Agent: **POPOVICH, Milan, Momcilo**; Creative Physics Ltd., 53 Westfield Road, Leicester LF3 6HU (GB).

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Published:

— *with international search report (Art. 21(3))*

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WO 2016/116733 A1

(54) Title: HOLOGRAPHIC WAVEGUIDE LIDAR

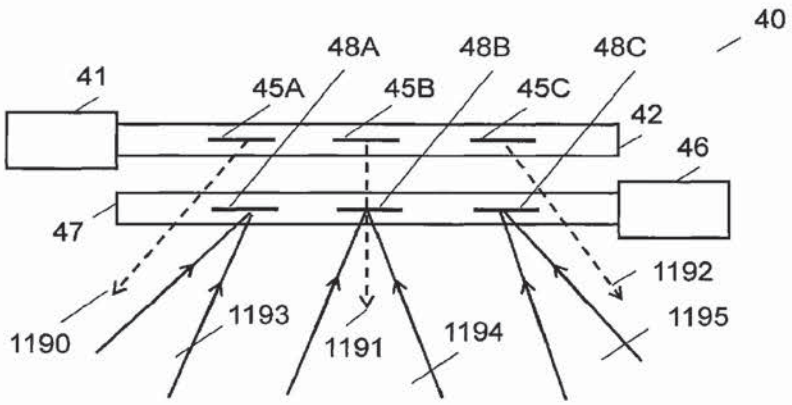


FIG.3

(57) Abstract: A holographic waveguide LIDAR comprises a transmitter waveguide coupled to a beam deflector and a receiver waveguide coupled to a detector module. The transmitter waveguide contains an array of grating elements for diffracting a scanned laser beam into a predefined angular ranges. The receiver waveguide contains an array of grating elements for diffracting light reflected from external points within a predefined angular range towards the detector module.

HOLOGRAPHIC WAVEGUIDE LIDAR

PRIORITY CLAIM

This application claims priority from US Provisional Application Serial No.: 62/125,351 entitled HOLOGRAPHIC WAVEGUIDE LIDAR filed on 20 January 2015, which is hereby incorporated by reference in its entirety.

CROSS REFERENCE TO RELATED APPLICATIONS

The following patent applications are incorporated by reference herein in their entireties: US Patent Application No.13/506,389 entitled COMPACT EDGE ILLUMINATED DIFFRACTIVE DISPLAY, , United States Patent No. 8,233,204 entitled OPTICAL DISPLAYS, PCT Application No.: US2006/043938, entitled METHOD AND APPARATUS FOR PROVIDING A TRANSPARENT DISPLAY, PCT Application No.: GB2012/000677 entitled WEARABLE DATA DISPLAY, United States Patent Application No.: 13/317,468 entitled COMPACT EDGE ILLUMINATED EYEGLASS DISPLAY, United States Patent Application No.: 13/869,866 entitled HOLOGRAPHIC WIDE ANGLE DISPLAY, and United States Patent Application No.: 13/844,456 entitled TRANSPARENT WAVEGUIDE DISPLAY, US Patent No. US8,224,133 entitled LASER ILLUMINATION DEVICE, US Patent No. US8, 565,560 entitled LASER ILLUMINATION DEVICE, United States Patent No. 6,115,152 entitled HOLOGRAPHIC ILLUMINATION SYSTEMPCT Application No.: PCT/GB2013/000005 entitled CONTACT IMAGE SENSOR USING SWITCHABLE BRAGG GRATINGS, PCT Application No.: PCT/GB2012/000680, entitled IMPROVEMENTS TO HOLOGRAPHIC POLYMER DISPERSED LIQUID CRYSTAL MATERIALS AND

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DEVICES, PCT Application No.: PCT/GB2014/000197 entitled HOLOGRAPHIC WAVEGUIDE EYE TRACKER, US Provisional Patent Application No. 62/071,534 entitled HOLOGRAPHIC WAVEGUIDE FOR TRACKING AN OBJECT IN 3D SPACE, PCT/GB2013/000210 entitled APPARATUS FOR EYE TRACKING, PCT Application No.:GB2013/000210 entitled APPARATUS FOR EYE TRACKING.

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BACKGROUND OF THE INVENTION

This invention relates to a sensor, and more particularly to a LIDAR using switchable gratings.

LIDAR is a remote-sensing technology that creates a 3D map of an environment by illuminating a target with a pulsed angularly-scanned laser and analyzing the reflected "point cloud". The advantages of LIDAR over cameras are well known. Since LIDAR uses emitted light, it is robust against interference from ambient light and has much higher resolution than radar. Artificial light sources are required for nighttime operation. Current computer vision is inadequate for complex scene representation and is susceptible to illumination variation. Currently, there is growing interest in LIDAR systems for a range of platforms including: cars (for applications such as collision avoidance and cruise control systems), robot vehicle, UAVs and wearable displays for night vision. The increasing use of key-hole procedures in surgery is also stimulating medical applications. An exemplary car LIDAR specification (based on the Velodyne HDL64E) has a FOV of 360° in azimuth; 26.5 ° elevation (+2° to -24.5°); a rerefresh rate of 15Hz; a point cloud rate of 1 million points per second; a maximum range of 120 metres; a horizontal resolution of 0.05 degree; a distance error of less than 1 inch; a laser pulse duration of 5 nanoseconds and a power output of typically 60 watts. However, LIDAR equipment meeting this specification is extremely bulk and expensive. LIDAR operating at around 1.55 microns has the advantage of being eye safe with longer range capability but is even more expensive. Most current LIDAR equipment relies on bulky rotating optics technology. LIDAR systems based on imaging array technology have been developed but are currently very expensive. The inventors believe that the key to overcoming the problems of bulk and cost is waveguide optics based on switchable grating technology.

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One important class of switchable gratings is based on Switchable Bragg Gratings (SBGs). SBGs are fabricated by first placing a thin film of a mixture of photopolymerizable monomers and liquid crystal material between parallel glass plates. One or both glass plates support electrodes, typically transparent indium tin oxide films, for applying an electric field across the film. A volume phase grating is then recorded by illuminating the liquid material (often referred to as the syrup) with two mutually coherent laser beams, which interfere to form a slanted fringe grating structure. During the recording process, the monomers polymerize and the mixture undergoes a phase separation, creating regions densely populated by liquid crystal micro-droplets, interspersed with regions of clear polymer. The alternating liquid crystal-rich and liquid crystal-depleted regions form the fringe planes of the grating. The resulting volume phase grating can exhibit very high diffraction efficiency, which may be controlled by the magnitude of the electric field applied across the film. When an electric field is applied to the grating via transparent electrodes, the natural orientation of the LC droplets is changed causing the refractive index modulation of the fringes to reduce and the hologram diffraction efficiency to drop to very low levels. Typically, SBG Elements are switched clear in 30 μs. With a longer relaxation time to switch ON. Note that the diffraction efficiency of the device can be adjusted, by means of the applied voltage, over a continuous range. The device exhibits near 100% efficiency with no voltage applied and essentially zero efficiency with a sufficiently high voltage applied. In certain types of HPDLC devices magnetic fields may be used to control the LC orientation. In certain types of HPDLC phase separation of the LC material from the polymer may be accomplished to such a degree that no discernible droplet structure results.

SBGs may be used to provide transmission or reflection gratings for free space applications. SBGs may be implemented as waveguide devices in which the HPDLC forms

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either the waveguide core or an evanescently coupled layer in proximity to the waveguide. The parallel glass plates used to form the HPDLC cell provide a total internal reflection (TIR) light guiding structure. Light is "coupled" out of the SBG when the switchable grating diffracts the light at an angle beyond the TIR condition. Waveguides are currently of interest in a range of display and sensor applications. Although much of the earlier work on HPDLC has been directed at reflection holograms transmission devices are proving to be much more versatile as optical system building blocks. Typically, the HPDLC used in SBGs comprise liquid crystal (LC), monomers, photoinitiator dyes, and coinitiators. The mixture frequently includes a surfactant. The patent and scientific literature contains many examples of material systems and processes that may be used to fabricate SBGs. Two fundamental patents are: United States Patent No.5,942,157 by Sutherland, and U. S Patent No. 5,751,452 by Tanaka et al. Both filings describe monomer and liquid crystal material combinations suitable for fabricating SBG devices. One of the known attributes of transmission SBGs is that the LC molecules tend to align normal to the grating fringe planes. The effect of the LC molecule alignment is that transmission SBGs efficiently diffract P polarized light (ie light with the polarization vector in the plane of incidence) but have nearly zero diffraction efficiency for S polarized light (ie light with the polarization vector normal to the plane of incidence. Transmission SBGs may not be used at near-grazing incidence as the diffraction efficiency of any grating for P polarization falls to zero when the included angle between the incident and reflected light is small.

There is a requirement for a compact, lightweight, low cost LIDAR capable of providing wide angle, high-resolution, long-range operation.

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SUMMARY OF THE INVENTION

It is a first object of the invention to provide a compact, lightweight, low cost LIDAR capable of providing wide angle, high-resolution, long-range operation.

The objects of the invention are achieved in one embodiment of the invention in which there is provided a waveguide sensor, comprising: a source of first wavelength light; at least one beam deflector for scanning the light; a transmitter waveguide; a receiver waveguide; and a detector optically coupled to the receiver waveguide. The beam deflector is optically coupled to the transmitter waveguide and configured such that scanned light coupled into the transmitter waveguide executes angular sweeps about the principal diffraction directions of the grating elements. The transmitter waveguide contains a multiplicity of grating elements disposed in at least one grating layer. Each grating element is operative to diffract light into a predefined range of output directions. The receiver waveguide contains a multiplicity of grating elements disposed in at least one grating layer. Each grating element diffracts light reflected from external points and incident within a predefined angular range into a TIR path to the detector.

In some embodiments the grating elements in at least one of the transmitter waveguide or the receiver waveguide are elements of a two dimensional array.

In some embodiments the grating elements in at least one of the transmitter waveguide or the receiver waveguide are elements of a one dimensional array.

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In some embodiments the grating elements in at least one of the transmitter waveguide or the receiver waveguide are elongate elements with longer dimensions aligned orthogonally to the propagation direction of the waveguides.

In some embodiments the grating elements in at least one of the transmitter waveguide or the receiver waveguide are electrically switchable.

In some embodiments the grating elements in at least one of the transmitter waveguide or the receiver waveguide have at least one of aspect ratio or surface area varying across the waveguide.

In some embodiments the receiver waveguide and the transmitter waveguide substantially overlap.

In some embodiments the transmitter waveguide and the receiver waveguide each contain grating elements having at least two different grating vectors.

In some embodiments at least one of the transmitter waveguide or the receiver waveguide contains grating layers operating over different angular ranges.

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In some embodiments at least one of the transmitter waveguide or the receiver waveguide includes at least one grating layer containing a fold grating.

In some embodiments the transmitter waveguide and the receiver waveguide are combined into a single waveguide containing a multiplicity of grating elements disposed in at least one grating layer. Each grating element is operative to diffract the light into a predefined range of output directions. Each grating element diffracts light reflected from external points and incident within a predefined angular range into a TIR path to the detector.

In some embodiments the apparatus is configured to detect a 3D point cloud.

In some embodiments coupling between the scanner and the transmitter waveguide is performed by one of a prism, a grating, a switchable grating, or via edge coupling.

In some embodiments the beam deflector is a micro-electro-mechanical system.

In some embodiments the source is an infrared light emitting diode or an infrared laser. In some embodiments the first wavelength is approximately 1550 nm.

In some embodiments the grating is one of a Bragg grating, a surface relief grating or a switchable Bragg grating recorded in a HPDLC material, a uniform modulation HPDLC material or a reverse mode HPDLC material.

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In some embodiments a waveguide LIDAR according to the principles of the invention forms a layer in a stack further comprising at least one of a waveguide HMD or a waveguide eye tracker.

In some embodiments the apparatus further comprises a beamsplitter for providing optical paths between the source and the transmitter waveguide and the detector and the receiver waveguide.

In some embodiments the detector is a heterodyne detection device.

A more complete understanding of the invention can be obtained by considering the following detailed description in conjunction with the accompanying drawings, wherein like index numerals indicate like parts. For purposes of clarity, details relating to technical material that is known in the technical fields related to the invention have not been described in detail.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a schematic side view of a LIDAR receiver waveguide in one embodiment.

FIG.2 is a schematic side view of a LIDAR transmitter waveguide in one embodiment.

FIG.3 is a schematic side view of a LIDAR comprising a transmitter waveguide and a receiver waveguide in one embodiment.

FIG.4 is a schematic view of a LIDAR comprising multiple receiver-transmitter waveguide layers in one embodiment.

FIG.5A is a schematic plan view of a LIDAR transmitter waveguide and laser scanner module in one embodiment.

FIG.5B is a schematic plan view of a LIDAR receiver waveguide and detector module in one embodiment.

FIG.5C is a schematic plan view of a detail of a LIDAR receiver waveguide in one embodiment.

FIG.6 is an illustration of the scanning geometry of a LIDAR in one embodiment.

FIG.7is a block diagram of a LIDAR signal processor in one embodiment.

FIG.8A is a schematic plan view of a LIDAR transmitter/receiver waveguide and beams scanner and detector modules in one embodiment.

FIG.8B is a schematic plan view a beam steering module used in the embodiment of FIG.8A.

FIG.9 is plan view showing the geometry of a SBG array used in a LIDAR receiver waveguide in one embodiment.

FIG.10 is a schematic view of a LIDAR in which the transmitter and receiver waveguides are fiber-coupled to a beam scanner module and detector module in one embodiment.

FIG.11 is a schematic side view of a LIDAR transmitter waveguide using passive grating in one embodiment.

FIG.12 is a schematic side view of a LIDAR waveguide in which transmitter and receiver waveguides are disposed adjacent each other.

FIG.13 is a schematic view of an eye tracked wearable waveguide display including a LIDAR waveguide layer.

FIG.14 is a schematic view of a LIDAR receiver waveguide stack comprising two waveguides operating over different fields of view.

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DETAILED DESCRIPTION OF THE INVENTION

The invention will now be further described by way of example only with reference to the accompanying drawings. It will apparent to those skilled in the art that the present invention may be practiced with some or all of the present invention as disclosed in the following description. For the purposes of explaining the invention well-known features of optical technology known to those skilled in the art of optical design and visual displays have been omitted or simplified in order not to obscure the basic principles of the invention. Unless otherwise stated the term "on-axis" in relation to a ray or a beam direction refers to propagation parallel to an axis normal to the surfaces of the optical components described in relation to the invention. In the following description the terms light, ray, beam and direction may be used interchangeably and in association with each other to indicate the direction of propagation of light energy along rectilinear trajectories. Parts of the following description will be presented using terminology commonly employed by those skilled in the art of optical design. It should also be noted that in the following description of the invention repeated usage of the phrase "in one embodiment" does not necessarily refer to the same embodiment.

LIDAR works by sending out short infrared laser pulses. The return signal can be used to build up a 3D map of an environment by timing the pulse return time. The basic optical components of a LIDAR system are a pulsed laser, a means for scanning the laser beam over a wide angle, a receiver means comprising optics and a detector for recording the return signal. The present invention addresses the problem of providing a passive, wide angle transmitter/receiver that eliminates the need to rotate the optical assembly. Instead, we use

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waveguides containing arrays of switchable gratings each optimized to collect signal over a predefined field of view range. It is not necessary to rotate the waveguides. The laser is scanned across each field of view range to provide the required angular resolution. By optimizing the laser scanning cycle to coincide with the duration of the diffracting state of each grating it is possible to build up a large field of view with a high (angular) resolution. The waveguide approach also brings the benefits of transparency, light weight and a very thin form factor. Furthermore, a waveguide LIDAR can be integrated with other waveguide devices such as displays and eye trackers in a thin stack. Advantageously, the LIDAR operates at 1550 which has the advantages of being eye safety and invisible to current night vision technology. However, the invention may be applied at any wavelength in the spectrum from UV to infrared. We will now discuss a series of exemplary embodiments of the invention.

In one embodiment shown in FIG.1 a LIDAR receiver waveguide 20 comprises the light detection module 21 a waveguide 22 with electrodes applied to opposing surfaces the electrodes comprising a common electrode 23 and an array of electrodes 24A-24D the two electrode layers sandwiching grating regions 25A-24C to form a switchable grating array. In one embodiment the grating array is two dimensional. In one embodiment the array comprises a one-dimensional array of column shaped elements. The detector module will typically comprise a lens and an infrared (IR) detector. Advantageously, the IR detector is a fast, high sensitivity device such as an avalanche photodiode. In many applications the preferred wavelength is 1550 nm which is eye safe and is invisible to current night vision devices. Each grating region has a unique k-vector (that is a vector normal to the Bragg fringes) as indicated by 1170-1172. The gratings in their diffracting state couple signal light into a TIR path inside the waveguide. The guided beam

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is coupled into the detector module, typically by a grating or prism. In one embodiment the IR detector is coupled to the end of the waveguide. Each grating has an angular detection field determined by the diffraction efficiency bandwidth of the grating. The principal rays of the fields of view of the grating elements 25A-25C are represented by 1175-1177. Typically, the field of view of a single element is in the region of 10-15 degrees. By switching the gratings to their active state sequentially the entire field of view is covered. For example, if we consider grating region 25A with k-vector 1170 sandwiched by the electrode 24A and the common electrode, when the grating is in its active state light 1175 is coupled into the TIR path indicated by the rays 1173-1174 which are coupled into the detector module. Note that although in FIG.1 (and in the embodiments to be described below) more than one grating is shown in a diffracting state, in practice only one grating region will be diffracting at any time.

In some embodiments the gratings are recorded in uniform modulation liquid crystal-polymer material system such as the ones disclosed in United State Patent Application Publication No.: US2007/0019152 by Caputo et al and PCT Application No.: PCT/EP2005/006950 by Stumpe et al. both of which are incorporated herein by reference in their entireties. Uniform modulation gratings are characterized by high refractive index modulation (and hence high diffraction efficiency) and low scatter. In some embodiments the gratings are recorded in a reverse mode HPDLC material. Reverse mode HPDLC differs from conventional HPDLC in that the grating is passive when no electric field is applied and becomes diffractive in the presence of an electric field. The reverse mode HPDLC may be based on any of the recipes and processes disclosed in PCT Application No.: PCT/GB2012/000680, entitled IMPROVEMENTS TO HOLOGRAPHIC POLYMER DISPERSED LIQUID CRYSTAL

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MATERIALS AND DEVICES.

In one embodiment shown in FIG.2 a LIDAR transmitter waveguide 30 comprises a scanning module (beam deflector) 31 a waveguide 32 with electrodes applied to opposing surfaces, the electrodes comprising a common electrode 33 and an array of electrodes 34A-34D. The electrode layers sandwich the grating regions 35A-34C. The invention does not assume any particular beam scanning technology. At the time of writing this application the preferred technology is based on a micro electro mechanical system (MEMs). Exemplary MEMs scanners are manufactured by Lemoptix Inc. These devices can provide a resolution of 720p (1280×720 pixels) at 60Hz with scanning angles in excess of 60 degrees. Referring again to FIG.2 the scanning beam is coupled into the waveguide by a grating or prism coupler. In one embodiment the beam may be coupled through the end of the waveguide. Each grating region has a unique k-vector (that is a vector normal to the Bragg fringes) as indicated by 1170-1172. The gratings in their diffracting state couple signal light into a TIR path inside the waveguide. Each grating has an angular detection field determined by the diffraction efficiency bandwidth. The principal rays of the fields of view of grating elements 35A-35C are represented by 1185-1187. Typically, the field of view of a single element is in the region 10-15 degrees. By switching the gratings to their active state sequentially the entire field of view is covered. For example, switching grating region 35A with k-vector 1180 is sandwiched by the electrode 34A and the common electrode which switches the grating region 35A between diffracting and non-diffracting states such that light 1185 is coupled out of the TIR path indicated by the rays 1183-1184.

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In one embodiment illustrated in the schematic side view of FIG.3 a complete LIDAR 40 comprises receiver and transmitter waveguides based on the embodiments of FIGS.1-2. The transmitter component comprises the scanner module 41 and the waveguide 42 containing switchable grating elements 45A-45C which deflect light out of the TIR path into scanned beam ranges having the principal rays 1190-92 when in their diffracting states. The receiver component comprises the detector module 46 and the waveguide 47 containing the switchable grating elements48A-48C which couple in signal light in the FOVs 1190-1195 into TIR paths to the detector module when in their diffracting states. The switching electors in the receiver and transmitter waveguides are not shown.

In one embodiment shown in FIG.4 there is provided a LIDAR system 50 comprising a stack of waveguides 51-53 each containing SBG columns such as 54-56. The number of columns in a waveguide will depend on the grating angular bandwidth and the size of the overall field of view of the LIDAR. A scanned laser beam is coupled into each waveguide layer in turn via a coupling means such as a grating or prism. Alternatively, the laser beam may be edge coupled into the waveguide. Each waveguide layer may have a separate coupler designed to accept input beams in a predefined angular range. The coupler may employ at least one switching grating. A single coupler may be used to address multiple layers. In one embodiment the LIDAR may comprise a single waveguide layer. The SBG columns 54-56 have unique k-vectors for deflecting scanned laser beams into unique angular ranges with principal ray directions such 1202-1204. A scanned laser beam 1200 is coupled into the waveguides via a prism 57 into the TIR path 1201 in waveguide 51 and is deflected out of the waveguide 51 into a unique direction 1204 by an active (that is, diffracting) SBG column 56 according to the

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principles of the above described embodiments. The scanned laser beam irradiates a region 1205 of a remote reflective surface. The return signal 1206 reflected from the reflective surface is coupled into the waveguide 51 by the same active SBG column and relayed to the beam scanner and detector module 58 along the TIR path1207 and an external path 1208 substantially parallel to the input beam path 1207. The transmitted and received laser beams are separated using beam splitting techniques that are well documented in the literature of laser sensors. The beams may be separated using polarization or angular selectivity. The detection system may employ heterodyne detection. The embodiment of FIG.4 may be based on ones disclosed in PCT/GB2014/000197 entitled HOLOGRAPHIC WAVEGUIDE EYE TRACKER, US Provisional Patent Application No. 62/071,534 entitled HOLOGRAPHIC WAVEGUIDE FOR TRACKING AN OBJECT IN 3D SPACE, PCT/GB2013/000210 entitled APPARATUS FOR EYE TRACKING, PCT Application No.:GB2013/000210 entitled APPARATUS FOR EYE TRACKING which are incorporated herein by reference in their entireties. Said filings address eye trackers using SBG column array waveguides for infrared eye tracking. With some implementation modifications that will be obvious to those skilled in the art the embodiments disclosed therein are equally applicable to LIDAR systems. Each receiver transmitter (R/T) SBG element has unique a unique K-vector which together with the MEMs scanner sweep defines a unique FOV tile. This eliminates the need for complex, bulk and expensive rotating optics. Singe the target surfaces are typically at long range the beams entering the receiver waveguide are substantially collimated allowing optimal matching of R/T channels at all angles. Desirably the grating elements are designed to make the received element apertures as large as possible while the apertures of the transmitter elements need to be large enough to accommodate the laser beam sweep from the beam scanner. The beam width will be very narrow, typically of the order

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of millimetres.

The beam scanner and detector modules may be coupled to the transmission and receiver waveguides by an optical fibre. Multiple waveguides may be stacked to provide a larger field of view or to implement a hyper-spectral LIDAR with each waveguide operating within a defined wavelength band.

In a further embodiment of the invention shown in FIG.5 a LIDAR system comprises a transmitter component 70 and a receiver component 80. The receiver component comprises a waveguide 71 containing a single row of switchable grating elements 72A-72F with an active grating indicated by 72D. Each grating has a unique k-vector corresponding to a unique beam diffraction direction. The transmitter component further comprises a pulsed laser emitting the beam 1210, collimation and beam expansion optics indicated schematically by 76 forming the beam 1211 and a beam scanner module 77 for scanning the beam 1212 in two orthogonal directions. The scanned beam enters the waveguide via a coupling element78 (typically a grating or prism). The component of the scanned beam in the waveguide X direction 1213 is shown for simplicity. The active grating element 74 deflects the beam 1213 in the direction 1214. Principal beam directions 1215-1217 corresponding to the active states of grating elements 72A-72C are indicated. Turning now to FIG.5B the detector waveguide 80 contains the SBG array 81 comprising elements such as 81 and 83 and a fold grating 80. To better understand the function of a fold grating note that the waveguide gratings in the previously discussed embodiments are tilted around an axis lying in the waveguide plane. Fold gratings have a more generalized tilt. In their simplest implementation, as used in the present invention they are tilted around an axis perpendicular to the waveguide plane such they deflect beams in

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the waveguide plane. More generally, they may have tilts defined by two rotation angles so that, for example, light can be coupled into the waveguide and deflected into an orthogonal direction inside the waveguide, all in one step. Of particular importance for the present invention, they can perform ninety degree turning and two-axis beam expansion in a single layer, avoiding orthogonal superimposed grating layers. Figure 5C is a plan view of the fold grating 82. When rays 1225 encounter the grating, they diffract in a manner that changes the direction of propagation by 90°. Unlike a conventional vertical extraction grating, the light does not leave the waveguide. Note that when a ray encounters the grating, regardless of whether it intersects the grating from above or below, a fraction of it changes direction and the remainder continues unimpeded. A typical ray will interact many times with vertically (in the Y direction) while some light will be moving laterally (in the X direction). From a design perspective, it is desirable to engineer the amount of light 1228 emerging from the output edge of the grating to be uniformly distributed laterally and the amount of light 1227 emerging from the side edge of the grating to be as small as possible. Referring to the Cartesian XY reference frame in the figure, the fold grating turns the TIR light 1225 through ninety degrees into the Y direction. The light 1226 emerging from the fold grating is coupled out of the waveguide (prisms, grating or edge) and focused onto a IR detector 86 by the lens 87. The detector is connected to a signal processor 84 by an electrical communication link 85. Element 83, which is shown in its active state, couples signals from regions 1221-1224 along the scan path 1225. For example, light from regions 1221,1222 scanned by the instantaneous beams 1224,1225 is coupled by active element 83 which deflects the light into the TIR path in the direction 1225 (X-axis). In a typical application the laser has pulse duration of 5 ns. The laser power will depend on the application. In a typical automotive application, a LIDAR output power in the region of 60W may be required. The

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MEMS scanner is typically a single element scanner. Desirably the device (with the laser) should allow 1200 x 600 resolution cells across the field of view with 60 Hz update. In one embodiment a LIDAR is based on an array of 6x3 SBG gratings each having a field of view of 10° x10° giving a total field of view of 60° x30°. During the detector element active period 200x200 elements are swept out over the 10° x10° resulting in an angular resolution of 0.05° .

FIG 6 illustrates the scanning geometry in more detail showing the scanned field of view regions formed by the transmitter which are labelled by 1230-1235. The backscatter signal from a reflective surface 90 is collected by a receiver over the angular range bounded by the rays 1236-1237. The beam scanner and the pulsed laser divide the field of view into discrete angular resolution elements such as 1236-1239. FIG.7 is a block diagram of the signal processor 92. The data communication link from the receiver component transmits the received signal to an analogue to digital converter (ADC) 93. The digitised signal is transmitted to a digital signal processor (DSP) module 94. Finally, the signal is communicated to peripheral devices via an Ethernet link 95. The modules operate under the control of the executive program 96.

The embodiment of FIG.8 is similar to the one of FIG.5 except in that the transmitter component uses a two dimensional array of SBG elements and the fold grating in the receiver components is replaced by a large aperture detector lens. A further distinction is that in the FIG.8 embodiment the transmitter and receiver components are integrated in one waveguide. The LIDAR 100 comprises a waveguide 101, a pulsed laser 102 emitted a beam 1240, a beam expansion/collimator lens system103 providing the beam 1241, a beam scanner 104 producing the scanned beam represented by 1242, and a beam steering module 105 which provides a

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multiplicity of beam paths into the transmitter waveguide one of which, namely the beam 1244, is shown being injected into the waveguide along the SBG element row labelled 109. The beam steering module is illustrated in more detail in FIG.8B. In one embodiment it comprises a set of three switchable fold grating elements 105A-105C and a non-switching fold grating 105D for steering the scanned beam 1243 of FIG.8A into the vertical (Y) direction. The vertical beam 1243A crosses each of the switching fold grating elements in turn. Each element is operative to switch the scanned beam into the X direction into the transmitter waveguide. In FIG.8B the element 105A is in its diffracting state and switches the beam into the output direction 1244. The elements 105B, 105C, which would otherwise switch the beam in the directions 1243B, 1243C shown by the dotted lines, are shown in their passive states. Not shown in FIG.8B is a means for coupling the scanned beam 1243 into the beam steering module and for coupling the out beams from the beam steering module into the transmitter waveguide. As already discussed the coupling means may comprise a prism or grating. Alternatively, the beam may be injected into the edge of the waveguide. The transmitter portion comprises a two dimensional array of SBG elements such as 106-108. The rows are labelled by 109-111. The elements each have a unique k-vector defining a discrete horizontal and vertical field of view region. The active element scanned beam portion extracted from the waveguide by the active SBG element 108 is represented by the set of rays 1245. The receiver waveguide contains a two dimensional array of SBG elements 112 with rows starting with the elements labelled 113-115. The return signal which is indicated by the set of rays 1246 incident on the active element 116 is diffracted in the TIR path 1247 along the element row 113 and is coupled in to detector module 117 comprising the large aperture lens 118 and the IR detector 119. The lens focuses the guided beams onto the detector to form a focal spot of size determined by the range of angles detected by the element

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116, as indicated by the dashed line rays 1248A,1248B. The full range of angles detected (for all SBG element rows) is indicated by the dashed lines 1249. In one embodiment the detector module 117 is fold back over the receiver waveguide by means of mirrors or prisms to provide a more compact configuration. In one embodiment the lens 118 is replaced by an equivalent mirror. In another embodiment the lens 118 may be replaced by a holographic optical element.

In one embodiment shown in FIG.9 the widths of SBG elements in the receiver component SBG array 120 increase from the centre of the array (122) to the edge (121) in order to maintain a fixed detection aperture at all angles.

The embodiment illustrated in FIG.10 provides a fiber optic LIDAR 130 in which the transmitter and receiver waveguides are coupled to the scanner module and the detector module by an optical fiber. The optical fiber may be based on GRIN technology. The apparatus comprises a receiver waveguide 131 containing grating elements such as 132 for receiving light over the ang8ular range 1262, a transmitter waveguide 133 containing grating elements such as 134 for beam scanning light over a predefined angular range. An optical fiber couples the input 1264 to the transmitter waveguide and the output 1261 from the receiver waveguide to a remote transmitter /receiver module comprising a beam scanner 138 and detector module 139 and a coupler for couple transmitted beam 1260 and the received beam 1265 between the transmitter/receiver module and the fiber. The waveguides and the transmitter /receiver module may be based on any of the above described embodiments. Techniques for coupling signals to fibers will be well known to those skilled in the art.

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So far we have considered transmitter and receiver waveguides that use switching grating elements. FIG.11 shows an embodiment in which the gratings elements are passive but are designed to operate within different TIR angle ranges. The apparatus 140 comprises a transmitter waveguide 141 containing grating elements 142-145. Each FOV range of the LIDAR corresponds to a unique SBG element and TIR range. The principal rays of three different TIR beams 1270-1272 and the diffraction of the TIR beams by the gratings 142,143,145 (in their diffracting states) into the transmitter beams 1273-1275 is shown. One way to ensure that the TIR angles are sufficiently well separated for this scheme to work is to design the grating to have a larger thickness and consequently a narrower angular bandwidth. Thick gratings are normally more difficult to switch, requiring higher switching voltages. A passive grating would be highly desirable in medical endoscopes. Note that FIG.11 also serves to illustrate a either a passive transmitter waveguide or a passive receiver waveguide (reversing the ray vectors).

In one embodiment shown in FIG.12 a LIDAR 150 comprises transmitter 151 and receiver 152 waveguides abutting end to end. The waveguides may be based on any of the above described embodiments. The transmitted and received beam directions are generally indicated by 1280,1281.

In one embodiment shown in FIG.13 there is provided an apparatus comprising a LIDAR 160 according to the principles of the invention, a waveguide display161 and a waveguide eye tracker 162. The transmitted and received beams at the LIDAR are indicated by 1300,1301. The field of view provided by the display is indicated by the rays 1302,1303. The eye tracker illuminates the eye 163 with the infrared beam indicated by 1306 and detects the backscatter

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signal indicated by 1305. The waveguide display may be based on any of the embodiments disclosed in US Patent Application No.13/506,389 entitled COMPACT EDGE ILLUMINATED DIFFRACTIVE DISPLAY, , United States Patent No. 8,233,204 entitled OPTICAL DISPLAYS, PCT Application No.: US2006/043938, entitled METHOD AND APPARATUS FOR PROVIDING A TRANSPARENT DISPLAY, PCT Application No.: GB2012/000677 entitled WEARABLE DATA DISPLAY, United States Patent Application No.: 13/317,468 entitled COMPACT EDGE ILLUMINATED EYEGLASS DISPLAY, United States Patent Application No.: 13/869,866 entitled HOLOGRAPHIC WIDE ANGLE DISPLAY, and United States Patent Application No.: 13/844,456 entitled TRANSPARENT WAVEGUIDE DISPLAY. The eye tracker may be based on any of the embodiments disclosed in PCT Application No.: PCT/GB2014/000197 entitled HOLOGRAPHIC WAVEGUIDE EYE TRACKER, US Provisional Patent Application No. 62/071,534 entitled HOLOGRAPHIC WAVEGUIDE FOR TRACKING AN OBJECT IN 3D SPACE, PCT/GB2013/000210 entitled APPARATUS FOR EYE TRACKING, PCT Application No.: GB2013/000210 entitled APPARATUS FOR EYE TRACKING.

In one embodiment shown in FIG.14 a LIDAR receiver component 170 comprises a first waveguide 172 for receiving light from a first field of view indicated by the set of principal rays 1310 and a second waveguide 171 for receiving light from a second field of view indicated by the set of principal rays 1311. It should be apparent from the drawing that FIG.14 may also be used to illustrate a LIDAR transmitter component (with the ray directions reversed).

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The invention provides a transparent, thin architecture, using single laser/detector. The LIDAR uses SBG arrays for dividing the receiver and transmitter fields of view into small selectively switched field of view regions that can be detected more efficiency than would be the case if a singe wide angle imaging optical system were used.

Any of the embodiments of the invention may be implemented using either one dimensional or two dimensional grating arrays. In any of the above embodiments the waveguides may be curved or formed from a mosaic of planar or curved facets. It should be emphasized that the drawings are exemplary and that the dimensions have been exaggerated. For example, thicknesses of the SBG layers have been greatly exaggerated.

A waveguide device based on any of the above-described embodiments may be implemented using plastic substrates using the materials and processes disclosed in PCT Application No.: PCT/GB2012/000680, entitled IMPROVEMENTS TO HOLOGRAPHIC POLYMER DISPERSED LIQUID CRYSTAL MATERIALS AND DEVICES.

Advantageously, the SBGs are recorded in a reverse mode HPDLC material in which the diffracting state of SBG occurs when an electric field is applied across the electrodes. An eye tracker based on any of the above-described embodiments may be implemented using reverse mode materials and processes disclosed in the above PCT application. While the invention may be applied with gratings of any type including switching or non-switching gratings based on Bragg (volume) holograms, or surface-relief gratings the preferred grating technology is a SBG, which offers the advantages of fast switching, high optical efficiency and transparency and high index modulation. It should also be noted that the gratings used in the above embodiments are not necessarily all switching gratings. Switching gratings may be used in combination with

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passive grating technologies. As has been indicated by the description and drawings more than one grating layer (lamina) may be used. The grating layers discussed above are SBGs disposed between internal waveguide surfaces (or in other words sandwiched between transparent substrates that combine to form the waveguide. However, in equivalent embodiments some of the gratings layers could be applied to external waveguide surfaces. This would apply in the case of surface relief gratings. The method of fabricating the SBG pixel elements and the ITO electrodes used in any of the above-described embodiments of the invention may be based on the process disclosed in the PCT Application No. US2006/043938, entitled METHOD AND APPARATUS FOR PROVIDING A TRANSPARENT DISPLAY.

It should be understood by those skilled in the art that while the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. Various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

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CLAIMS

What is claimed is:

1. A waveguide sensor, comprising:

a source of first wavelength light;

at least one beam deflector for scanning said light;

a transmitter waveguide;

a receiver waveguide; and

a detector optically coupled to said receiver waveguide,

said beam deflector optically coupled to said transmitter waveguide and configured such that scanned light coupled into said transmitter waveguide executes angular sweeps about the principal diffraction directions of said grating elements,

said transmitter waveguide containing a multiplicity of grating elements disposed in at least one grating layer, each said element operative to diffract light into a predefined range of output directions

said receiver waveguide containing a multiplicity of grating elements disposed in at least one grating layer, each said element diffracting light reflected from external points and incident within a predefined angular range into a TIR path to said detector.

2. The apparatus of claim 1 wherein said grating elements in at least one of said transmitter waveguide or said receiver waveguide are elements of a two dimensional array.

3. The apparatus of claim 1 wherein said grating elements in at least one of said transmitter waveguide or said receiver waveguide are elements of a one dimensional array.

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4. The apparatus of claim 1 wherein said grating elements in at least one of said transmitter waveguide or said receiver waveguide are elongate elements with longer dimensions aligned orthogonally to the propagation direction of said waveguides.

5. The apparatus of claim 1 wherein said grating elements in at least one of said transmitter waveguide or said receiver waveguide are electrically switchable.

6. The apparatus of claim 1 wherein said grating elements in at least one of said transmitter waveguide or said receiver waveguide have at least one of aspect ratio or surface area varying across the waveguide.

7. The apparatus of claim 1 wherein said receiver waveguide and said transmitter waveguide substantially overlap.

8. The apparatus of claim 1 wherein said transmitter waveguide and said receiver waveguide each contain grating elements having at least two different grating vectors.

9. The apparatus of claim 1 at least one of said transmitter waveguide or said receiver waveguide contains grating layers operating over different angular ranges.

10. The apparatus of claim 1 wherein at least one of said transmitter waveguide or said receiver waveguide includes at least one grating layer containing a fold grating.

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11. The apparatus of claim 1 wherein said transmitter waveguide and said receiver waveguide are combined into a single waveguide containing a multiplicity of grating elements disposed in at least one grating letter, each said element operative to diffract said light into a predefined range of output directions, each said element diffracting light reflected from external points and incident within a predefined angular range into a TIR path to said detector.

12. The apparatus of claim 1 configured to detect a 3D point cloud.

13. The apparatus of claim 1 wherein coupling between said scanner and said transmitter waveguide is performed by one of a prism, a grating, a switchable grating, or via edge coupling.

14. The apparatus of claim 1 wherein said beam deflector is a micro-electro-mechanical system.

15. The apparatus of claim 1 wherein said source is an infrared light emitting diode or an infrared laser.

16. The apparatus of claim 1 wherein said first wavelength is approximately 1550 nm.

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17. The apparatus of claim 1 wherein said grating is one of a Bragg Grating, a surface relief grating or a switchable Bragg grating recorded in a HPDLC material, a uniform modulation HPDLC material or a reverse mode HPDLC material.

18. The apparatus of claim 1 forming a layer in a stack further comprising at least one of a waveguide HMD or a waveguide eye tracker.

19. The apparatus of claim 12 further comprising a beamsplitter for providing optical paths between said source and said transmitter waveguide and said detector and said receiver waveguide.

20. The apparatus of claim 1 wherein said detector is a heterodyne detection device.

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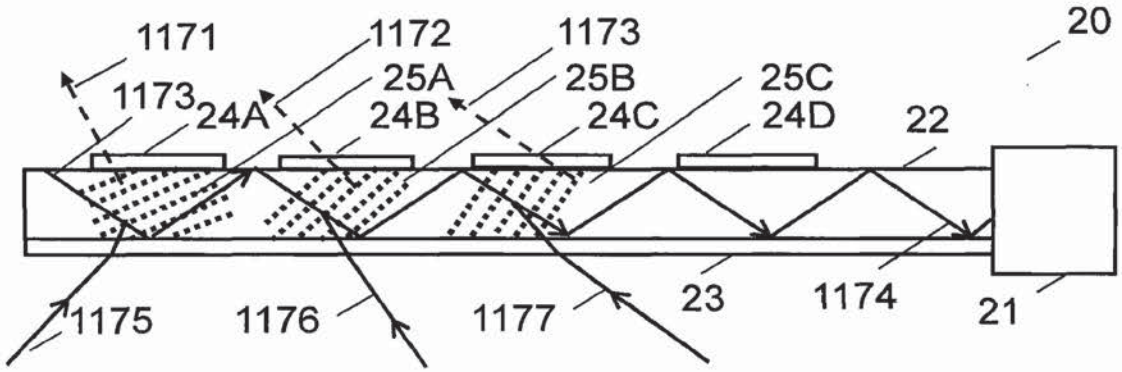


FIG.1

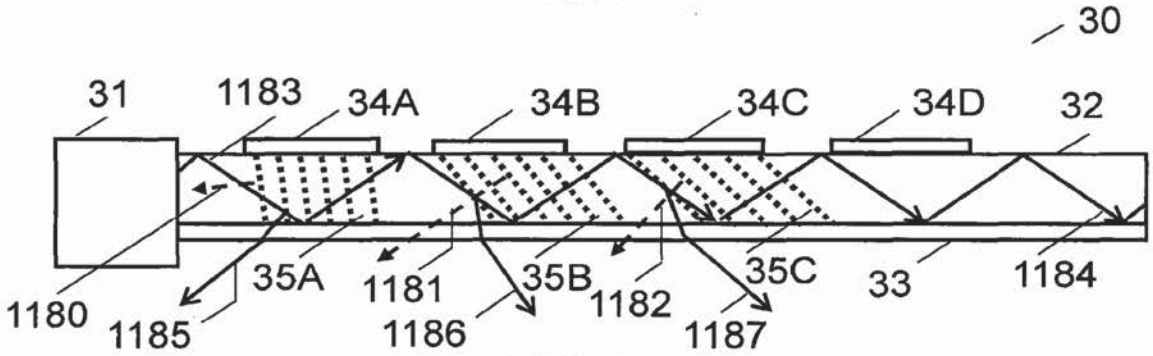


FIG.2

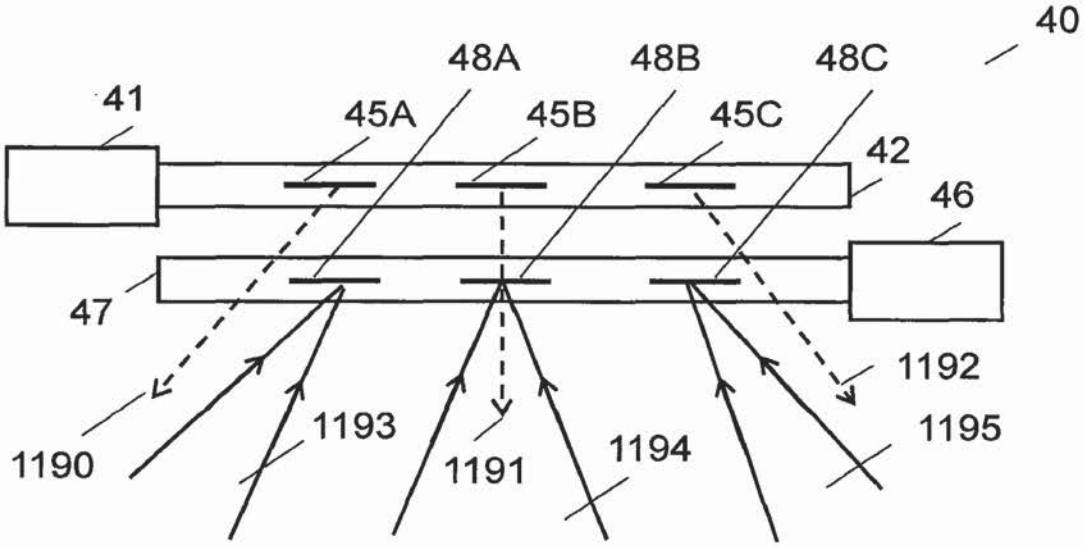


FIG.3

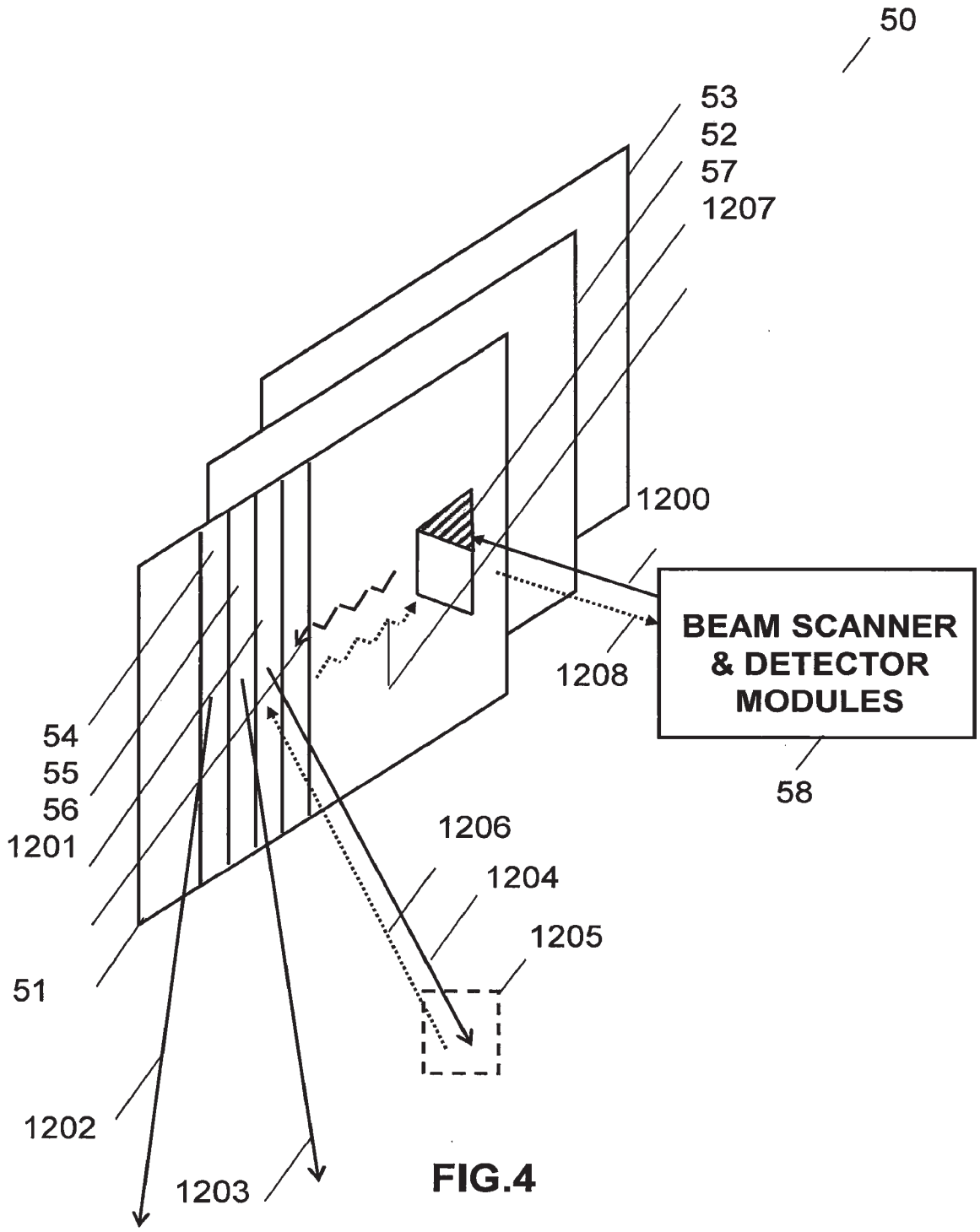

50
53
52
57
1207
1200
BEAM SCANNER & DETECTOR MODULES
1208
58
54
55
56
1201
51
1206
1204
1205
1202
1203

FIG.4

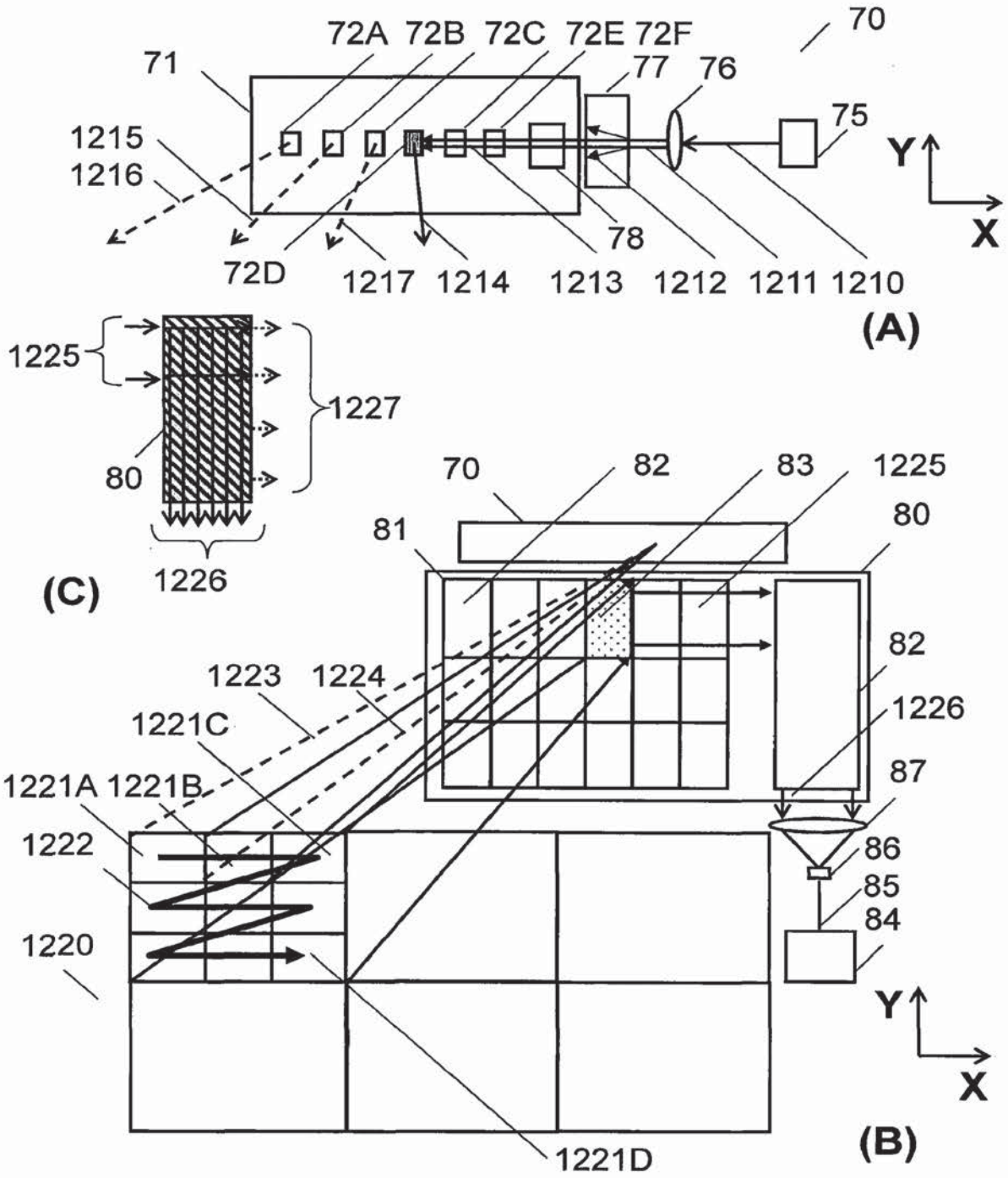

72A 72B 72C 72E 72F
70
71
77
76
75
1215
1216
Y
X
78
72D
1217 1214 1213 1212 1211 1210
(A)
1225
1227
80
(C)
1226
70
82
83
1225
81
80
82
1223
1224
1226
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X
1221D
(B)

FIG.5

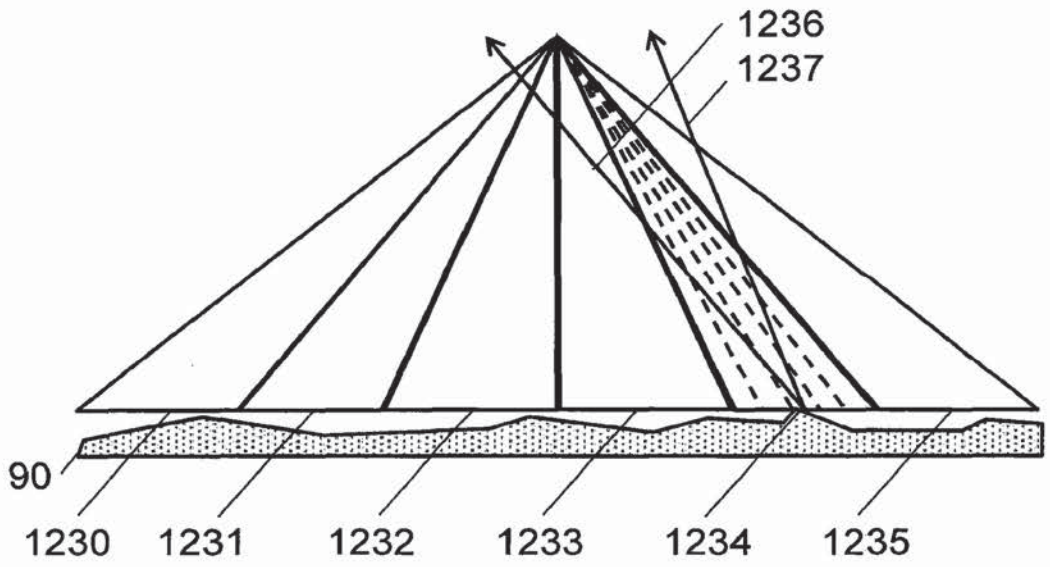


FIG.6

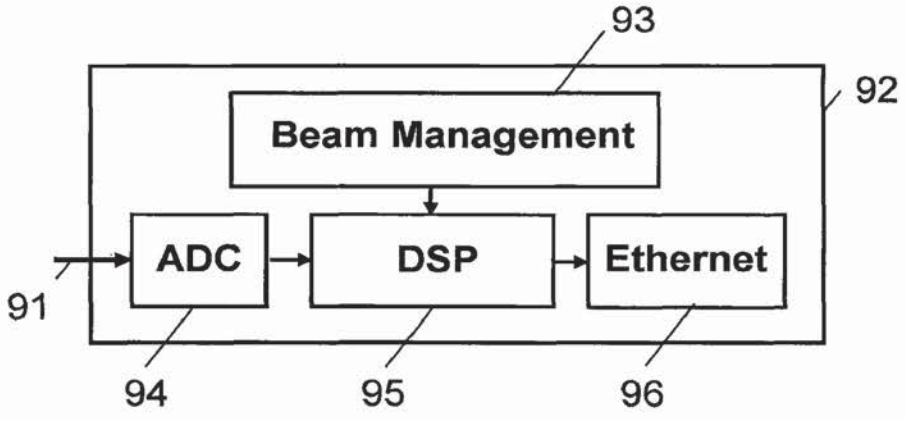


FIG.7

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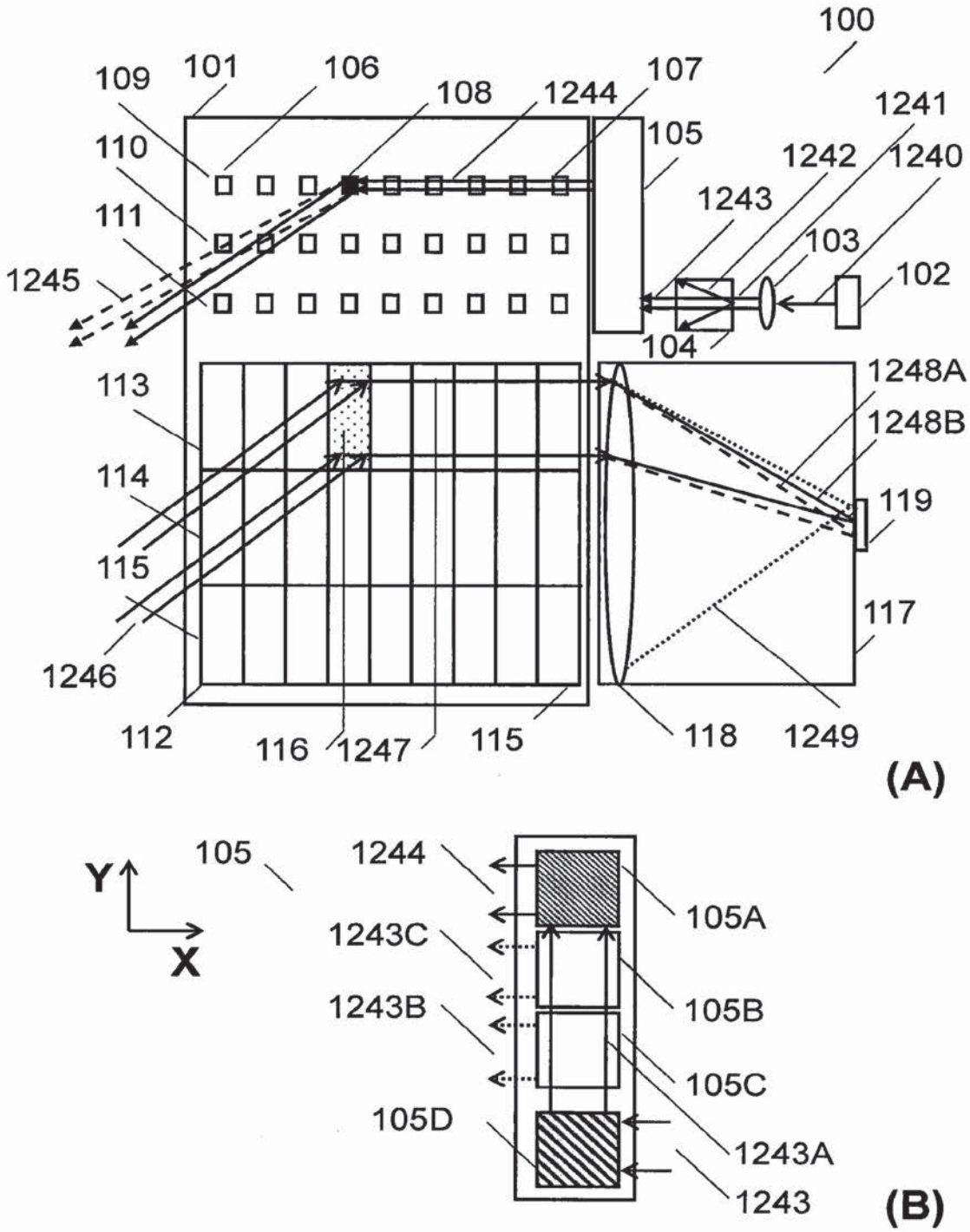


FIG.8

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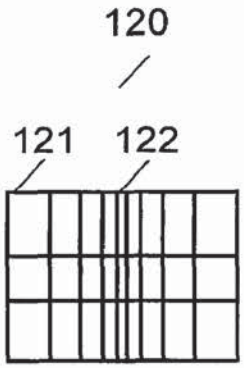


FIG.9

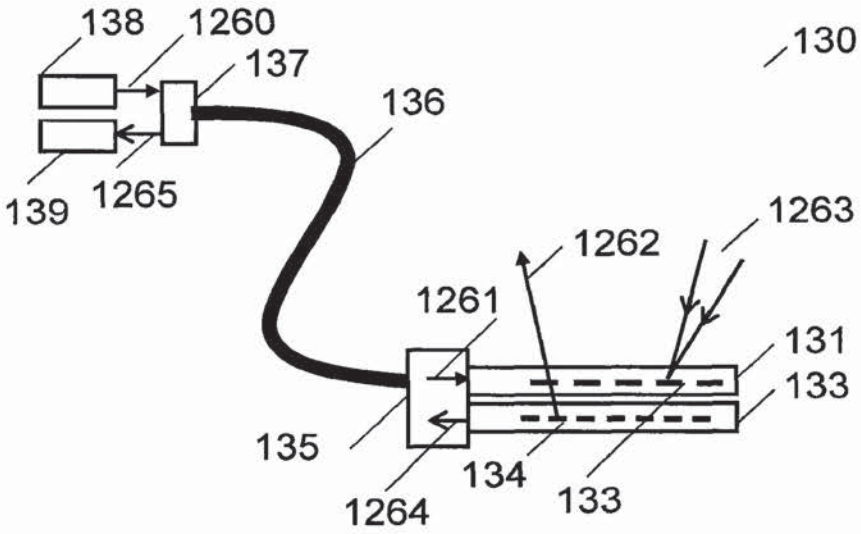


FIG.10

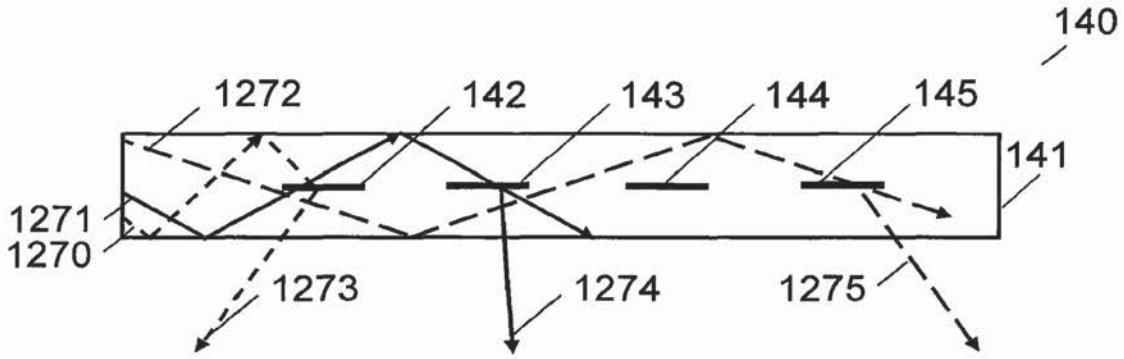


FIG.11

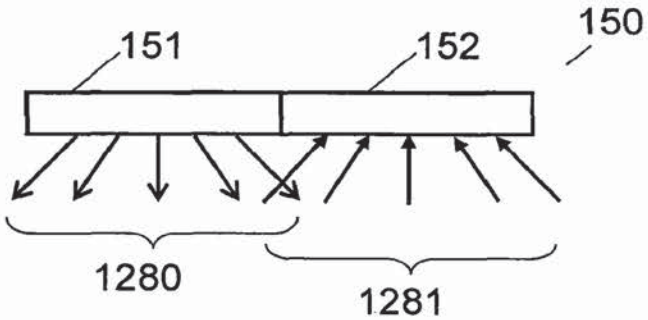


FIG.12

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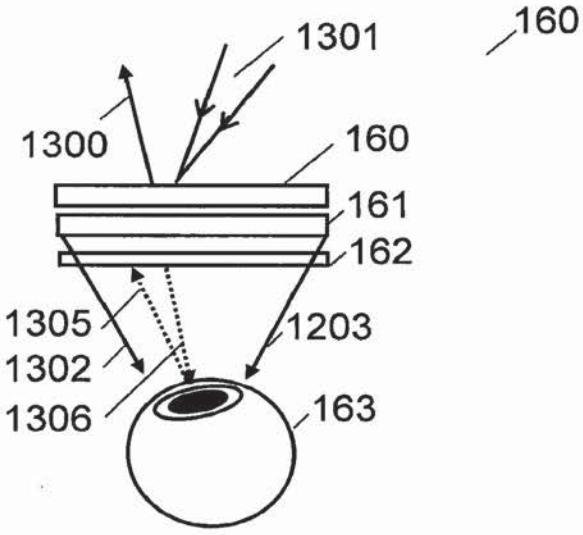


FIG.13

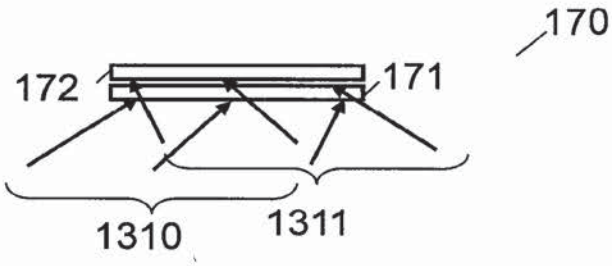


FIG.14

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/000014

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S7/481 G01S17/42 G02B26/10
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/077049 A1 (BOHN DAVID D [US]) 28 March 2013 (2013-03-28) paragraphs [0038] - [0045], [0077] - [0079]; figures 2B,7B	1,15
Y	WO 2014/188149 A1 (POPOVICH MILAN MOMCILO [GB]; WALDERN JONATHAN DAVID; GRANT ALASTAIR JO) 27 November 2014 (2014-11-27) cited in the application page 16, line 8 - page 22, line 1; figure 1 page 41, line 5 - page 42, line 17; figure 33	1-20
Y	WO 2012/172295 A1 (POPOVICH MILAN MOMCILO [GB]; WALDERN JONATHAN DAVID [US]) 20 December 2012 (2012-12-20) abstract; figures 1,19	1-20

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 June 2016	07/07/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fanjul Caudevilla, J

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/000014

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	YAQOOB Z ET AL: "High-speed two-dimensional laser scanner based on Bragg gratings stored in photothermorefractive glass", APPLIED OPTICS, OPTICAL SOCIETY OF AMERICA, WASHINGTON, DC; US, vol. 42, no. 26, 10 September 2003 (2003-09-10), pages 5251-5262, XP002327305, ISSN: 0003-6935, DOI: 10.1364/AO.42.005251 the whole document -----	1-20

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2016/000014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013077049 A1	28-03-2013	CN 102955255 A	06-03-2013
		HK 1180771 A1	22-01-2016
		TW 201314263 A	01-04-2013
		US 2013077049 A1	28-03-2013
		WO 2013049012 A1	04-04-2013
WO 2014188149 A1	27-11-2014	NONE	
WO 2012172295 A1	20-12-2012	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)

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15/420,366 31 January 2017 (31.01.2017) US

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[Continued on next page]

(54) Title: LIDAR BASED 3-D IMAGING WITH FAR-FIELD ILLUMINATION OVERLAP

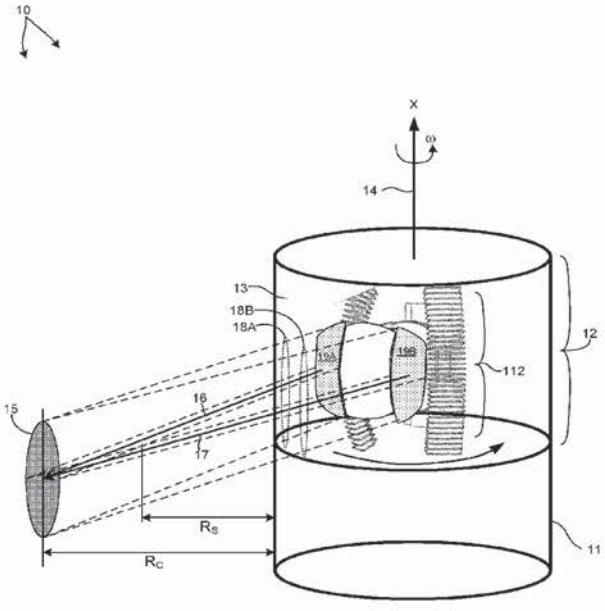


FIG. 3

(57) Abstract: Methods and systems for performing 3-D LIDAR measurements of objects simultaneously illuminated by two or more beams of light in the far field are described herein. A 3-D LIDAR based measurement device simultaneously emits at least two beams of light into a three dimensional environment from different locations. A portion of the three dimensional environment is simultaneously illuminated by the two or more light beams at a distance of at least five meters from the LIDAR device. However, the two or more light beams do not overlap at a distance less than five meters from the LIDAR device. The beams of light are slightly divergent, having highest intensity at the device and steadily lower intensity further away. By overlapping illumination beams in the far field, but not near the LIDAR device, overall intensity is maintained at moderate levels throughout the field of view of the LIDAR device.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

LIDAR BASED 3-D IMAGING WITH FAR-FIELD ILLUMINATION OVERLAP

David S. Hall
Mathew Noel Rekow
Pieter J. Kerstens

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application for patent claims priority from U.S. patent application serial number 15/420,366, entitled LIDAR Based 3-D Imaging With Far-Field Illumination Overlap," filed January 31, 2017, which, in turn, claims priority under 35 U.S.C. §119 from U.S. provisional patent application serial number 62/289,278, entitled "LIDAR Based 3-D Imaging With Far-Field Illumination Overlap," filed January 31, 2016, the subject matter of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The described embodiments relate to LIDAR based 3-D point cloud measuring systems.

BACKGROUND INFORMATION

[0003] LIDAR systems employ pulses of light to measure distance to an object based on the time of flight (TOF) of each pulse of light. A pulse of light emitted from a light source of a LIDAR system interacts with a distal object. A portion of the light reflects from the object and returns to a detector of the LIDAR system. Based on the time elapsed between emission of the pulse of light and detection of the returned pulse of light, a distance is estimated. In some examples, pulses of light are generated by a laser emitter. The light pulses are

focused through a lens or lens assembly. The time it takes for a pulse of laser light to return to a detector mounted near the emitter is measured. A distance is derived from the time measurement with high accuracy.

[0004] Some LIDAR systems employ a single laser emitter/detector combination combined with a rotating mirror to effectively scan across a plane. Distance measurements performed by such a system are effectively two dimensional (i.e., planar), and the captured distance points are rendered as a 2-D (i.e. single plane) point cloud. In some examples, rotating mirrors are rotated at very fast speeds (e.g., thousands of revolutions per minute).

[0005] In many operational scenarios, a 3-D point cloud is required. A number of schemes have been employed to interrogate the surrounding environment in three dimensions. In some examples, a 2-D instrument is actuated up and down and/or back and forth, often on a gimbal. This is commonly known within the art as "winking" or "nodding" the sensor. Thus, a single beam LIDAR unit can be employed to capture an entire 3-D array of distance points, albeit one point at a time. In a related example, a prism is employed to "divide" the laser pulse into multiple layers, each having a slightly different vertical angle. This simulates the nodding effect described above, but without actuation of the sensor itself.

[0006] In all the above examples, the light path of a single laser emitter/detector combination is somehow altered to achieve a broader field of view than a single sensor. The number of pixels such devices can generate per unit time is inherently limited due limitations on the pulse repetition rate of a single laser. Any alteration of the beam path, whether it is by mirror, prism, or actuation of the device that achieves a larger

coverage area comes at a cost of decreased point cloud density.

[0007] As noted above, 3-D point cloud systems exist in several configurations. However, in many applications it is necessary to generate image information over a broad field of view. For example, in an autonomous vehicle application, the vertical field of view should extend down as close as possible to see the ground in front of the vehicle. In addition, the vertical field of view should extend above the horizon, in the event the car enters a dip in the road. In addition, it is necessary to have a minimum of delay between the actions happening in the real world and the imaging of those actions. In some examples, it is desirable to provide a complete image update at least five times per second. To address these requirements, a 3-D LIDAR system has been developed that includes an array of multiple laser emitters and detectors. This system is described in U.S. Patent No. 7,969,558 issued on June 28, 2011, the subject matter of which is incorporated herein by reference in its entirety.

[0008] In many applications, a sequence of pulses is emitted. The direction of each pulse is sequentially varied in rapid succession. In these examples, a distance measurement associated with each individual pulse can be considered a pixel, and a collection of pixels emitted and captured in rapid succession (i.e., "point cloud") can be rendered as an image or analyzed for other reasons (e.g., detecting obstacles). In some examples, viewing software is employed to render the resulting point clouds as images that appear three dimensional to a user. Different schemes can be used to depict the distance measurements as 3-D images that appear as if they were captured by a live action camera.

[0009] In some examples, the timing of successive light emission pulses is set such that the return signal associated with a particular pulse emission is detected before the subsequent pulse emission is triggered. This ensures that a detected return signal is properly associated with the particular pulse emission that generated the detected return signal.

[0010] In some other examples, multiple pulses are emitted into the surrounding environment before a return signal from any of the multiple pulses is detected. Traditionally, this approach raises the potential for cross-talk among detected signals. In other words, when multiple pulses are emitted into the surrounding environment before a return signal from any of the multiple pulses is detected, a detected return signal might be incorrectly associated with a different pulse emission than the particular pulse emission that gave rise to detected return signal. This can potentially cause errors in distance measurement.

[0011] Traditionally, to avoid cross-talk among multiple pulses, each of the multiple pulses is projected in a different direction. By projecting each of the multiple pulses in a different direction, each volume of space interrogated by each of the multiple pulses is completely separated from any volume of space interrogated by any of the other multiple pulses. As the separation among simultaneously interrogated spaces is increased, the likelihood of inducing measurement error due to cross-talk is reduced.

[0012] Existing LIDAR systems employ a single 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. These problems are exacerbated as

measurement ranges are extended for a LIDAR system without increasing laser pulse intensity.

[0013] These systems are limited in the intensity of light that can be projected onto the volume of the environment subject to measurement by each beam of light. In some examples, human eye safety protocols limit the intensity of light emitted from the LIDAR device.

[0014] Improvements in signal strength and noise rejection are desired to extend the measurement range of a LIDAR system.

SUMMARY

[0015] Methods and systems for performing 3-D LIDAR measurements of objects simultaneously illuminated by two or more beams of light in the far field are described herein. A 3-D LIDAR based measurement device simultaneously emits at least two beams of light into a three dimensional environment. Each beam of light is emitted from the 3-D LIDAR device at a different location. At least two of the emitted beams are projected from the 3-D LIDAR device such that a portion of the three dimensional environment is illuminated by the two or more light beams at a distance of at least five meters from the LIDAR device. In addition, the two or more light beams do not overlap at a distance of less than five meters from the LIDAR device.

[0016] The beams of light emitted from the 3-D LIDAR device are slightly divergent. Thus, the beam intensity is highest at the window of the device, and steadily decreases further away from the device. It follows that the risk of damage to the human eye is greatest in short range of the device and the risk diminishes as the distance from the device increases.

[0017] By emitting multiple beams of light from the 3-D LIDAR device at different locations, the risk of eye

damage is minimized at short distances because the beams are not overlapping. Hence, at short distances, only a single beam may incidentally interact with a human eye. As the distances increase, the beams begin to overlap, until a critical distance is reached where, ideally, two or more beams fully overlap with each other. In some examples, the critical distance is in a range of 100-200 meters away from the 3-D LIDAR device. At these distances, more than one beam may incidentally interact with a human eye without risk of harm due to beam divergence.

[0018] In a further aspect, the LIDAR system determines the time of flight of the multiple beams of illumination light projected from the LIDAR device to a location in three dimensional environment and back to the LIDAR device. The distance between the LIDAR device and the particular location of the three dimensional environment illuminated by the beams of illumination light is determined based on the time of flight.

[0019] The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is not limiting in any way. Other aspects, inventive features, and advantages of the devices and/or processes described herein will become apparent in the non-limiting detailed description set forth herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is a simplified diagram illustrative of one embodiment of a 3-D LIDAR system 100 in at least one novel aspect.

[0021] FIG. 2 depicts an exploded view of 3-D LIDAR system 100 in one exemplary embodiment.

[0022] FIG. 3 is a simplified diagram illustrative of another embodiment of a 3-D LIDAR system 10 in at least one novel aspect.

[0023] FIG. 4 depicts a view of light emission and collection engine 112 of 3-D LIDAR system 100.

[0024] FIG. 5 depicts a view of collection optics 116 of 3-D LIDAR system 100 in greater detail.

[0025] FIG. 6 depicts a cutaway view of collection optics 116 of 3-D LIDAR system 100 that illustrates the shaping of each beam of collected light 118.

[0026] FIG. 7 depicts elements of a LIDAR system including a pulsed illumination system 130, a light detection system 150, and controller 140.

[0027] FIG. 8 depicts an exemplary diagram 180 illustrating the timing of light emission from each of sixteen different multiple beam illumination systems.

[0028] FIG. 9 depicts an illustration of the timing of emission of a pulse measurement beam and capture of the returning measurement pulse.

[0029] FIG. 10 depicts a flowchart illustrative of a method 200 of performing LIDAR measurements in at least one novel aspect.

DETAILED DESCRIPTION

[0030] Reference will now be made in detail to background examples and some embodiments of the invention, examples of which are illustrated in the accompanying drawings.

[0031] FIG. 1 is a diagram illustrative of an embodiment of a 3-D LIDAR system 100 in one exemplary operational scenario. 3-D LIDAR system 100 includes a lower housing 101 and an upper housing 102 that includes a domed shell element 103 constructed from a material that is transparent to infrared light (e.g., light having a wavelength within the spectral range of 700 to 1,700 nanometers). In one example, domed shell element 103 is

transparent to light having a wavelengths centered at 905 nanometers.

[0032] As depicted in FIG. 1, a plurality of beams of light 105 are emitted from 3-D LIDAR system 100 through domed shell element 103 over an angular range, α, measured from a central axis 104. In the embodiment depicted in FIG. 1, each beam of light is projected onto a plane defined by the x and y axes at a plurality of different locations spaced apart from one another. For example, beam 106 is projected onto the xy plane at location 107.

[0033] In the embodiment depicted in FIG. 1, 3-D LIDAR system 100 is configured to scan each of the plurality of beams of light 105 about central axis 104. Each beam of light projected onto the xy plane traces a circular pattern centered about the intersection point of the central axis 104 and the xy plane. For example, over time, beam 106 projected onto the xy plane traces out a circular trajectory 108 centered about central axis 104.

[0034] FIG. 2 depicts an exploded view of 3-D LIDAR system 100 in one exemplary embodiment. 3-D LIDAR system 100 further includes a light emission/collection engine 112 that rotates about central axis 104. In the depicted embodiment, a central optical axis 117 of light emission/collection engine 112 is tilted at an angle, θ, with respect to central axis 104. As depicted in FIG. 2, 3-D LIDAR system 100 includes a stationary electronics board 110 mounted in a fixed position with respect to lower housing 101. Rotating electronics board 111 is disposed above stationary electronics board 110 and is configured to rotate with respect to stationary electronics board 110 at a predetermined rotational velocity (e.g., more than 200 revolutions per minute). Electrical power signals and electronic signals are communicated between stationary electronics board 110 and

rotating electronics board 111 over one or more transformer, capacitive, or optical elements, resulting in a contactless transmission of these signals. Light emission/collection engine 112 is fixedly positioned with respect to the rotating electronics board 111, and thus rotates about central axis 104 at the predetermined angular velocity, ω.

[0035] As depicted in FIG. 2, 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.

[0036] In one aspect, a 3-D LIDAR device emits at least two beams of light into a three dimensional environment. Each beam of light is emitted from the 3-D LIDAR device at a different location. At least two of the emitted beams are projected from the 3-D LIDAR device such that the portion of the three dimensional environment illuminated by a first of the plurality of light beams substantially overlaps a portion of the three dimensional environment illuminated by a second of the plurality of light beams at a distance of at least five meters from

the LIDAR device. In addition, the portion of the three dimensional environment illuminated by a first of the plurality of light beams does not substantially overlap a portion of the three dimensional environment illuminated by a second of the plurality of light beams at a distance of less than five meters from the LIDAR device.

[0037] The beams of light emitted from the 3-D LIDAR device are slightly divergent. In one example, the beam diameter is approximately 15 millimeters at the window of the device, and is approximately 20 centimeters at a distance of 100 meters from the device. Thus, the beam intensity is highest at the window of the device, and steadily decreases further away from the device. It follows that the risk of damage to the human eye is greatest in short range of the device and the risk diminishes as the distance from the device increases.

[0038] By emitting multiple beams of light from the 3-D LIDAR device at different locations, at short distances, the risk of eye damage is minimized because the beams are not overlapping. Hence, at short distances, only a single beam may incidentally interact with a human eye. As the distances increase, the beams begin to overlap, until a critical distance is reached where, ideally, two or more beams fully overlap with each other. In some examples, the critical distance is in a range of 100-200 meters away from the 3-D LIDAR device. In these distance ranges, more than one beam may incidentally interact with a human eye. However, at these distances, the combined beam intensity is below eye damage limits due to beam divergence.

[0039] FIG. 3 is a diagram illustrative of another embodiment of a 3-D LIDAR system 10 in one exemplary operational scenario. 3-D LIDAR system 10 includes a lower housing 11 and an upper housing 12 that includes a cylindrical shell element 13 (e.g., outer lens)

constructed from a material that is transparent to infrared light (e.g., light having a wavelength within the spectral range of 700 to 1,700 nanometers). In one example, cylindrical shell element 13 is transparent to light having a wavelengths centered at 905 nanometers.

[0040] As depicted in FIG. 3, 3-D LIDAR system 10 includes a light emission/collection engine 112 tilted at a ninety degree angle with respect to central axis 14. In one aspect, two beams of light are emitted from 3-D LIDAR system 10 from different, spatially distinct locations of the 3-D LIDAR device. As depicted in FIG. 3, a beam of light characterized by chief ray 16 is emitted from light emission/collection engine 112 at the surface of illumination optic 19A and a beam of light characterized by chief ray 17 is simultaneously emitted from light emission/collection engine 112 at the surface of illumination optic 19B. The surfaces of illumination optics 19A and 19B are spatially distinct. In addition, the beam of light characterized by chief ray 16 is emitted from 3-D LIDAR system 10 at location 18A on the outer lens 13 and the beam of light characterized by chief ray 17 is simultaneously emitted from the 3-D LIDAR system 10 at location 18B on the outer lens 13. Location 18A and 18B are spatially distinct.

[0041] Furthermore, the beams are pointed such that they begin to overlap at a distance, R_s, from the device and maximally overlap at a critical distance, R_c, (e.g., 100-200 meters from 3-D LIDAR device 10). In the embodiment depicted in FIG. 3, the chief ray 16 of one illumination beam of light and the chief ray 17 of another illumination beam of light are illustrated. Each beam of light is projected outward into the surrounding environment along different trajectories. The trajectories intersect at location 15 in the far-field.

Location 15 is located at a critical distance, R_c, from 3-D LIDAR system 10.

[0042] Each beam of light emitted from system 10 diverges slightly as illustrated in FIG. 3. In one example, a beam of light emitted from system 10 illuminates a spot size of 20 centimeters in diameter at a distance of 100 meters from system 10. In this manner, each beam of illumination light is a cone of illumination light emitted from system 10. For a portion of each beam trajectory from 3-D LIDAR system 10 to location 15, the beams do not intersect. At a distance, R_S, the beams begin to overlap. In some examples, the distance, R_s, where the beams begin to overlap is five meters, or more. Hence, at a distance of less than five meters, the beams do not overlap at all. As the distance increases beyond R_s, the percentage of overlap continues to increase until a maximum overlap is reached at the critical distance, R_c. Ideally, the percentage of overlap at the critical distance is 100%. However, in practice, any significant amount of overlap is beneficial as the overlapping illumination provides a stronger return signal to 3-D LIDAR device 10.

[0043] As depicted in FIG. 3, two beams of light are emitted from 3-D LIDAR system 10 from different locations of the 3-D LIDAR device and from two different lens elements. Furthermore, the beams are pointed such that they overlap at a critical distance from the device (e.g., 100-200 meters from 3-D LIDAR device 20). As depicted in FIG. 3, emission lens 19A and 19B are two different lens elements, each having their own optical axis. In some other embodiments, lens elements 19A and 19B may be constructed as a single optical component that includes two different lens elements, each having their own optical axis.

[0044] In the embodiment depicted in FIG. 3, 3-D LIDAR system 10 is configured to scan each of the plurality of beams of light 16 and 17 about central axis 14. As the beams of light rotate about central axis 14, each beam of light projected into the surrounding environment (e.g., each cone of illumination light associated with each beam) illuminates a volume of the environment corresponding the cone shaped illumination beam as it is swept around central axis 14. In general, any number of beams may be emitted from 3-D LIDAR system 10 to provide overlapping illumination in the far-field, or in different locations in the far-field.

[0045] In some embodiments, each beam configured to overlap with another beam in the far-field is generated by a separate illumination source (e.g., laser diode, LED, etc.) In some other embodiments, illumination light generated by a particular illumination source is subdivided and collimated to generate two or more different beams that are each directed such that they overlap in the far field.

[0046] FIG. 4 depicts another view of light emission/collection engine 112. In the depicted embodiment, light emission/collection engine 112 includes intermediate electronics boards 121, 122, and 123 which provide mechanical support and electrical connectivity between rotating electronics board 111 and various elements of light emission/collection engine 112. For example, each of the array of light detecting elements 113 is mounted to intermediate electronics board 121. Intermediate electronics board 121, in turn, is mechanically and electrically coupled to rotating electronics board 111. Similarly, each of the array of light emitting elements 114 is mounted to intermediate electronics board 123. Intermediate electronics board 123, in turn, is mechanically and electrically coupled to

rotating electronics board 111. In another example, illumination optics 115 and collection optics 116 are mechanically mounted to intermediate electronics board 122. In this example, intermediate electronics board 122 spatially and optically separates the illumination optics 115 and the collection optics 116 to avoid contamination of the collected light with illumination light. Intermediate electronics board 122, in turn, is mechanically and electrically coupled to rotating electronics board 111. In this manner, the intermediate electronics boards provide mechanical and electrical connectivity and additional board area for mounting electrical components required for the operation of 3-D LIDAR system 100.

[0047] FIG. 5 depicts a view of collection optics 116 in greater detail. As depicted in FIG. 5, collection optics 116 include four lens elements 116A-D arranged to focus collected light 118 onto each of the array of detecting elements 113. Light passing through collection optics 116 is reflected from mirror 124 and is directed onto each of the array of detecting elements 113. In another aspect, 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.

[0048] FIG. 6 depicts a cutaway view of collection optics 116 to illustrate the shaping of each beam of collected light 118.

[0049] As described hereinbefore, 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. However, in general, one or more of the optical elements of illumination optics 115 may also be 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.

[0050] A LIDAR system, such as 3-D LIDAR system 10 depicted in FIG. 3, and system 100, depicted in FIG. 1, includes multiple, pulsed illumination sources emitting pulsed beams of illumination light from the LIDAR device into the surrounding environment. In some embodiments, the pulsed illumination sources are laser based. In some embodiments, the pulsed illumination sources are based on one or more light emitting diodes. In general, any suitable pulsed illumination source may be contemplated.

[0051] In one embodiment, two or more pulsed beams of illumination light simultaneously illuminate a particular location of the three dimensional environment (e.g., pixel) with pulses of illumination light. Light reflected from the location is detected by a photosensitive detector of the LIDAR system during a measurement window having a duration that is less than or equal to the time of flight of light from the LIDAR system out to the programmed range of the LIDAR system, and back. The photosensitive detector detects a return pulse or pulses of light reflected from a particular location of the three dimensional environment

simultaneously illuminated by two or more illumination beams. In this manner, the reflection from a particular measurement location of each of the multiple illumination beams is captured by the LIDAR system.

[0052] In a further aspect, the LIDAR system determines the time of flight of the beams of illumination light from the LIDAR device to the particular spot of the three dimensional environment illuminated by the beams of illumination light and back to the LIDAR device. This determination is based on the reflected light detected during the measurement window. The distance between the LIDAR device and the particular location of the three dimensional environment illuminated by the beams of illumination light is determined based on the time of flight.

[0053] FIG. 7 depicts elements of a LIDAR system including a pulsed illumination system 130, a light detection system 150, and controller 140.

[0054] Pulsed illumination system 130 includes pulsed light emitting devices 136 and 137. Pulsed light emitting devices 136 and 137 generate simultaneous, pulsed light emission in response to pulsed electrical current signals 134 and 133, respectively. The light generated by pulsed light emitting devices 136 and 137 is focused and projected onto a particular location 138 in the surrounding environment by one or more optical elements of the LIDAR system. The beams of light generated by the pulsed lighting emitting devices 136 and 137 are directed such that they overlap at location 138. In one example, light emitted by pulsed light emitting devices 136 and 137 is focused and projected onto a particular location by illumination optics 115 that collimate the emitted light into pulsed beams of light 16 and 17 emitted from 3-D LIDAR system 10 as depicted in FIG. 3.

[0055] Pulsed illumination system 130 includes drivers 131 and 132 that supply current pulses to light emitting devices 137 and 136, respectively. The current pulses generated by drivers 131 and 132 are controlled by control signal, MPC. In this manner, the timing and shape of pulses generated by light emitting devices 136 and 137 are controlled by controller 140.

[0056] In a further embodiment, a LIDAR system, such as LIDAR system 100 depicted in FIG. 1, includes sixteen, multiple beam, pulsed illumination systems operating in coordination with a common controller (e.g., controller 140). FIG. 8 depicts an exemplary diagram 180 illustrating the timing of light emission from each of the sixteen, multiple beam illumination systems.

[0057] As depicted in FIG. 8, a measurement pulse is emitted from a first multiple beam illumination system. After a delay time, T_{DELAY}, a measurement pulse is emitted from a second multiple beam illumination system of the LIDAR device. In this manner a sequence of sixteen measurement pulses are emitted in different directions from the LIDAR device during a measurement period, $T_{MEASUREMENT}$. The drivers of each of the sixteen multiple beam illumination systems are charged after the measurement period for a charging period, T_{CHARGE}. After, the charging period, another measurement pulse is emitted from each multiple beam illumination system over a subsequent measurement period.

[0058] In some embodiments, the delay time is set to be greater than the time of flight of the measurement pulse to and from an object located at the maximum range of the LIDAR device. In this manner, there is no cross-talk among any of the sixteen multiple beam illumination systems.

[0059] In some other embodiments, a measurement pulse may be emitted from one multiple beam illumination system

before a measurement pulse emitted from another multiple beam illumination system has had time to return to the LIDAR device. In some of these embodiments, care is taken to ensure that there is sufficient spatial separation between the areas of the surrounding environment interrogated by each set of beams to avoid cross-talk.

[0060] As depicted in FIG. 7, light reflected from location 138 simultaneously illuminated by multiple beams is detected by light detector 155. Light detector 155 generates an output signal 151 that is amplified by an analog trans-impedance amplifier 152. In general, the amplification of output signal 151 may include multiple, amplifier stages. In this sense, analog trans-impedance amplifier 152 is provided by way of non-limiting example, as many other analog signal amplification schemes may be contemplated within the scope of this patent document.

[0061] The amplified signal 153 is communicated to controller 140. An analog-to-digital converter (ADC) 144 of controller 140 is employed to convert the analog signal 153 into a digital signal used for further processing. Controller 140 generates an enable/disable signal 145 employed to control the timing of data acquisition by ADC 144 in concert with control signal, MPC.

[0062] FIG. 9 depicts an illustration of the timing associated with the emission of a measurement pulse and capture of the returning measurement pulse sequence. As depicted in FIG. 9, the measurement begins with pulse firing signals 161 (e.g., MPC[1] and MPC[2]) generated by controller 140. Due to internal system delay, a pulse index signal 162 is determined that is shifted from the multiple pulse firing signal 161 by a time delay, T_D. The time delay includes the known delays associated with emitting light from the LIDAR system (e.g., signal

communication delays and latency associated with the switching elements, energy storage elements, and pulsed light emitting device) and known delays associated with collecting light and generating signals indicative of the collected light (e.g., amplifier latency, analog-digital conversion delay, etc.).

[0063] As depicted in FIG. 9, a return signal 163 is detected by the LIDAR system in response to the illumination of a particular location by both light emitting devices 136 and 137. A measurement window (i.e., a period of time over which collected return signal data is associated with a particular measurement pulse) is initiated by enabling data acquisition from light detecting element 150. Controller 140 controls the timing of the measurement window to correspond with the window of time when a return signal is expected in response to the emission of the corresponding measurement pulse. In some examples, the measurement window is enabled at the point in time when the measurement pulse is emitted and is disabled at a time corresponding to the time of flight of light over a distance that is twice the range of the LIDAR system. In this manner, the measurement window is open to collect return light from objects adjacent to the LIDAR system (i.e., negligible time of flight) to objects that are located at the maximum range of the LIDAR system. In this manner, all other light that cannot possibly contribute to useful return signal is rejected.

[0064] As depicted in FIG. 9, return signal 163 includes two return measurement pulses that correspond with different objects in the path of the multiple beams. In general, signal detection is performed on all detected measurement pulses. Further signal analysis may be performed to identify the closest signal (i.e., first instance of the return measurement pulse), the strongest

signal, and the furthest signal (i.e., last instance of the return measurement pulse in the measurement window). Any of these instances may be reported as potentially valid distance measurements by the LIDAR system. For example, a time of flight, TOF_1, may be calculated from the closest (i.e., earliest) return measurement pulse that corresponds with the emitted measurement pulse sequence as depicted in FIG. 9.

[0065] In the embodiment described with reference to FIG. 7, two different light emitting devices (i.e., light emitting devices 136 and 137) are employed to simultaneously generate two different beams directed to overlap in the far field. However, in general, a single light emitting device may be employed along with a beam splitting optic to subdivide the beam of light emitted from the single light emitting device into two or more beams that are directed to overlap in the far field by additional optical elements. In these embodiments, a single light emitting source simultaneously generates multiple beams that overlap in the far field with a single trigger signal, rather than having to coordinate the timing of multiple trigger signals (e.g., MPC[1] and MPC[2]) to achieve simultaneous overlapping illumination in the far field.

[0066] FIG. 10 illustrates a method 200 of performing LIDAR measurements with multiple illumination beams overlapping in the far field in at least one novel aspect. Method 200 is suitable for implementation by any of the embodiments described herein. In one aspect, it is recognized that data processing blocks of method 200 may be carried out via a pre-programmed algorithm executed by one or more processors of controller 140, or any other general purpose computing system. It is recognized herein that the particular structural aspects

of the described embodiments do not represent limitations and should be interpreted as illustrative only.

[0067] In block 201, two or more light beams are emitted from a LIDAR device into a three dimensional environment in a plurality of different directions. Portions of the three dimensional environment illuminated by each of the two or more light beams substantially overlap at a distance of at least five meters from the LIDAR device. None of the two or more light beams overlap any of the other two or more light beams at a distance less than five meters from the LIDAR device.

[0068] In block 202, an amount of light reflected from a location in the three dimensional environment simultaneously illuminated by the two or more light beams is detected.

[0069] In block 203, a time of flight of the two or more light beams emitted from the LIDAR device and detected by one or more photosensitive detectors of the LIDAR device is determined.

[0070] In one or more exemplary embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of

instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0071] Although certain specific embodiments are described above for instructional purposes, the teachings of this patent document have general applicability and are not limited to the specific embodiments described above. Accordingly, various modifications, adaptations, and combinations of various features of the described embodiments can be practiced without departing from the scope of the invention as set forth in the claims.

CLAIMS

What is claimed is:

1. A light detection and ranging (LIDAR) device, comprising:

one or more illumination sources configured to emit two or more light beams from the LIDAR device into a three dimensional environment in a plurality of different directions such that a portion of the three dimensional environment is illuminated by each of the two or more light beams, wherein a first of the two or more light beams is emitted from the LIDAR device at a first location, and a second of the two or more light beams is emitted from the LIDAR device at a second location that is spatially distinct from the first location;

one or more photosensitive detectors configured to detect an amount of light reflected from a location in the three dimensional environment simultaneously illuminated by the two or more light beams; and

a computing system configured to determine a time of flight of the two or more light beams emitted from the one or more illumination sources and detected by the one or more photosensitive detectors.

2. The LIDAR device of Claim 1, wherein the portion of the three dimensional environment illuminated by each of the two or more light beams is located at least five meters from the LIDAR device and none of the two or more light beams overlap any of the other two or more light beams at a distance less than five meters from the LIDAR device.

3. The LIDAR device of Claim 2, wherein the first and second locations are located on a surface of an optical element.

4. The LIDAR device of Claim 2, wherein the first location is located on a surface of a first optical element and the second location is located on a surface of a second optical element.

5. The LIDAR device of Claim 1, wherein the one or more illumination sources comprises:

a light emitting device configured to emit a first amount of light;

one or more optical elements configured to collimate the first amount of light into a first beam of light; and

a beam splitting element configured to separate the first beam of light into a second beam of light and a third beam of light, wherein the second beam of light is emitted from the LIDAR device at a first location, and wherein the third beam of light is emitted from the LIDAR device at a second location that is spatially distinct from the first location, and wherein portions of the three dimensional environment illuminated by the second beam of light and the third beam of light substantially overlap at a distance of at least five meters from the LIDAR device and no portions of the second beam of light and the third beam of light overlap at any distance less than five meters from the LIDAR device.

6. The LIDAR device of Claim 1, wherein a first of the one or more illumination sources emits a first of the two or more light beams from the LIDAR device at a first location, and a second of the one or more illumination sources emits a second of the two or more light beams from the LIDAR device at a second location, wherein the first and second locations are spatially distinct.

7. The LIDAR device of Claim 1, wherein each of the one or more illumination sources is laser based.

8. The LIDAR device of Claim 1, wherein each of the one or more illumination sources includes a light emitting diode.

9. The LIDAR device of Claim 1, wherein each of the one or more illumination sources emit pulses of illumination light.

10. A light detection and ranging (LIDAR) device, comprising:

one or more light emitting devices configured to emit a first amount of light;

one or more optical elements configured to collimate the first amount of light into a first beam of light;

a beam splitting element configured to separate the first beam of light into a second beam of light and a third beam of light, wherein the second beam of light is emitted from the LIDAR device at a first location, and wherein the third beam of light is emitted from the LIDAR device at a second location that is spatially distinct from the first location, and wherein portions of the three dimensional environment illuminated by the second beam of light and the third beam of light substantially overlap at a distance of at least five meters from the LIDAR device and no portions of the second beam of light and the third beam of light overlap at any distance less than five meters from the LIDAR device.

11. The LIDAR device of Claim 10, further comprising:

one or more photosensitive detectors configured to detect an amount of light reflected from a location in

the three dimensional environment simultaneously illuminated by the second and third beams of light; and

a computing system configured to determine a time of flight of the second and third beams of light emitted from the one or more light emitting devices and detected by the one or more photosensitive detectors.

12. The LIDAR device of Claim 10, wherein the first location is located on a surface of a first optical element and the second location is located on a surface of a second optical element.

13. The LIDAR device of Claim 10, wherein the first location is located on a surface of a first optical element and the second location is located on a surface of a second optical element.

14. The LIDAR device of Claim 10, wherein each of the one or more light emitting devices is laser based.

15. The LIDAR device of Claim 10, wherein each of the one or more light emitting devices is a light emitting diode.

16. A method comprising:

emitting two or more light beams from a LIDAR device into a three dimensional environment in a plurality of different directions such that portions of the three dimensional environment illuminated by each of the two or more light beams substantially overlap at a distance of at least five meters from the LIDAR device and none of the two or more light beams overlap any of the other two or more light beams at a distance less than five meters from the LIDAR device;

detecting an amount of light reflected from a location in the three dimensional environment simultaneously illuminated by the two or more light beams; and

determining a time of flight of the two or more light beams emitted from the LIDAR device and detected by one or more photosensitive detectors of the LIDAR device.

17. The method of Claim 16, wherein a first of the two or more light beams is emitted from the LIDAR device at a first location, and a second of the two or more light beams is emitted from the LIDAR device at a second location that is spatially distinct from the first location.

18. The method of Claim 17, wherein the first location is located on a surface of a first optical element and the second location is located on a surface of a second optical element.

19. The method of Claim 17, wherein the first location is located on a surface of a first optical element and the second location is located on a surface of a second optical element.

20. The method of Claim 17, further comprising:

emitting a first amount of light from one or more light emitting devices;

collimating the first amount of light into a first beam of light; and

splitting the first beam of light into a second beam of light and a third beam of light, wherein the second beam of light is emitted from the LIDAR device at a first location, and wherein the third beam of light is emitted from the LIDAR device at a second location that is

spatially distinct from the first location, and wherein portions of the three dimensional environment illuminated by the second beam of light and the third beam of light substantially overlap at a distance of at least five meters from the LIDAR device and no portions of the second beam of light and the third beam of light overlap at any distance less than five meters from the LIDAR device.

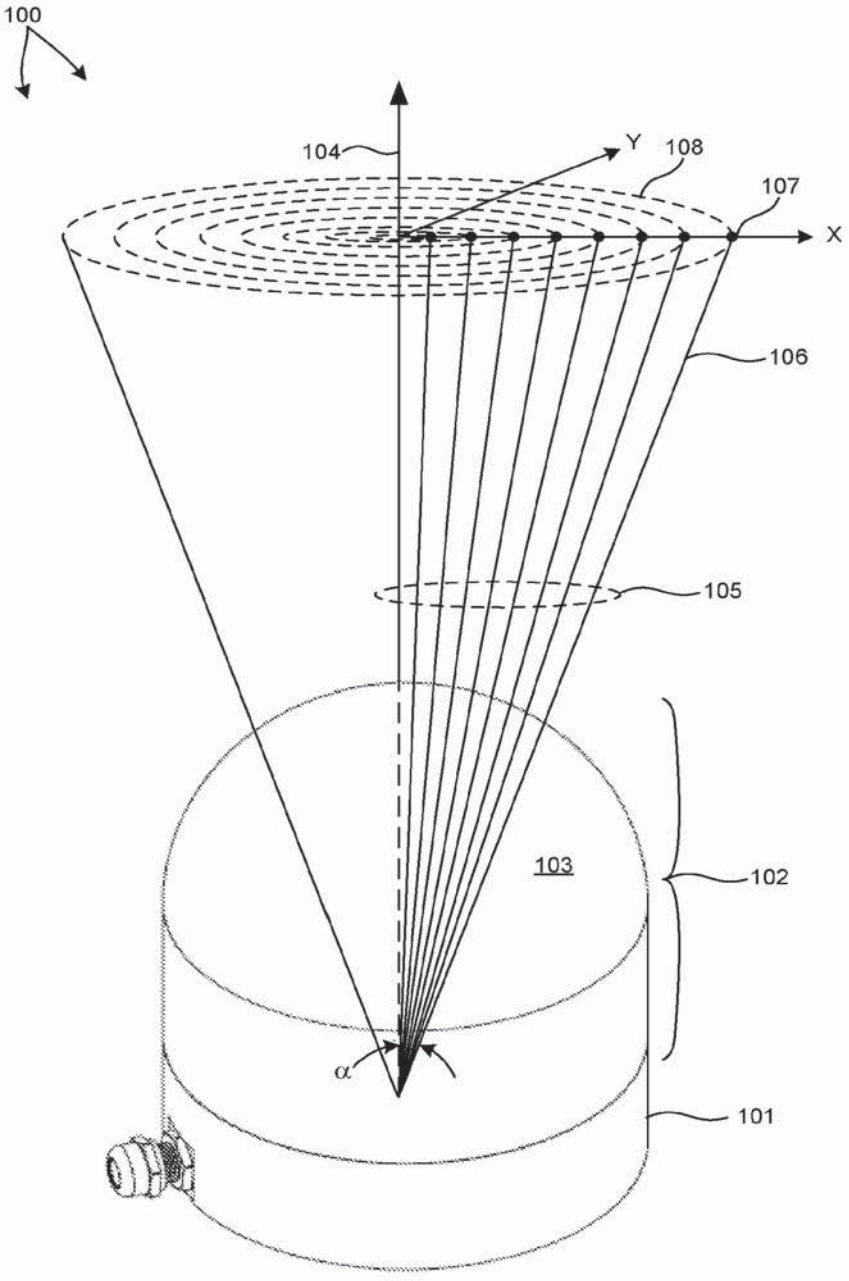


FIG. 1

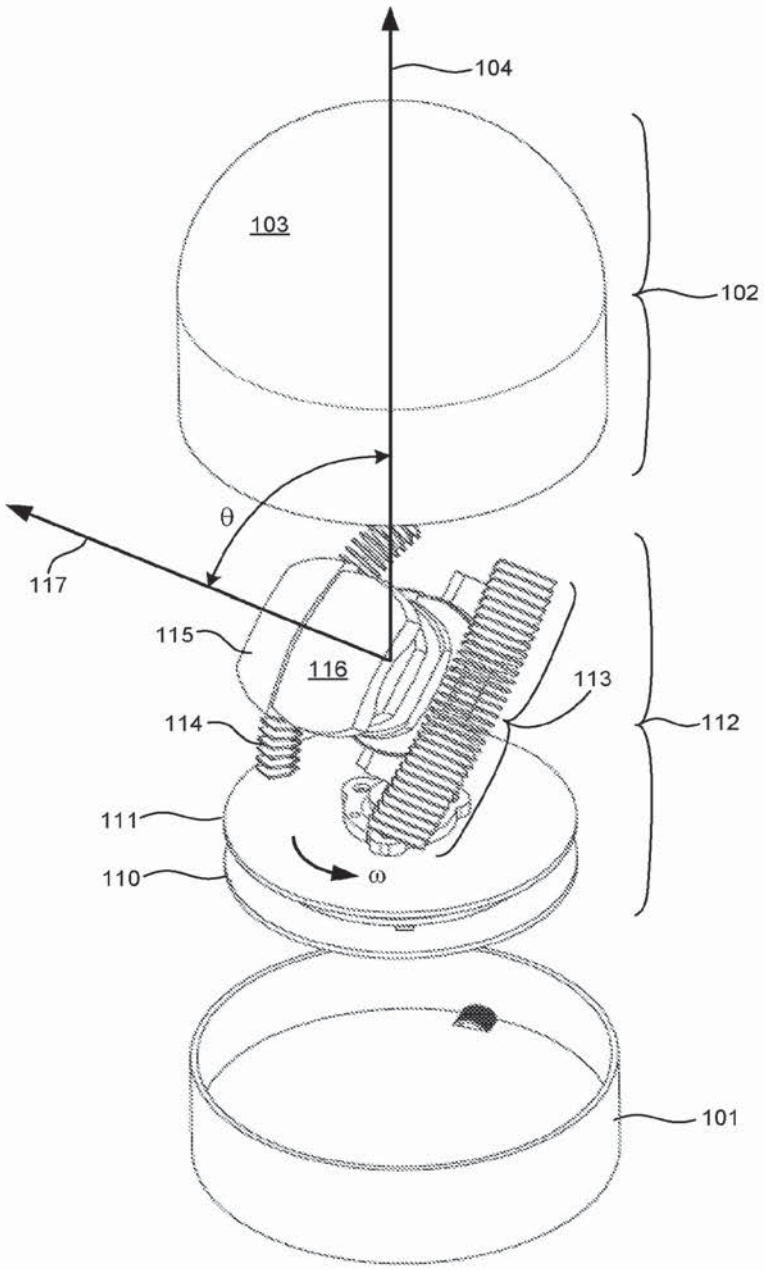


FIG. 2

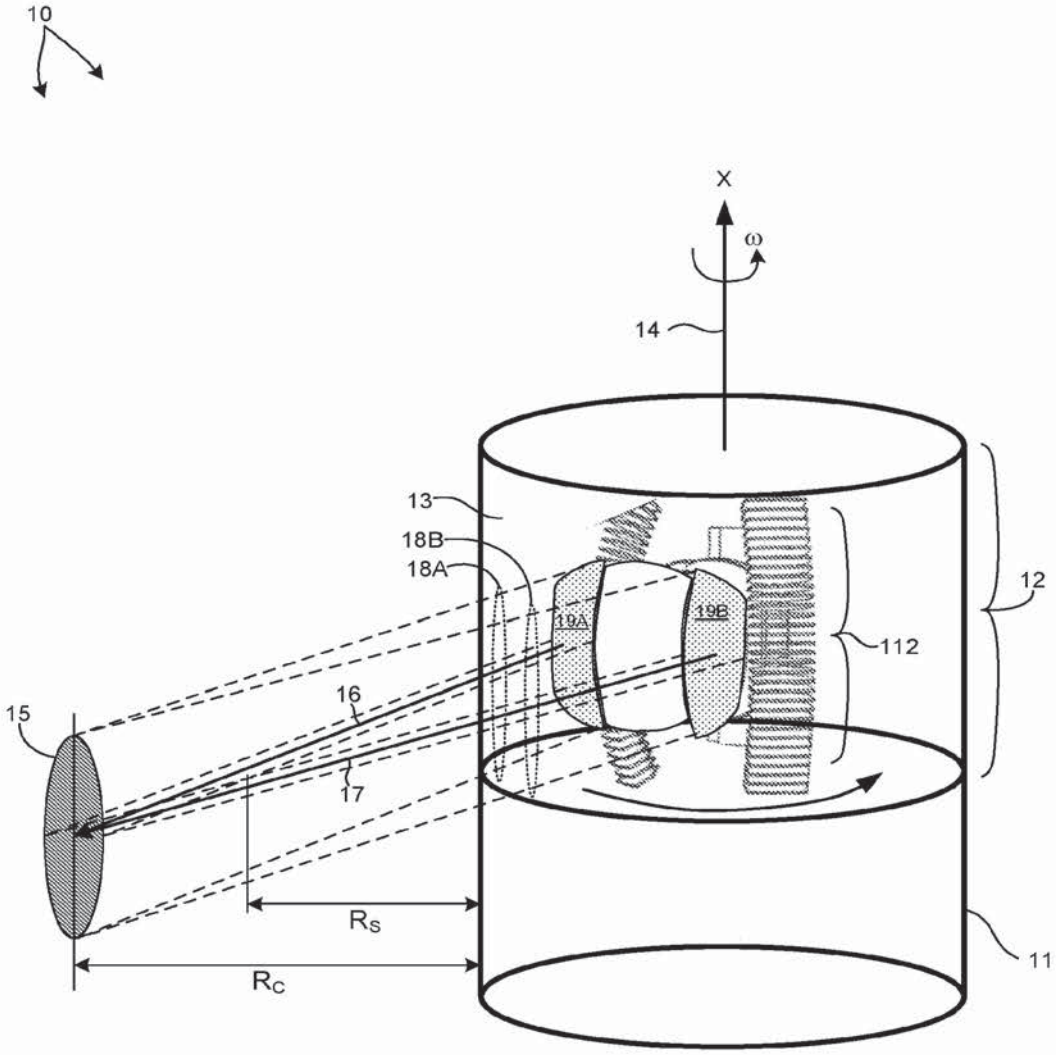


FIG. 3

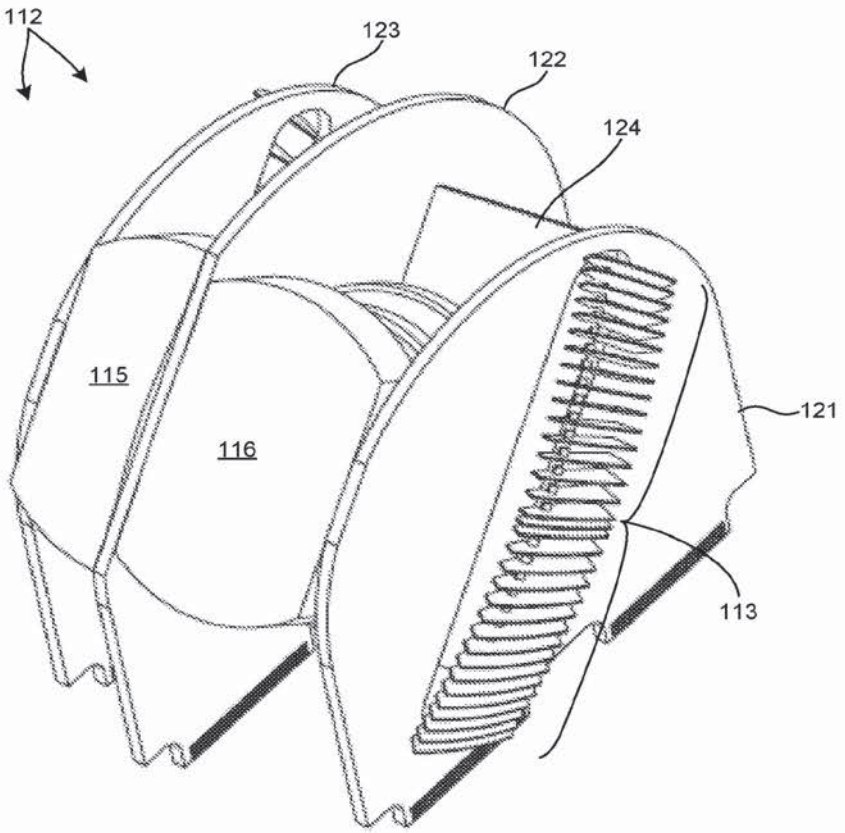


FIG. 4

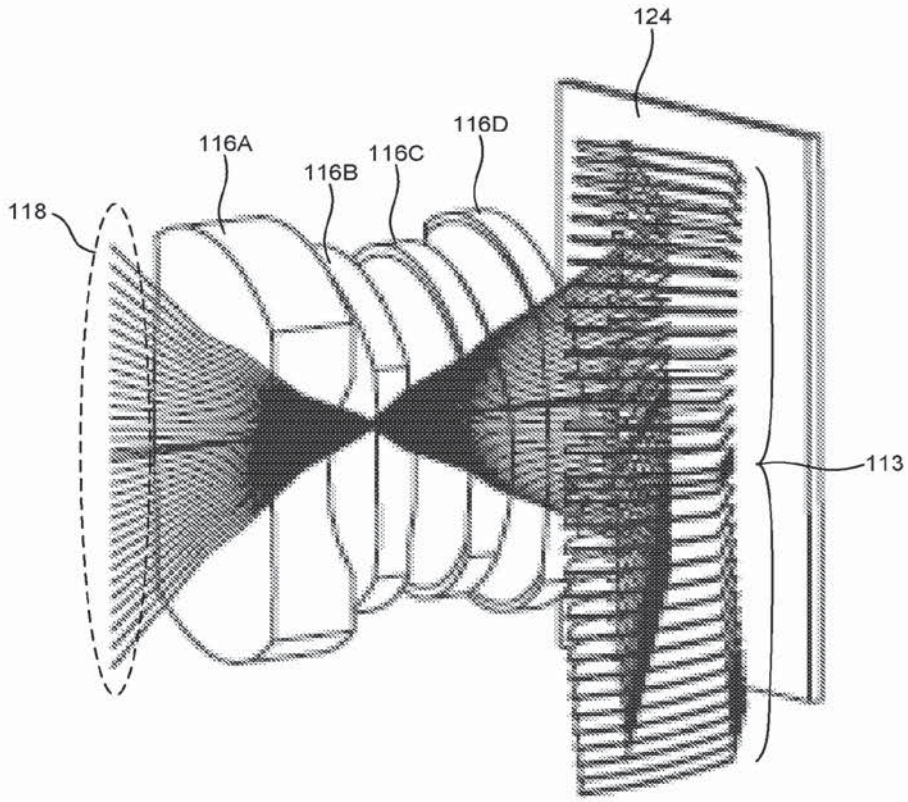


FIG. 5

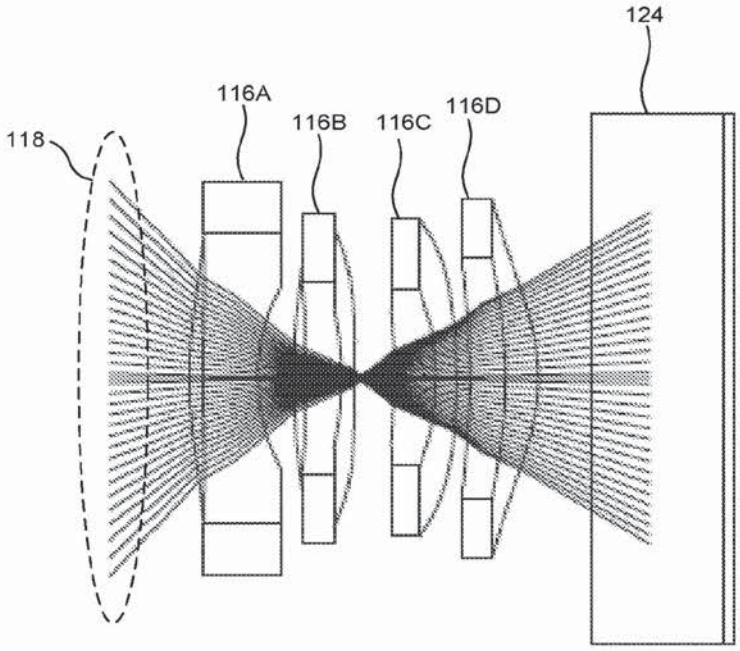


FIG. 6

7/10

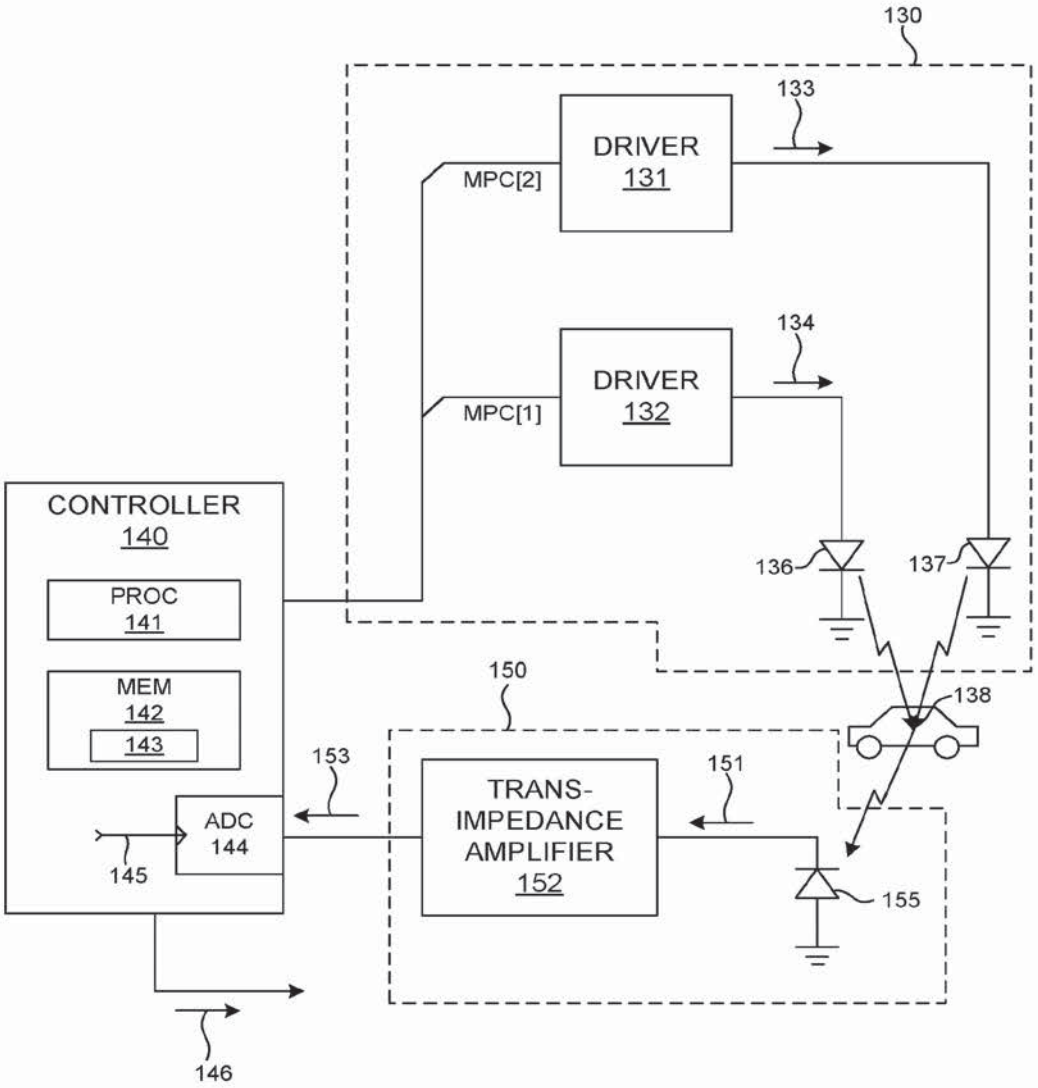

130
133
DRIVER
131
MPC[2]
134
DRIVER
132
MPC[1]
CONTROLLER
140
PROC
141
MEM
142
143
ADC
144
145
146
153
150
TRANS-
IMPEDANCE
AMPLIFIER
152
151
136
137
138
155

FIG. 7

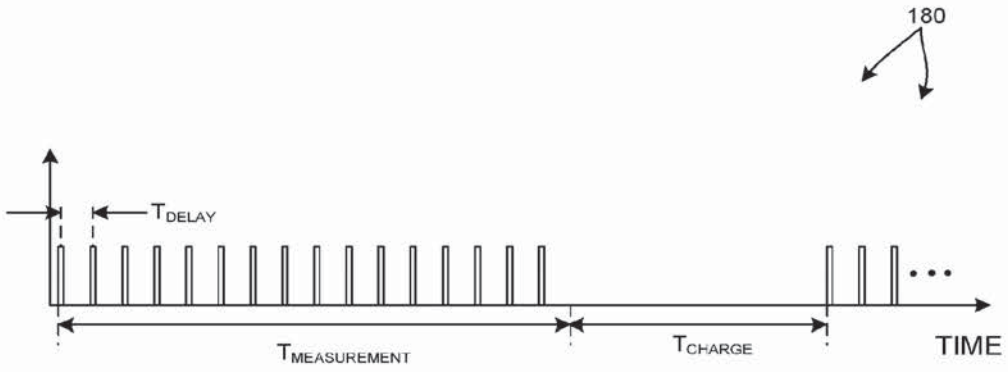


FIG. 8

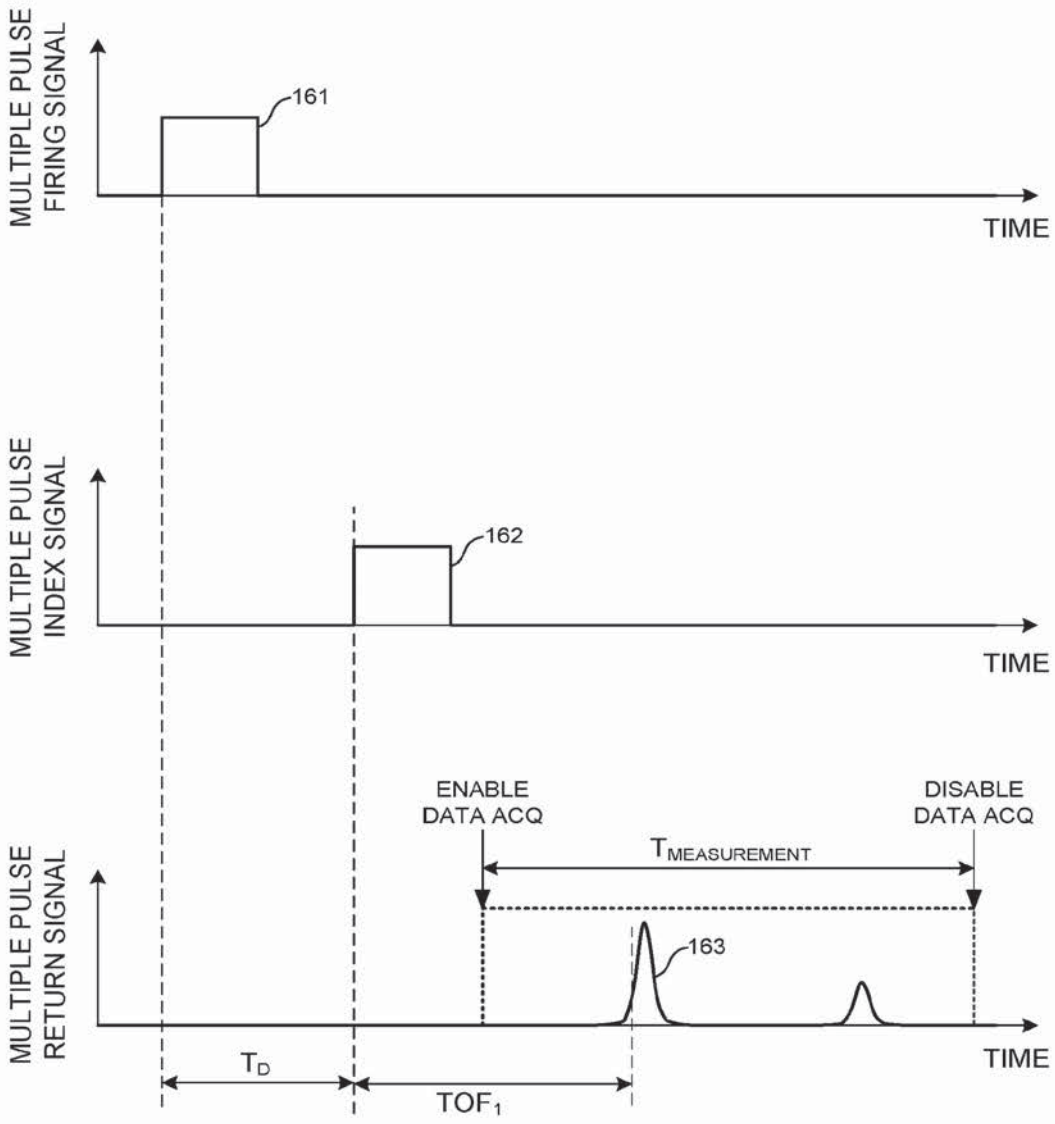

MULTIPLE PULSE FIRING SIGNAL
161
TIME
MULTIPLE PULSE INDEX SIGNAL
162
TIME
ENABLE DATA ACQ
DISABLE DATA ACQ
$T_{MEASUREMENT}$
MULTIPLE PULSE RETURN SIGNAL
163
TIME
T_D
TOF_1

FIG. 9

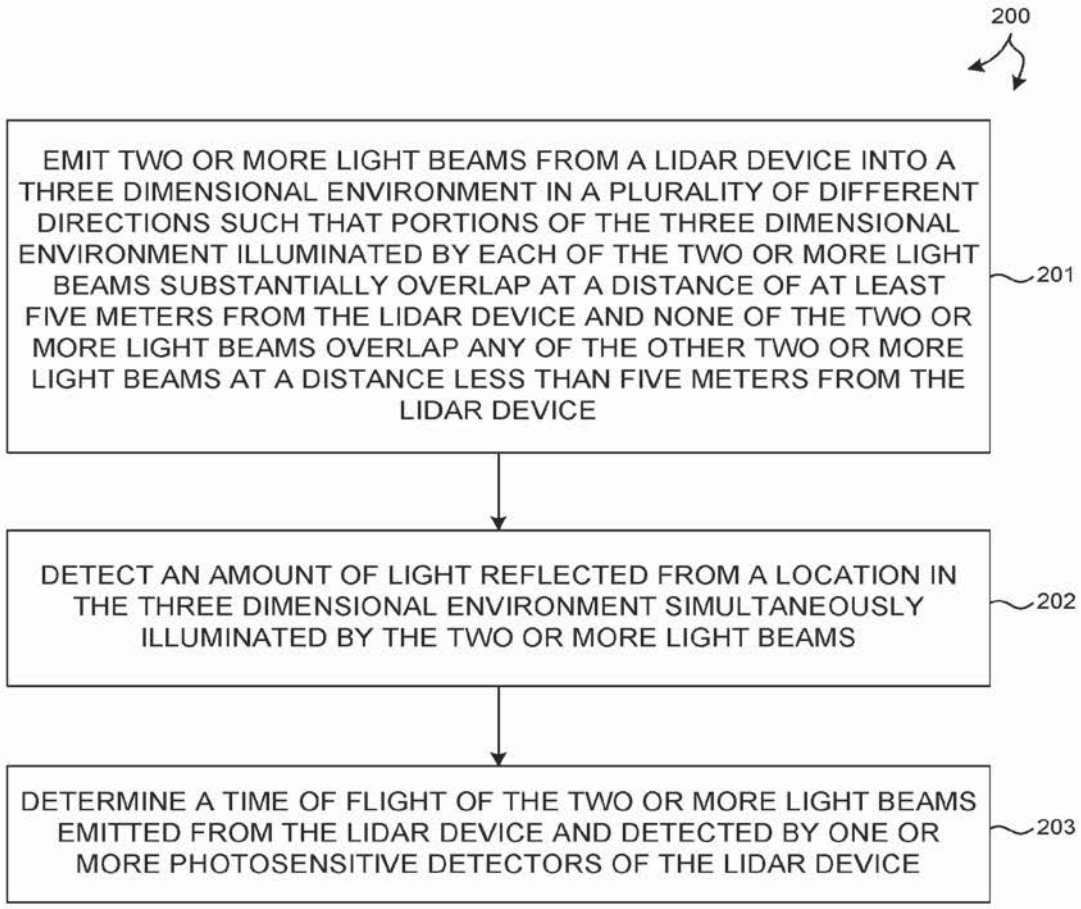

200
EMIT TWO OR MORE LIGHT BEAMS FROM A LIDAR DEVICE INTO A THREE DIMENSIONAL ENVIRONMENT IN A PLURALITY OF DIFFERENT DIRECTIONS SUCH THAT PORTIONS OF THE THREE DIMENSIONAL ENVIRONMENT ILLUMINATED BY EACH OF THE TWO OR MORE LIGHT BEAMS SUBSTANTIALLY OVERLAP AT A DISTANCE OF AT LEAST FIVE METERS FROM THE LIDAR DEVICE AND NONE OF THE TWO OR MORE LIGHT BEAMS OVERLAP ANY OF THE OTHER TWO OR MORE LIGHT BEAMS AT A DISTANCE LESS THAN FIVE METERS FROM THE LIDAR DEVICE
201
DETECT AN AMOUNT OF LIGHT REFLECTED FROM A LOCATION IN THE THREE DIMENSIONAL ENVIRONMENT SIMULTANEOUSLY ILLUMINATED BY THE TWO OR MORE LIGHT BEAMS
202
DETERMINE A TIME OF FLIGHT OF THE TWO OR MORE LIGHT BEAMS EMITTED FROM THE LIDAR DEVICE AND DETECTED BY ONE OR MORE PHOTOSENSITIVE DETECTORS OF THE LIDAR DEVICE
203

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/015874

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01S 17/89; G01C 3/08; G01J 3/02; G01J 3/28; G01J 3/44; G01S 7/497; G01S 17/06 (2017.01)

CPC - G01S 17/89; G01C 21/30; G01J 3/0278; G01J 3/2803; G01J 3/4406; G01S 7/4814; G01S 7/4815; G01S 7/4863; G01S 7/4865; G01S 7/497; G01S 17/06; G01S 17/10; G01S 17/93; G06Q 10/047; G06Q 30/02; H04N 13/025; H04N 13/0271 (2017.02)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015/0131080 A1 (FACET TECHNOLOGY CORP.) 14 May 2015 (14.05.2015) entire document	1-9, 16-20
Y	US 2014/0071234 A1 (MILLETT) 13 March 2014 (13.03.2014) entire document	1-9, 16-20
Y	US 2010/0020306 A1 (HALL) 28 January 2010 (28.01.2010) entire document	6, 17-20
Y	US 2015/0015895 A1 (FARO TECHNOLOGIES, INC.) 15 January 2015 (15.01.2015) entire document	8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 April 2017	23 MAY 2017
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/015874

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See Extra Sheet(s)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-9, 16-20

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/015874

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-9,16-20, drawn to a light detection and ranging (LIDAR) device.
Group II, claims 10-20, drawn to a light detection and ranging (LIDAR) device wherein portions of the three dimensional environment illuminated by the second beam of light and the third beam of light substantially overlap at a distance of at least five meters.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: one or more photosensitive detectors configured to detect an amount of light reflected from a location in the three dimensional environment simultaneously illuminated by the two or more light beams; and a computing system configured to determine a time of flight of the two or more light beams emitted from the one or more illumination sources and detected by the one or more photosensitive detectors as claimed therein is not present in the invention of Group II. The special technical feature of the Group II invention: wherein portions of the three dimensional environment illuminated by the second beam of light and the third beam of light substantially overlap at a distance of at least five meters from the LIDAR device and no portions of the second beam of light and the third beam of light overlap at any distance less than five meters from the LIDAR device as claimed therein is not present in the invention of Group I.

Groups I and II lack unity of invention because even though the inventions of these groups require the technical feature of one or more illumination sources configured to emit two or more light beams from the LIDAR device into a three dimensional environment in a plurality of different directions such that a portion of the three dimensional environment is illuminated by each of the two or more light beams, wherein a first of the two or more light beams is emitted from the LIDAR device at a first location, and a second of the two or more light beams is emitted from the LIDAR device at a second location that is spatially distinct from the first location, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2010/0020306 A1 (HALL) 28 January 2010 (28.01.2010) teaches one or more illumination sources configured to emit two or more light beams from the LIDAR device into a three dimensional environment in a plurality of different directions such that a portion of the three dimensional environment is illuminated by each of the two or more light beams (Paras. 36-38 and Figs. 5-8), wherein a first of the two or more light beams is emitted from the LIDAR device at a first location, and a second of the two or more light beams is emitted from the LIDAR device at a second location that is spatially distinct from the first location (Paras. 45-46 and Figs. 9-10).

Since none of the special technical features of the Group I or II inventions are found in more than one of the inventions, unity of invention is lacking.

RECEIVED
NOV 06 2017
NIXON PEABODY LLP

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: JENNIFER HAYES
NIXON PEABODY LLP
300 SOUTH GRAND AVENUE
SUITE 4100
LOS ANGELES, CA 90071-3151

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference: 078715-000003WO00	Date of mailing (day/month/year): 02 NOV 2017
International application No.: PCT/US2017/048379	FOR FURTHER ACTION See paragraphs 1 and 4 below
Applicant: OUSTER, INC.	International filing date (day/month/year): 24 August 2017

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46).

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to: 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts **for entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.066-8.073.

Name and mailing address of the ISA/US: Mail Stop PCT, Attn: ISA/US, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450	Authorized officer: Blaine R. Copenheaver
Facsimile No. 571-273-8300	Telephone No. PCT Helpdesk: 571-272-4300, PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2017)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 078715-000003WO00	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2017/048379	International filing date *(day/month/year)* 24 August 2017	(Earliest) Priority Date *(day/month/year)* 24 August 2016
Applicant OUSTER, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. 1

   ☒ as suggested by the applicant.

   ☐ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/048379

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302 (2017.01)

CPC - B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302; H01L 27/146 (2017.08)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 250/208.1; 358/482; 359/622; 438/57; 438/69 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,374,024 B1 (IIJIMA) 16 April 2002 (16.04.2002) entire document	1, 5, 6, 10, 14, 21, 24, 26, 27, 37, 41, 42, 46
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Y		2-4, 7-9, 11-13, 15-20, 22, 23, 25, 28-36, 38-40, 43-45, 47-49
Y	US 2009/0179142 A1 (DUPARRE et al) 16 July 2009 (16.07.2009) entire document	2-4, 7, 15, 20, 22, 23, 28, 38-40, 43
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A		10, 26, 46
Y	US 6,014,232 A (CLARKE) 11 January 2000 (11.01.2000) entire document	2-4, 20, 23, 38-40
Y	US 6,255,133 B1 (ORMOND et al) 03 July 2001 (03.07.2001) entire document	8, 9, 16, 17, 25, 29, 30, 44, 45
Y	US 2014/0158900 A1 (SAMSUNG ELECTRONICS CO., LTD.) 12 June 2014 (12.06.2014) entire document	11-13, 31, 32, 47-49
Y	US 2003/0006676 A1 (SMITH et al) 09 January 2003 (09.01.2003) entire document	12, 13, 18, 19, 34-36, 48, 49
Y	US 5,267,016 A (MEINZER et al) 30 November 1993 (30.11.1993) entire document	33

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 October 2017	02 NOV 2017
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/048379

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/0061502 A1 (HASSER) 01 April 2004 (01.04.2004) entire document	12, 13, 18, 19, 34-36, 48, 49
A	US 5,982,552 A (NAKAMA et al) 09 November 1999 (09.11.1999) entire document	1-49

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: JENNIFER HAYES
NIXON PEABODY LLP
300 SOUTH GRAND AVENUE
SUITE 4100
LOS ANGELES, CA 90071-3151

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 02 NOV 2017

Applicant's or agent's file reference
078715-000003WO00

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2017/048379	24 August 2017	24 August 2016

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302 (2017.01)
CPC - B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302; H01L 27/146 (2017.08)

Applicant OUSTER, INC.

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	12 October 2017	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	2-4, 7-13, 15-20, 22, 23, 25, 26, 28-36, 38-40, 43-49	YES
	Claims	1, 5, 6, 14, 21, 24, 27, 37, 41, 42	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-49	NO
Industrial applicability (IA)	Claims	1-49	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1, 5, 6, 14, 21, 24, 27, 37, 41, and 42 lack novelty under PCT Article 33(2) as being anticipated by Iijima.

Regarding Claims 1, 14, 27, 37, Iijima discloses an optical system ([and method]) for collecting distance information (an image sensor including an array of micro-lenses, abstract) comprising: a first transmitting optic (micro-lens array 3, col. 5, lines 35-43) configured to collect illumination beams of a plurality of illumination sources (LED array 1, col. 5, lines 35-43; [array contains a plurality]) reflected from a field outside the optical system (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5); a pixel array (light-receiving element array 5, col. 5, lines 35-43; a CCD type linear sensor is used as the light-receiving element array 5, col. 7, lines 4-10) comprising at least a first column of pixels and a second column of pixels (light-receiving windows each having a size of 110x110 microns in the main and sub scanning directions, respectively, are arranged at intervals of 125 microns in an array, col. 7, lines 4-10), each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch (light-receiving windows each having a size of 110x110 microns in the main and sub scanning directions, respectively, are arranged at intervals of 125 microns in an array, col. 7, lines 4-10; [matrix of detector pixels include first, second columns separated by pitch]); and a set of input channels (optical fiber array 4, col. 5, lines 35-43) interposed between the first transmitting optic and the pixel array (a micro-lens array 3 transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43), the set of input channels comprising at least a first plurality of input channels (optical fiber array 4, col. 5, lines 35-43; fig. 4, 5; see also claims 1 and 2; [fig. 5 shows a first plurality of input channels roughly on the left side, and a second plurality of input channels roughly on the right side]) and a second plurality of input channels (optical fiber array 4, col. 5, lines 35-43; fig. 4, 5; see also claims 1 and 2; [fig. 5 shows a first plurality of input channels roughly on the left side, and a second plurality of input channels roughly on the right side]), each of the first plurality of input channels configured to communicate one of the collected illumination beams from the first transmitting optic to a corresponding pixel in the first column of pixels (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5), each of the second plurality of input channels configured to communicate one of the collected illumination beams from the first transmitting optic to a corresponding pixel in the second column of pixels (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5).

Regarding Claims 5, 21, 41, modified Iijima discloses wherein each input channel in the set of input channels is coaxial with a corresponding pixel in the pixel array such that the set of input channels is positioned in a skewed grid array substantially similar to the pixel array (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5).

Regarding Claims 6, 24, 42, Iijima discloses further comprising a second transmitting optic (micro-lens array 3, col. 5, lines 35-43; [array includes multiple lenses]), wherein the plurality of illumination sources is positioned along a focal plane of the second transmitting optic (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5), each illumination beam projected by the second transmitting optic having substantially the same size and geometry as a field of view of a corresponding input channel in the set of input channels (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5).

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Claims 10, 26, and 46 lack an inventive step under PCT Article 33(3) as being obvious over Iijima.

Regarding Claims 10, 26, 46, modified Iijima, but lacks the teaching wherein the fix pixel pitch is n times of the first vertical pitch, and wherein n is a positive integer. However, it would have been obvious to one of ordinary skill in the art at the time of the invention to have the fix pixel pitch be n times of the first vertical pitch, wherein n is a positive integer, since discovering the optimum value of a result effective variable involves only routine skill in the art; or since such a modification would involve a mere change in size of a component. The motivation would have been to allow control of the optical path or the arising image by allowing a desired pitch grading between different elements (Duparre, para. 12).

Claims 2-4, 20, 23, and 38-40 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Duparre et al. (hereinafter Duparre) and Clarke.

Regarding Claims 2, 20, 38, Iijima discloses wherein the first transmitting optic has a first focal length (micro-lens array 3, col. 5, lines 35-43; [lenses have focal length]) and defines a focal plane opposite the field (fig. 4, 5), and wherein the set of input channels (optical fiber array 4, col. 5, lines 35-43) comprise: a layer disposed substantially coincident the focal plane (fig. 4, 5); a substrate (transparent substrate 8, col. 6, lines 39-49), the substrate corresponding to one of the first plurality of input channels (transparent substrate 8 is bonded to the end-face of the optical fiber array 4, col. 6, lines 39-49; fig. 4, 5); but lacks the teaching of an aperture layer; the aperture layer comprising a set of apertures that comprises at least a first plurality of apertures and a second plurality of apertures; a set of lens, the set of lens comprising at least a first plurality of lens and a second plurality of lens, each of the first plurality of lens corresponding to one of the first plurality of apertures, each of the second plurality of lens corresponding to one of the second plurality of apertures; and an optical filter disposed adjacent to the set of lens and opposite the set of apertures. Duparre is in the field of image detection systems (abstract) and teaches an aperture layer (aperture diaphragm array 2, para. 31); the aperture layer comprising a set of apertures that comprises at least a first plurality of apertures and a second plurality of apertures (an aperture diaphragm array 2, para. 31; fig. 1, 2); a set of lens, the set of lens comprising at least a first plurality of lens and a second plurality of lens (microlens array 1 with a multitude of individual lenses 1', para. 31), each of the first plurality of lens corresponding to one of the first plurality of apertures, each of the second plurality of lens corresponding to one of the second plurality of apertures (an aperture diaphragm array 2 is arranged between the microlenses 1' and the objective body 3, directly below the microlens array 1, para. 31; fig. 1); and an optical filter (aperture diaphragms 4', likewise in the form of an array 4, are provided below the objective body 3 for the suppression of ghost images [filtering] axially close to the image plane of the microlenses 1', para. 31) disposed near to the set of lens and opposite the set of apertures (fig. 1). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the aperture layer and set of lens of Duparre in the optical system with the transmitting optic of Iijima. The motivation would have been to allow the path of light to follow a specified channel to the detector (Duparre, para. 10, 19); or, further, to allow an arrangement of an optical system that provides a higher accuracy (Duparre, para. 22). Modified Iijima lacks the explicit teaching that the filter is disposed adjacent the set of lens. Clarke is in the field of a plurality of panels, each having a respective sub-array of pixels, associated with lens elements (abstract) and teaches an optical device (fig. 10 shows an optical arrangement corresponding to that shown in fig. 2, but with the microlens array 40 replaced by a microlens array 60 with spaced apart microlenses 62, the spacing being filled by an opaque material [filtering]; this reduces the open area of each microlens 62 and has the effect of increasing the depth of focus, which is desirable for image sensor applications; for an image sensor, an image will be focused if light received by a pixel is received uniquely from the desired portion of the image to be sensed, col. 7, lines 7-21) is disposed adjacent (fig. 10) the set of lens (the invention provides a lens array 40 associated with a sub-array of pixels of each panel 10 and which comprises an array of individual lens elements 42, col. 4, lines 4-15; each microlens 42 can be considered to be associated with an individual pixel 11 of the sub-array, col. 4, lines 16-33; microlens array 60 with spaced apart microlenses 62, col. 7, lines 7-21). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the optical arrangement of Clarke in the optical system of Iijima. The motivation would have been to allow the optical system to be better suited to use with image sensor applications (Clarke, col. 7, lines 7-21); or, further, to have a desired optical effect or to control an optical signal, as desired, and as was known in the art; or, further, to allow a more compact or simplified arrangement.

Regarding Claims 3, 23, 39, Iijima discloses the first transmitting optic, as disclosed above, wherein each of the set of lens has a second focal length, and is configured to offset the focal plane opposite the optic by the second focal length and collimate light rays having wavelengths substantially equivalent to an operating wavelength of the optical system. Duparre is in the field of image detection systems (abstract) and teaches each of the set of lens has a second focal length (microlens array 1 with a multitude of individual lenses 1', para. 31; [lenses have focal length]), and is configured to offset the focal plane opposite the optic by the second focal length (para. 31; fig. 1, 2) and pass light rays having wavelengths substantially equivalent to an operating wavelength of the optical system (the centre distance of the holes or openings of an array 4 is selected such that just only a bundle from the lens onto the associated detector is focussed at the angle of incidence envisaged for this, but other angles of incidence are blocked, para. 34; [lenses pass light to detector]). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the set of lens of Duparre in the optical system with the transmitting optic of Iijima. The motivation would have been to allow the path of light to follow a specified channel to the detector (Duparre, para. 10, 19); or, further, to allow an arrangement of an optical system that provides a higher accuracy (Duparre, para. 22). Modified Iijima lacks the explicit teaching of collimating light rays. Clarke is in the field of a plurality of panels, each having a respective sub-array of pixels, associated with lens elements (abstract) and teaches collimating light rays (the field lens 44 serves to deflect light to form substantially parallel beams within the depth of focus 64, col. 7, lines 22-30; the field lens 44 and microlens array 40 may be combined as a single unit as shown in fig. 7, 8, with the flat surface of the field lens 44 acting as the substrate for the microlens array 40 or as a surface to which the microlens array module may be bonded, col. 6, lines 54-58). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the optical arrangement of Clarke in the optical system of Iijima. The motivation would have been to allow the optical system to be better suited to use with image sensor applications (Clarke, col. 7, lines 7-21); or, further, to have a desired optical effect or to control an optical signal, as desired, and as was known in the art; or, further, to allow a more compact or simplified arrangement.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Regarding Claims 4, 22, modified Iijima discloses wherein each input channel in the set of input channels (optical fiber array 4, col. 5, lines 35-43) comprises a lens (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5); but lacks the teaching that each input channel in the set of input channels comprises a lens in the set of lens and a corresponding aperture in the set of apertures, the lens being substantially aligned with the corresponding aperture. Duparre is in the field of image detection systems (abstract) and teaches each input channel in the set of input channels comprises a lens in the set of lens and a corresponding aperture in the set of apertures, the lens being substantially aligned with the corresponding aperture (an aperture diaphragm array 2 is arranged between the microlenses 1' and the objective body 3, directly below the microlens array 1, para. 31; fig. 1).. It would have been obvious to one of ordinary skill in the art at the time of the invention to use the aperture layer and set of lens of Duparre in the optical system of Iijima. The motivation would have been to allow the path of light to follow a specified channel to the detector (Duparre, para. 10, 19); or, further, to allow an arrangement of an optical system that provides a higher accuracy (Duparre, para. 22).

Regarding Claim 40, modified Iijima discloses the method of claim 38, wherein each input channel in the set of input channels (optical fiber array 4, col. 5, lines 35-43) comprises a lens (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5); but lacks the teaching that each input channel in the set of input channels comprises a lens in the set of lens and a corresponding aperture in the set of apertures, the lens being substantially aligned with the corresponding aperture. Duparre is in the field of image detection systems (abstract) and teaches each input channel in the set of input channels comprises a lens in the set of lens and a corresponding aperture in the set of apertures, the lens being substantially aligned with the corresponding aperture (an aperture diaphragm array 2 is arranged between the microlenses 1' and the objective body 3, directly below the microlens array 1, para. 31; fig. 1).. It would have been obvious to one of ordinary skill in the art at the time of the invention to use the aperture layer and set of lens of Duparre in the optical system of Iijima. The motivation would have been to allow the path of light to follow a specified channel to the detector (Duparre, para. 10, 19); or, further, to allow an arrangement of an optical system that provides a higher accuracy (Duparre, para. 22).

Claims 7, 15, 22, 28, and 43 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Duparre et al. (hereinafter Duparre).

Regarding Claims 7, 15, 28, 43, modified Iijima lacks the teaching wherein the aperture layer is fabricated by selectively metallizing a glass wafer and etching the set of apertures into metallized glass wafer. Duparre teaches wherein the aperture layer is fabricated by selectively metallizing a glass wafer and etching the set of apertures into metallized glass wafer (the manufacture is described by way of fig. 4; the imaging system is produced by the front side and rear side structuring on a thin objective body 3, preferably of glass; firstly the aperture diaphragm array 2 assigned to the microlens array is deposited onto the objective body 3 on the front side, e.g. in a metal, by way of coating and lithography, para. 38). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the metallization, etching of Duparre in the optical system of Iijima. The motivation would have been to allow a means of manufacturing that uses known or established techniques, such as coating and lithography (Duparre, para. 38), that are known to be controllable, predictable, or cost-effective.

Claims 8, 9, 16, 17, 25, 29, 30, 44, and 45 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Ormond et al. (hereinafter Ormond).

Regarding Claims 8, 16, 29, 44, modified Iijima discloses wherein the pixel array is integrated on a substrate (a substrate holding thereon the light-receiving elements, such as CCD type linear sensor, col. 7, lines 4-23); but lacks the explicit teaching of a semiconductor wafer. Ormond is in the field of electro optical devices including a semiconductor wafer with pixels (abstract) and teaches a semiconductor wafer (chips 10 are generally made of a semiconductor substrate in which circuitry and other elements are formed, such as by photolithographic etching; a few of the most relevant structures are a linear array of pixel photosites 12, each of which forms the photosensitive surface of photosensor circuitry within each chip 10, col. 4, lines 17-31). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the semiconductor wafer of Ormond in the optical system of Iijima. The motivation would have been to allow the use of known manufacturing techniques, such as photolithographic etching (Ormond, col. 4, lines 17-31), and thereby reduce production costs or allow the use of known infrastructure or manufacturing devices.

Regarding Claims 9, 17, 25, 30, 45, Iijima discloses wherein the first transmitting optic and the set of input channels are fabricated on the substrate using at least one of photolithography technique or wafer-level bond technique (a transparent substrate 8 is bonded to the end-face of the optical fiber array 4; a uniform coat of photoresist is then applied on a whole surface of the substrate 8; UV radiation is applied to the substrate and hit only the resist portion 14; cylindrical islands 15 are formed by developing, col. 6, lines 39-57); ; but lacks the explicit teaching of a semiconductor wafer. Ormond is in the field of electro optical devices including a semiconductor wafer with pixels (abstract) and teaches a semiconductor wafer (chips 10 are generally made of a semiconductor substrate in which circuitry and other elements are formed, such as by photolithographic etching; a few of the most relevant structures are a linear array of pixel photosites 12, each of which forms the photosensitive surface of photosensor circuitry within each chip 10, col. 4, lines 17-31). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the semiconductor wafer of Ormond in the optical system of Iijima. The motivation would have been to allow the use of known manufacturing techniques, such as photolithographic etching (Ormond, col. 4, lines 17-31), and thereby reduce production costs or allow the use of known infrastructure or manufacturing devices.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Claims 11, 31, 32, and 47 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Samsung Electronics Co., Ltd. (hereinafter Samsung).

Regarding Claims 11, 31, 47, modified Iijima lacks the teaching wherein each pixel in the pixel array is configured to output a count of incident photons, a time of an incident photon, and/or a time between two incident photons. Samsung is in the field of photon-counting detectors configured to detect photons (abstract) and teaches each pixel in the pixel array is configured to output a count of incident photons, a time of an incident photon, and/or a time between two incident photons (the photon-counting detector 11 may include a sensor 21 and a readout chip 22; the sensor 21 may detect photons, convert the detected photons to electrical signals, and output the electrical signals through the output terminals of the sensor 21 to readout circuits 23 of the redout chip 22; the sensor 21 includes a plurality of unit sensors that each correspond to a portion of the sensor 21 to which each pixel of the pixel area corresponds, para. 42; fig. 2). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the photon-counting detector of Samsung in the optical system of modified Iijima. The motivation would have been to allow a means of generating an image based on photon data (Samsung, para. 33); or, further, allow a means of imaging that incorporates pixel arrays to produce a high-resolution image (Samsung, para. 36).

Regarding Claim 32, Iijima discloses the method of claim 31, wherein the distance information is determined based at least upon the photons from each pixel in the first column of pixels and the second column of pixels (the image sensor has an optical system in which light from an LED array 1 is reflected from an original document surface 2 and then forms an image of light by a micro-lens array 3 that then transmits the image as a light signal to an optical fiber array 4 that in turn transmits the light signal to a light-receiving element array 5, col. 5, lines 35-43; fig. 4, 5); but lacks the explicit teaching of the count of incident photons, the time of an incident photon, or the time between two incident photons. Samsung is in the field of photon-counting detectors configured to detect photons (abstract) and teaches the count of incident photons, the time of an incident photon, or the time between two incident photons (the photon-counting detector 11 may include a sensor 21 and a readout chip 22; the sensor 21 may detect photons, convert the detected photons to electrical signals, and output the electrical signals through the output terminals of the sensor 21 to readout circuits 23 of the redout chip 22; the sensor 21 includes a plurality of unit sensors that each correspond to a portion of the sensor 21 to which each pixel of the pixel area corresponds, para. 42; fig. 2). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the photon-counting detector of Samsung in the optical system of modified Iijima. The motivation would have been to allow a means of generating an image based on photon data (Samsung, para. 33); or, further, allow a means of imaging that incorporates pixel arrays to produce a high-resolution image (Samsung, para. 36).

Claims 12, 13, 48, and 49 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Samsung Electronics Co., Ltd. (hereinafter Samsung) and Smith et al. (hereinafter Smith).

Regarding Claims 12, 48, Iijima discloses further comprising the pixel array, the set of input channels and the first transmitting optic around a vertical axis (fig. 4, 5); but lacks the explicit teaching of an actuator configured to rotate the array. Smith is in the field of closed loop motion control systems employing at least one actuator (abstract) and teaches an actuator (the system 5 comprises one or more relaxor actuator devices 10 and one or more corresponding closed loop controllers 20 for controlling each actuator device 10, para. 37) configured to rotate (the actuator device 10 provides rotational displacement; the mechanical system 25 includes a base 14 which is fixed in place, and a rotating arm 18 which is attached to the base 14 via a hinge 18; one end of the actuator body 11 is attached to the base 14 and the rotating arm 19 is disposed at the other end of the actuator body 11; when an electric field is applied to the actuator device 10, the actuator body 11 expands or contracts and the rotating arm 19 is correspondingly caused to rotate accordingly about the hing 18, para. 42) the array about a vertical axis (the sensor 31 may be considered to act as a probe that measures the displacement between the free end sensor surface 16 and a proximate surface 17 on the end cap 15, para. 47; fig. 6 shows rotational displacement of arm 19, cap 15; [orientation of apparatus with respect to axis not shown, so axis of hinge can be the vertical axis]). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the actuator of Smith in the optical system of Iijima. The motivation would have been to an apparatus for controlling precision motion with actuators using dynamic control (Smith, para. 13).

Regarding Claims 13, 49, modified Iijima discloses the pixel array, the set of input channels, and the first transmitting optic, as disclosed above, but lacks the teaching wherein the actuator comprises a rotary electric motor and an optical encoder, the rotary electric motor configured to control a rotational speed of the array based upon outputs of the optical encoder, the optical encoder coupled to the array via a closed-loop feedback circuit. Smith is in the field of closed loop motion control systems employing at least one actuator (abstract) and teaches the actuator (the system 5 comprises one or more relaxor actuator devices 10 and one or more corresponding closed loop controllers 20 for controlling each actuator device 10, para. 37) comprises a rotary electric motor (the actuator device 10 provides rotational displacement; the mechanical system 25 includes a base 14 which is fixed in place, and a rotating arm 18 which is attached to the base 14 via a hinge 18; one end of the actuator body 11 is attached to the base 14 and the rotating arm 19 is disposed at the other end of the actuator body 11; when an electric field is applied to the actuator device 10, the actuator body 11 expands or contracts and the rotating arm 19 is correspondingly caused to rotate accordingly about the hing 18, para. 42; [form of rotary electric motor]) and an optical encoder (a wide variety of sensor types may be used as displacement sensors 31; suitable sensor types include encoders, para. 48), the rotary electric motor configured to control a rotational speed of the array based upon outputs of the optical encoder, the optical encoder coupled to the array via a closed-loop feedback circuit (each closed loop controller 20 includes a feedback loop 30 for feeding back information about the current state of the actuator 10 in the mechanical system 25, a comparator 35 for comparing current actuator state information with input information representing the desired state of the actuator 10, a motion controller 40 and one or more drivers 45; the feedback sensor transmits a feedback signal based on some physical phenomenon of the mechanical system 25 to the comparator 35; any physical phenomenon from which a measurable signal may be produced by the sensor may be used for feedback, para. 44). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the actuator and feedback loop of Smith in the optical system of Iijima. The motivation would have been to an apparatus for controlling precision motion with actuators using dynamic control (Smith, para. 13).

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Claims 18, 19, and 34-36 lack an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Smith et al. (hereinafter Smith).

Regarding Claims 18, 34, Iijima discloses further comprising the pixel array, the set of input channels and the first transmitting optic around a vertical axis (fig. 4, 5); but lacks the explicit teaching of an actuator configured to rotate the array. Smith is in the field of closed loop motion control systems employing at least one actuator (abstract) and teaches an actuator (the system 5 comprises one or more relaxor actuator devices 10 and one or more corresponding closed loop controllers 20 for controlling each actuator device 10, para. 37) configured to rotate (the actuator device 10 provides rotational displacement; the mechanical system 25 includes a base 14 which is fixed in place, and a rotating arm 18 which is attached to the base 14 via a hinge 18; one end of the actuator body 11 is attached to the base 14 and the rotating arm 19 is disposed at the other end of the actuator body 11; when an electric field is applied to the actuator device 10, the actuator body 11 expands or contracts and the rotating arm 19 is correspondingly caused to rotate accordingly about the hing 18, para. 42) the array about a vertical axis (the sensor 31 may be considered to act as a probe that measures the displacement between the free end sensor surface 16 and a proximate surface 17 on the end cap 15, para. 47; fig. 6 shows rotational displacement of arm 19, cap 15; [orientation of apparatus with respect to axis not shown, so axis of hinge can be the vertical axis]). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the actuator of Smith in the optical system of Iijima. The motivation would have been to an apparatus for controlling precision motion with actuators using dynamic control (Smith, para. 13).

Regarding Claim 19, 35, Iijima discloses the pixel array, the set of input channels, and the first transmitting optic, as disclosed above, but lacks the teaching wherein the actuator comprises a rotary electric motor and an optical encoder, the rotary electric motor configured to control a rotational speed of the pixel array, the set of input channels and the first transmitting optic based upon outputs of the optical encoder, the optical encoder coupled to the pixel array via a closed-loop feedback circuit. Smith is in the field of closed loop motion control systems employing at least one actuator (abstract) and teaches the actuator (the system 5 comprises one or more relaxor actuator devices 10 and one or more corresponding closed loop controllers 20 for controlling each actuator device 10, para. 37) comprises a rotary electric motor (the actuator device 10 provides rotational displacement; the mechanical system 25 includes a base 14 which is fixed in place, and a rotating arm 18 which is attached to the base 14 via a hinge 18; one end of the actuator body 11 is attached to the base 14 and the rotating arm 19 is disposed at the other end of the actuator body 11; when an electric field is applied to the actuator device 10, the actuator body 11 expands or contracts and the rotating arm 19 is correspondingly caused to rotate accordingly about the hing 18, para. 42; [form of rotary electric motor]) and an optical encoder (a wide variety of sensor types may be used as displacement sensors 31; suitable sensor types include encoders, para. 48), the rotary electric motor configured to control a rotational speed of the array based upon outputs of the optical encoder, the optical encoder coupled to the array via a closed-loop feedback circuit (each closed loop controller 20 includes a feedback loop 30 for feeding back information about the current state of the actuator 10 in the mechanical system 25, a comparator 35 for comparing current actuator state information with input information representing the desired state of the actuator 10, a motion controller 40 and one or more drivers 45; the feedback sensor transmits a feedback signal based on some physical phenomenon of the mechanical system 25 to the comparator 35; any physical phenomenon from which a measurable signal may be produced by the sensor may be used for feedback, para. 44). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the actuator and feedback loop of Smith in the optical system of Iijima. The motivation would have been to an apparatus for controlling precision motion with actuators using dynamic control (Smith, para. 13).

Regarding Claim 36, Iijima discloses the method of claim 35, but lacks the teaching of further comprising: causing the optical system to rotate at a rate of 360 rpm. Smith is in the field of closed loop motion control systems employing at least one actuator (abstract) and teaches causing the system to rotate (the actuator device 10 provides rotational displacement; the mechanical system 25 includes a base 14 which is fixed in place, and a rotating arm 18 which is attached to the base 14 via a hinge 18; one end of the actuator body 11 is attached to the base 14 and the rotating arm 19 is disposed at the other end of the actuator body 11; when an electric field is applied to the actuator device 10, the actuator body 11 expands or contracts and the rotating arm 19 is correspondingly caused to rotate accordingly about the hing 18, para. 42) at a rate (each closed loop controller 20 includes a feedback loop 30 for feeding back information about the current state of the actuator 10 in the mechanical system 25, a comparator 35 for comparing current actuator state information with input information representing the desired state of the actuator 10, a motion controller 40 and one or more drivers 45; the feedback sensor transmits a feedback signal based on some physical phenomenon of the mechanical system 25 to the comparator 35; any physical phenomenon from which a measurable signal may be produced by the sensor may be used for feedback, para. 44). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the rotation of Smith in the optical system of Iijima. The motivation would have been to an apparatus for controlling precision motion with actuators using dynamic control (Smith, para. 13). Modified Iijima lacks the teaching of rotating the optical system at a rate of 360 rpm. However, it would have been obvious to one of ordinary skill in the art at the time of the invention to rotate the optical system at a rate of 360 rpm, since discovering the optimum value of a result effective variable involves only routine skill in the art. The motivation would have been to allow a desired rotational speed for specific or desired uses, such as systems that require fast responses or output that more approximates real-time output.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2017/048379

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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Claim 33 lacks an inventive step under PCT Article 33(3) as being obvious over Iijima in view of Meinzer et al. (hereinafter Meinzer).

Regarding Claim 33, Iijima discloses the method of claim 27, but lacks the teaching of further comprising: transforming the time of the incident photon and a time of peak incident photon rate at each pixel between a current sampling period and a previous sampling period into a specific distance from the optical system to an external surface within a field view of a corresponding pixel. Meinzer is in the field of distance measurement devices (abstract) and teaches transforming photon data at each pixel between a current sampling period and a previous sampling period into a specific distance from the optical system to an external surface within a field of view of a corresponding pixel (the resultant number of counts in the counter after one sweep period of the up-ramp waveform is the difference between the number of pulses on the positive slope portion of the input signal on the line 112 and the number of pulses on the flat portion of the same signal; thus, the counter provides a digital binary signal N proportional to the distance L to the target 26, col. 10, lines 1-16). It would have been obvious to use the distance measuring using photon data of Meinzer in the method of Iijima. The motivation would have been to allow a means of distance measurement (Meinzer, col. 4, lines 67-68) using known, for instance, semiconductor devices (Meinzer, col. 11, lines 57-62); or, further, to allow an arrangement that improves accuracy and reliability (Meinzer, col. 4, lines 16-29). Modified Iijima lacks the explicit teaching of the time of the incident photon and a time of peak incident photon rate. However, it would have been obvious to one of ordinary skill in the art at the time of the invention to use the time of the incident photon and a time of peak incident photon rate, since where the prior art has shown a relationship between photon information or digital signal proportional to distance to a target, deriving the relationship between the time of the incident photon and a time of peak incident photon rate and distance to a target as recited in the claim is a matter of mere mathematical manipulation, a known practice in the art. It would have been obvious to derive a mathematical relationship between the time of the incident photon and a time of peak incident photon rate and the distance to the target, since where the general conditions of the claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art. The motivation would have been to allow the use of a desired electrical circuitry, or readout, such that a desired or specified reduction could be used; or, further, to allow a desired precision for specified applications, as was known in the art.

Claims 1-49 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

Search History:

Limited Classification Search

The Patent Analyst performed a limited classification search within the following US, IPC, CPC, ECLA, or F-Term classification areas:

CPC Class/Subclass(es): B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302; H01L 27/146 (2017.08)

IPC (8) Class/Subclass(es): B23P 17/00; G02B 6/04; G02B 6/06; G02B 27/10; H01L 21/00; H01L 21/302; H01L 27/146 (2017.01)

U.S. Class/Subclass(es): 250/208.1; 358/482; 359/622; 438/57; 438/69

See Global Search Results.

Global Patent Literature Text Search

The Patent Analyst performed the following global text search, which was not limited by classification but may or may not have been limited by other criteria:

Minesoft PatBase: https//www.patbase.com

#	Search query	Results
1	IC=H01L27/146	31739
2	CPC=H01L27/146	3449
3	IC=H01L21/00	72209
4	CPC=H01L21/00	8723
5	IC=B23P17/00	8328
6	CPC=B23P17/00	262
7	UC=250/208.1	6212
8	UC=438/69	1553
9	IC=G02B6/06	3217
10	CPC=G02B6/06	1270
11	IC=G02B6/04	6957
12	CPC=G02B6/04	839
13	IC=G02B27/10	10874
14	CPC=G02B27/10	332
15	UC=359/622	382
16	UC=358/482	801
17	IC=H01L21/302	50914

18	CPC=H01L21/302	3845
19	uc=438/57	2440
20	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR1 7 OR 18 OR 19	139291
21	20 AND FT=(optic*)	52981
22	21 AND FT=(pixel*)	17333
23	22 AND FT=(pitch*)	3457
24	23 AND FT=(actuat*)	542
25	24 AND FT=(encod*)	209
26	20 AND FT=(pitch* w8 pixel*)	2207
27	26 AND FT=(lens* w5 array*)	487
28	26 AND FT=(photon* w5 count*)	54
29	26 AND FT=(feedback* w5 loop*)	41

Google Patents: https://patents.google.com

#	Search query	Results
1	(actuator to rotate pixel array) (optical encoder) (feedback loop to control rotation speed)	3510
2	(actuator to rotate pixel array) (optical encoder) (feedback loop)	188
3	(pixel array) (semiconductor wafer) (transmitting optic)	35600
4	(pixel array) (pitch) (aperture layer) (lens array)	13900
5	(system for collecting distance information) (pixel array) (pitch) (input channels)	13900
6	(system for collecting distance information)	14500000
7	(pixel block) (channels)	1380000
8	(pixel to count incident photons)	12100

Computer Accessed Text Databases Searched

The Patent Analyst searched the following computer accessed text databases:

Google: https://www.google.com/

#	Search query	Results
1	(sensor for collecting distance information) (transmitting optic) (pixel array) ("pitch")	408000
2	(sensor for collecting distance information) (transmitting optic) (pixel array)	3190000
3	(sensor for collecting distance information) (transmitting optic)	42100000
4	(sensor for collecting distance information)	28400000

5	(sensor for collecting distance information) (pixel array with pitch) (feedback loop) (actuator)	307000

Date search was completed: 12 October 2017

SF/JG

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Jennifer Hayes
Nixon Peabody LLP
300 South Grand Avenue
Suite 4100
Los Angeles, California 90071-3151
United States of America

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 78715-001WO0	Date of mailing *(day/month/year)* 07 NOV 2017 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US17/39306	International filing date *(day/month/year)* 26 June 2017 (26.06.2017)
Applicant OUSTER, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300 PCT OSE: 571-272-7774

Form PCT/ISA/220 (July 2017)

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NOV 16 2017

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 78715-001WO0	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US17/39306	International filing date *(day/month/year)* 26 June 2017 (26.06.2017)	(Earliest) Priority Date *(day/month/year)* 26 September 2016 (26.09.2016)
Applicant OUSTER, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☒ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. 1

   ☒ as suggested by the applicant.

   ☐ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/39306

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
SEE EXTRA SHEET

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/39306

A. CLASSIFICATION OF SUBJECT MATTER
IPC - G01J1/02, G01J1/08, G02B6/00 (2017.01)
CPC - G01J1/026, G01J1/08, G02B6/002

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,433,042 B1 (CAVANAUGH, D. et al.) October 7, 2008; figures 1-3; column 2, lines 43-63; column 3, lines 1-5; column 4, lines 6- column 5, line 9; column 5, lines 22-33; column 7, lines 24-30	1-3, 6-9, 14, 17, 20-23, 28, 31, 34-37, 42, 45, 48-51, 56, 59, 62-65, 70, 73, 77, 78, and 80
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Y		4-5, 10-13, 15-16, 18-19, 24-27, 29-30, 32-33, 38-41, 43-44, 46-47, 52-55, 57-58, 60-61, 66-69, 71-72, 74-76, 79, and 81-86
Y	US 6,721,262 B1 (JORDACHE, N. et al.) April 13, 2004; figures 5-6(4); column 3, line 39-column 4, line 3	4, 5, 18, 19, 32, 33, 46-47, 60, 61
Y	US 2016/0150963 A1 (ROUKES, M. et al.) June 2, 2016; figure 13; paragraphs [0027, 0030, 0032, 0070].	10-13, 24-27, 38-41, 52-55, 66-69, 75, 76
Y	US 2015/0292948 A1 (VERIFOOD, LTD.) October 15, 2015; figure 5; paragraphs [0160, 0163].	15, 16, 29, 30, 43, 44, 57, 58, 71, 72, 74
Y	WO 2016/125165 A2 (VERIFOOD, LTD.) August 11, 2016; figures 11-13 and 20; paragraphs [0136, 0170, 0172, 0173, 0181, 0184-0186, 0218].	79, 81-84

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2017 (10.10.2017)	07 NOV 2017
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/39306

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0008588 A1 (FELDKHUN, D. et al.) Janaury 14, 2010; figures 1 and 12; paragraphs [0031, 0038-0040, 0120].	81-82, and 84-86

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/39306

-***-Continued from Box III -***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-72 are directed towards a micro-optical receiver channel, an image sensor, and a method.
Group II: Claims 1-16 and 73-86 are directed towards an optical channel for receiving photons and detecting the photons.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include at least wherein the aperture accepts an input cone of light containing a wide range of wavelengths, and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength, and wherein the pixel is configured to detect photons within the narrow band of wavelengths, which are not present in Group II.

The special technical features of Group II include at least a bulk imaging optic; an aperture layer located at an imaging plane of the bulk optic; a collimating lens layer behind the aperture layer and separated therefrom by a focal length of the collimating lens layer; an optical filter behind the collimating lens layer; and a pixel offset from the optical filter opposite the collimating lens layer, and responsive to photons incident on the pixel, which are not present in Group I.

The common technical features shared by Groups I-II are an optical channel comprising: an aperture; an optical lens adjacent the aperture; an optical filter adjacent the optical lens; and a pixel adjacent the optical filter.

However, these common features are previously disclosed by US 2012/0320164 A1 (LIPTON). Lipton discloses an optical channel comprising: an aperture (polarizing aperture 306; Fig. 3 and para [0046]); an optical lens adjacent the aperture (lens 302 adjacent to aperture 306; Fig. 3 and para [0046]); an optical filter adjacent the optical lens (a patterned polarizer (optical filter) adjacent lens 302; Fig. 3 and para [0046]); and a pixel adjacent the optical filter (a pixel image sensor 309 adjacent to the polarizer 308; Fig. 3, paras [0032], [0046]).

Since the common technical features are previously disclosed by the Lipton reference, these common features are not special and so Groups I-II lack unity.

Form PCT/ISA/210 (extra sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: Jennifer Hayes
Nixon Peabody LLP
300 South Grand Avenue
Suite 4100
Los Angeles, California 90071-3151
United States of America

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference 78715-001WO0	Date of mailing *(day/month/year)* 07 NOV 2017 **FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US17/39306	26 June 2017 (26.06.2017)	26 September 2016 (26.09.2016)

International Patent Classification (IPC) or both national classification and IPC
IPC - G01J1/02, G01J1/08, G02B6/00 (2017.01)
CPC - G01J1/026, G01J1/08, G02B6/002

Applicant OUSTER, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	10 October 2017 (10.10.2017)	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

Box No. IV Lack of unity of invention

1. ☒ In response to the invitation (Form PCT/ISA/206) to pay additional fees the applicant has, within the applicable time limit:

   ☒ paid additional fees.

   ☐ paid additional fees under protest and, where applicable, the protest fee.

   ☐ paid additional fees under protest but the applicable protest fee was not paid.

   ☐ not paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose not to invite the applicant to pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rule 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-72 are directed towards a micro-optical receiver channel, an image sensor, and a method.
Group II: Claims 1-16 and 73-86 are directed towards an optical channel for receiving photons and detecting the photons.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include at least wherein the aperture accepts an input cone of light containing a wide range of wavelengths, and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength, and wherein the pixel is configured to detect photons within the narrow band of wavelengths, which are not present in Group II.

The special technical features of Group II include at least a bulk imaging optic; an aperture layer located at an imaging plane of the bulk optic; a collimating lens layer behind the aperture layer and separated therefrom by a focal length of the collimating lens layer; an optical filter behind the collimating lens layer; and a pixel offset from the optical filter opposite the collimating lens layer, and responsive to photons incident on the pixel, which are not present in Group I.

The common technical features shared by Groups I-II are an optical channel comprising: an aperture; an optical lens adjacent the aperture; an optical filter adjacent the optical lens; and a pixel adjacent the optical filter.

However, these common features are previously disclosed by US 2012/0320164 A1 (LIPTON). Lipton discloses an optical channel comprising: an aperture (polarizing aperture 306; Fig. 3 and para [0046]); an optical lens adjacent the aperture (lens 302 adjacent to aperture 306; Fig. 3 and para [0046]); an optical filter adjacent the optical lens (a patterned polarizer (optical filter) adjacent lens 302; Fig. 3 and para [0046]); and a pixel adjacent the optical filter (a pixel image sensor 309 adjacent to the polarizer 308; Fig. 3, paras [0032], [0046]).

Since the common technical features are previously disclosed by the Lipton reference, these common features are not special and so Groups I-II lack unity.

4. Consequently, this opinion has been established in respect of the following parts of the international application:

   ☒ all parts.

   ☐ the parts relating to claims Nos. _____

Form PCT/ISA/237 (Box No. IV) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	SEE BELOW	YES
	Claims	SEE BELOW	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-86	NO
Industrial applicability (IA)	Claims	1-86	YES
	Claims	NONE	NO

2. Citations and explanations:

-***-Continued from Box No. V: 1. Statement-***-

NOVELTY

YES 4-5, 10-13, 15-16, 18-19, 24-27, 29-30, 32-33, 38-41, 43-44, 46-47, 52-55, 57-58, 60-61, 66-69, 71-72, 74-76, 79, and 81-86
NO 1-3, 6-9, 14, 17, 20-23, 28, 31, 34-37, 42, 45, 48-51, 56, 59, 62, 63-65, 70, 73, 77, 78, and 80

-***-Continued from Box No. V: 2. Citations and explanations:-***-

Claims 1-3, 6-9, 14, 17, 20-23, 28, 31, 34-37, 42, 45, 48-51, 56, 59, 62-65, 70, 73, 77, 78, and 80 lack novelty under PCT Article 33(2) as being anticipated by US 7,433,042 B1 to Cavanaugh, D. et al. (hereinafter 'Cavanaugh')

As for claim 1, Cavanaugh discloses a micro-optical receiver channel (a channel defined by the aperture masks 135 and 137 for the light to each superpixel of a detector 110; figure 2; column 4, lines 6-19, 52-58) comprising: an input aperture layer (aperture mask 135; figure 2; column 4, lines 52-58); an optical lens layer adjacent the input aperture layer (micro lens array 130 is between aperture mask 135 and aperture mask 137; figure 2; column 4, lines 6-19, 52-58); an optical filter layer adjacent the optical lens layer (color filter array 120 is adjacent the micro lens array 130; figure 2; column 4, lines 6-19); and a pixel layer adjacent the optical filter layer (color filter array 120 is as close as possible to detector array 110 (pixel array); figure 2; column 4, lines 6-19).

As for claim 2, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the input aperture layer comprises an aperture (aperture mask 135 has an array of openings restricting light to the shape of the super pixel (an aperture); figure 2; column 4, lines 52-58).

As for claim 3, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the input aperture layer comprises an aperture and a stop material surrounding the aperture (aperture mask 135 has an array of openings restricting light to the shape of the super pixel (an aperture) and may for a field stop, such as by being tubular baffles (stop material surrounding the aperture); figure 2; column 4, lines 52-58).

As for claim 6, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the optical lens layer comprises a collimating lens (micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation to help collimate the light; figure 2; column 4, lines 6-19; column 5, lines 22-33).

As for claim 7, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the input aperture layer comprises an aperture (aperture mask 135 has an array of openings restricting light to the shape of the super pixel (an aperture); figure 2; column 4, lines 52-58), and wherein the optical lens layer comprises a lens (micro lens array 130 is an array of lenses, one per super-pixel; figure 2; column 4, lines 6-19), the aperture aligned with the lens (micro lens array 130 is an array of lenses to fill each specific super-pixel with the apertures restricting light to the shape of the super pixel; figure 2; column 4, lines 6-19, 52-58).

As for claim 8, Cavanaugh discloses the micro-optical receiver channel of claim 1, further comprising a second aperture layer between the optical lens layer and the optical filter layer (micro lens array 130 is between aperture mask 135 and aperture mask 137 with optical filter 120 on the other side of aperture mask 137 from micro lens array 130; figure 2; column 4, lines 6-19, 52-58).

As for claim 9, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the optical filter layer comprises an optical bandpass filter (the color filter array is made of bandpass filters which may be narrow band; figures 2 and 3; column 3, lines 1-5; column 4, line 59- column 5, line 9).

As for claim 14, Cavanaugh discloses the micro-optical receiver channel of claim 1, wherein the pixel comprises a plurality of subpixels (each super pixel includes an array of subpixels such as a 4x4 array; figures 2 and 3; column 4, lines 6-19; 59-67).

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claims 23, 37, 51, and 65 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 23, 37, 51, and 65 lack antecedent basis for 'the optical filter layer'. For the purposes of this examination, claims 29, 43, 57, and 71 interpret 'the optical filter layer' as 'the optical filter'.

Claims 29, 43, 57 and 71 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 29, 43, 57 and 71 lack antecedent basis for 'the pixel layer'. For the purposes of this examination, claims 29, 43, 57, and 71 interpret 'the pixel layer' as 'the pixel'.

Claims 32 and 33 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 32 and 33 lack antecedent basis for 'the stop region'. For the purposes of this examination, claims 32 and 33 interpret 'the stop region' as 'a stop region for the aperture'.

Claims 77 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claim 77 lacks antecedent basis for 'the bulk imaging optic'. For the purposes of this examination, claim 77 is interpreted as depending on claim 73 rather than claim 63.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

-***-Continued from Box V: Citations and Explanations-***-

As for claim 17, Cavanaugh discloses a micro-optical receiver channel (a channel defined by the aperture masks 135 and 137 for the light to each superpixel of a detector 110; figure 2; column 4, lines 6-19, 52-58) comprising: an aperture surrounded by a stop region (aperture mask 135 is a tubular baffle; figure 2; column 4, lines 52-58); an optical lens adjacent the aperture (micro lens array 130 is between aperture mask 135 and aperture mask 137; figure 2; column 4, lines 6-19, 52-58); an optical filter adjacent the optical lens (color filter array 120 is adjacent the micro lens array 130; figure 2; column 4, lines 6-19); and a pixel adjacent the optical filter (color filter array 120 is as close as possible to detector array 110 (pixel array); figure 2; column 4, lines 6-19), wherein the aperture accepts an input cone of light containing a wide range of wavelengths (light is received into the lenses 130 in a limited cone shaped aperture due to the external aperture 150; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength (the optical filter array 120 may be an array of narrow band filters to filter the light into a series of narrow band wavelengths 10 nm wide (narrow band of wavelengths centered at an operating wavelength); figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and wherein the pixel is configured to detect photons within the narrow band of wavelengths (the super pixel has each sub-pixel receive light from a specific narrow band filter in the color filter array 120 to detect only the specific array; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9).

As for claim 20, Cavanaugh discloses the micro-optical receiver channel of claim 17, wherein the optical lens comprises a collimating lens (micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation; figure 2; column 4, lines 6-19; column 5, lines 22-33).

As for claim 21, Cavanaugh discloses the micro-optical receiver channel of claim 17, wherein the aperture is aligned with the lens (micro lens array 130 is an array of lenses to fill each specific super-pixel with the apertures restricting light to the shape of the super pixel; figure 2; column 4, lines 6-19, 52-58).

As for claim 22, Cavanaugh discloses the micro-optical receiver channel of claim 17, further comprising a second aperture between the optical lens and the optical filter (micro lens array 130 is between aperture mask 135 and aperture mask 137 with optical filter 120 on the other side of aperture mask 137 from micro lens array 130; figure 2; column 4, lines 6-19, 52-58).

As for claim 23, Cavanaugh discloses the micro-optical receiver channel of claim 17, wherein the optical filter comprises an optical bandpass filter (the color filter array is made of bandpass filters which may be narrow band; figures 2 and 3; column 3, lines 1-5; column 4, line 59- column 5, line 9).

As for claim 28, Cavanaugh discloses the micro-optical receiver channel of claim 17, wherein the pixel comprises a plurality of subpixels (each super pixel includes an array of subpixels such as a 4x4 array; figures 2 and 3; column 4, lines 6-19; 59-67).

As for claim 31, Cavanaugh discloses an image sensor (a hyperspectral imager; figure 2; column 4, lines 6-19) comprising: a plurality of micro-optical receiver channels (multiple channels defined by the aperture masks 135 and 137 for the light to reach each superpixel of a detector 110; figure 2; column 4, lines 6-19, 52-58), each micro optical receiver channel comprising: an aperture (aperture mask 135; figure 2; column 4, lines 52-58); an optical lens adjacent the aperture (micro lens array 130 is between aperture mask 135 and aperture mask 137; figure 2; column 4, lines 6-19, 52-58); an optical filter adjacent the optical lens (color filter array 120 is adjacent the micro lens array 130; figure 2; column 4, lines 6-19); and a pixel adjacent the optical filter (color filter array 120 is as close as possible to detector array 110 (pixel array); figure 2; column 4, lines 6-19).

As for claim 34, Cavanaugh discloses the micro-optical receiver channel of claim 31, wherein the optical lens comprises a collimating lens (micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation; figure 2; column 4, lines 6-19; column 5, lines 22-33).

As for claim 35, Cavanaugh discloses the micro-optical receiver channel of claim 31, wherein the aperture is aligned with the lens (micro lens array 130 is an array of lenses to fill each specific super-pixel with the apertures restricting light to the shape of the super pixel; figure 2; column 4, lines 6-19, 52-58).

As for claim 36, Cavanaugh discloses the micro-optical receiver channel of claim 31, further comprising a second aperture between the optical lens and the optical filter (micro lens array 130 is between aperture mask 135 and aperture mask 137 with optical filter 120 on the other side of aperture mask 137 from micro lens array 130; figure 2; column 4, lines 6-19, 52-58).

As for claim 37, Cavanaugh discloses the micro-optical receiver channel of claim 31, wherein the optical filter comprises an optical bandpass filter (the color filter array is made of bandpass filters which may be narrow band; figures 2 and 3; column 3, lines 1-5; column 4, line 59- column 5, line 9).

As for claim 42, Cavanaugh discloses the micro-optical receiver channel of claim 31, wherein the pixel comprises a plurality of subpixels (each super pixel includes an array of subpixels such as a 4x4 array; figures 2 and 3; column 4, lines 6-19; 59-67).

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

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As for claim 45, Cavanaugh discloses a method comprising: providing a micro-optical receiver channel (a channel defined by the aperture masks 135 and 137 for the light to each superpixel of a detector 110; figure 2; column 4, lines 6-19, 52-58) comprising: an aperture surrounded by a stop region (aperture mask 135 is a tubular baffle; figure 2; column 4, lines 52-58); an optical lens adjacent the aperture (micro lens array 130 is between aperture mask 135 and aperture mask 137; figure 2; column 4, lines 6-19, 52-58); an optical filter adjacent the optical lens (color filter array 120 is adjacent the micro lens array 130; figure 2; column 4, lines 6-19); and a pixel adjacent the optical filter (color filter array 120 is as close as possible to detector array 110 (pixel array); figure 2; column 4, lines 6-19), wherein the aperture accepts an input cone of light containing a wide range of wavelengths (light is received into the lenses 130 in a limited cone shaped aperture due to the external aperture 150; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength (the optical filter array 120 may be an array of narrow band filters to filter the light into a series of narrow band wavelengths 10 nm wide (narrow band of wavelengths centered at an operating wavelength); figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and wherein the pixel is configured to detect photons within the narrow band of wavelengths (the super pixel has each sub-pixel receive light from a specific narrow band filter in the color filter array 120 to detect only the specific array; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9).

As for claim 48, Cavanaugh discloses the method of claim 45, wherein the optical lens comprises a collimating lens (micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation; figure 2; column 4, lines 6-19; column 5, lines 22-33).

As for claim 49, Cavanaugh discloses the method of claim 45, wherein the aperture is aligned with the lens (micro lens array 130 is an array of lenses to fill each specific super-pixel with the apertures restricting light to the shape of the super pixel; figure 2; column 4, lines 6-19, 52-58).

As for claim 50, Cavanaugh discloses the method of claim 45, further comprising a second aperture between the optical lens and the optical filter (micro lens array 130 is between aperture mask 135 and aperture mask 137 with optical filter 120 on the other side of aperture mask 137 from micro lens array 130; figure 2; column 4, lines 6-19, 52-58).

As for claim 51, Cavanaugh discloses the method of claim 45, wherein the optical filter comprises an optical bandpass filter (the color filter array is made of bandpass filters which may be narrow band; figures 2 and 3; column 3, lines 1-5; column 4, line 59- column 5, line 9).

As for claim 56, Cavanaugh discloses the method of claim 45, wherein the pixel comprises a plurality of subpixels (each super pixel includes an array of subpixels such as a 4x4 array; figures 2 and 3; column 4, lines 6-19; 59-67).

As for claim 59, Cavanaugh discloses a method comprising: using a micro-optical receiver channel (a channel defined by the aperture masks 135 and 137 for the light to each superpixel of a detector 110; figure 2; column 4, lines 6-19, 52-58) comprising: an aperture surrounded by a stop region (aperture mask 135 is a tubular baffle; figure 2; column 4, lines 52-58); an optical lens adjacent the aperture (micro lens array 130 is between aperture mask 135 and aperture mask 137; figure 2; column 4, lines 6-19, 52-58); an optical filter adjacent the optical lens (color filter array 120 is adjacent the micro lens array 130; figure 2; column 4, lines 6-19); and a pixel adjacent the optical filter (color filter array 120 is as close as possible to detector array 110 (pixel array); figure 2; column 4, lines 6-19), wherein the aperture accepts an input cone of light containing a wide range of wavelengths (light is received into the lenses 130 in a limited cone shaped aperture due to the external aperture 150; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength (the optical filter array 120 may be an array of narrow band filters to filter the light into a series of narrow band wavelengths 10 nm wide (narrow band of wavelengths centered at an operating wavelength); figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9), and wherein the pixel is configured to detect photons within the narrow band of wavelengths (the super pixel has each sub-pixel receive light from a specific narrow band filter in the color filter array 120 to detect only the specific array; figures 2 and 3; column 2, lines 43-63; column 4, line 59- column 5, line 9).

As for claim 62, Cavanaugh discloses the method of claim 59, wherein the optical lens comprises a collimating lens (micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation; figure 2; column 4, lines 6-19; column 5, lines 22-33).

As for claim 63, Cavanaugh discloses the method of claim 59, wherein the aperture is aligned with the lens (micro lens array 130 is an array of lenses to fill each specific super-pixel with the apertures restricting light to the shape of the super pixel; figure 2; column 4, lines 6-19, 52-58).

As for claim 64, Cavanaugh discloses the method of claim 59, further comprising a second aperture between the optical lens and the optical filter (micro lens array 130 is between aperture mask 135 and aperture mask 137 with optical filter 120 on the other side of aperture mask 137 from micro lens array 130; figure 2; column 4, lines 6-19, 52-58).

As for claim 65, Cavanaugh discloses the method of claim 59, wherein the optical filter comprises an optical bandpass filter (the color filter array is made of bandpass filters which may be narrow band; figures 2 and 3; column 3, lines 1-5; column 4, line 59- column 5, line 9).

As for claim 70, Cavanaugh discloses the method of claim 59, wherein the pixel comprises a plurality of subpixels (each super pixel includes an array of subpixels such as a 4x4 array; figures 2 and 3; column 4, lines 6-19; 59-67).

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As for claim 73, Cavanaugh discloses an optical channel for receiving photons and detecting the photons (a channel defined by the apertures for the light to each superpixel of a detector 110; figure 1; column 4, lines 6-19) comprising: a bulk imaging optic (objective lens 140; figure 1; column 4, lines 6-19); an aperture layer located at an imaging plane of the bulk optic (aperture 152 is the exit pupil of the optical system with objective lens 140; figures 1 and 3; column 4, lines 28-43); a collimating lens layer behind the aperture layer and separated therefrom by a focal length of the collimating lens layer (to help collimate the light, the micro lens array 130 is placed at where the objective lens 140 forms an image of the object under observation so each MLA lens forms an image of the exit pupil of aperture 152, thus the aperture is separated by focal length from the MLA; figure 2; column 4, lines 28-51; column 5, lines 22-33); an optical filter behind the collimating lens layer (color filter array 120 is adjacent the micro lens array 130; figure 1; column 4, lines 6-19); and a pixel offset from the optical filter opposite the collimating lens layer (detector array 110 comprising super-pixels and is behind filter array 120 and the micro lens array 130; figure 1; column 4, lines 6-19), and responsive to photons incident on the pixel (the super pixels form a detector array to create a hyperspectral imager; figures 1 and 3; column 4, lines 6-19 and 59-67).

As for claim 77, Cavanaugh discloses the optical channel of claim 73, wherein the bulk imaging optic is image space telecentric (objective lens 140 is preferably a telecentric lens, and ; figure 1; column 4, lines 6-27).

As for claim 78, Cavanaugh discloses set of optical channels of claim 73 having the set of pixels of the set of optical channels being arranged on a single image sensor (the imager forms a series of channels for each superpixel, to receive an image from the superpixel, which may be part of a single detector array, such as a CMOS sensor; figures 1 and 3; column 4, lines 6-19 and 28-43; column 5, lines 1-8).

As for claim 80, Cavanaugh the discloses set of optical channels of claim 78 further comprising a bulk imaging optic having apertures at a focal plane projected into a field defining fields of view for each optical channel (lens 140 has the apertures 150 and 152 acting as entrance and exit pupils for the light to reach each superpixel of a detector 110, with the apertures forming the field of view for the superpixels; figure 1; column 4, lines 6-19 and 28-43).

Claims 4, 5, 18, 19, 32, 33, 47, 60, and 61 lack an inventive step under PCT Article 33(3) as being obvious over Cavanaugh in view of US 6,721,262 B1 to Jordache, N. et al. (hereinafter 'Jordache').

As for claim 4, Cavanaugh discloses the micro-optical receiver channel of claim 3, but Cavanaugh fails to disclose wherein the stop material comprises a reflective material. However, Jordache discloses wherein the stop material comprises a reflective material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a reflective material, as taught by Jordache, in order to provide an additional reflection which internal optics may capture scattered light in order to improve the signal.

As for claim 5, Cavanaugh discloses the micro-optical receiver channel of claim 3, but Cavanaugh fails to disclose wherein the stop material comprises a light absorbing material. However, Jordache discloses wherein the stop material comprises a light absorbing material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a light absorbing material, as taught by Jordache, in order to minimize internal reflections from the aperture stop and prevent cross-talk between channels.

As for claim 18, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the stop region comprises a reflective material. However, Jordache discloses wherein the stop material comprises a reflective material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a reflective material, as taught by Jordache, in order to provide an additional reflection which internal optics may capture scattered light in order to improve the signal.

As for claim 19, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the stop region comprises a light absorbing material. However, Jordache discloses wherein the stop material comprises a light absorbing material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a light absorbing material, as taught by Jordache, in order to minimize internal reflections from the aperture stop and prevent cross-talk between channels.

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As for claim 32, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein a stop region for the aperture comprises a reflective material. However, Jordache discloses wherein a stop region for the aperture comprises a reflective material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein a stop region for the aperture comprises a reflective material, as taught by Jordache, in order to provide an additional reflection which internal optics may capture scattered light in order to improve the signal.

As for claim 33, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein a stop region for the aperture comprises a light absorbing material. However, Jordache discloses wherein a stop region for the aperture comprises a light absorbing material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein a stop region for the aperture comprises a light absorbing material, as taught by Jordache, in order to minimize internal reflections from the aperture stop and prevent cross-talk between channels.

As for claim 46, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the stop region comprises a reflective material. However, Jordache discloses wherein the stop material comprises a reflective material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a reflective material, as taught by Jordache, in order to provide an additional reflection which internal optics may capture scattered light in order to improve the signal.

As for claim 47, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the stop region comprises a light absorbing material. However, Jordache discloses wherein the stop material comprises a light absorbing material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a light absorbing material, as taught by Jordache, in order to minimize internal reflections from the aperture stop and prevent cross-talk between channels.

As for claim 60, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the stop region comprises a reflective material. However, Jordache discloses wherein the stop material comprises a reflective material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a reflective material, as taught by Jordache, in order to provide an additional reflection which internal optics may capture scattered light in order to improve the signal.

As for claim 61, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the stop region comprises a light absorbing material. However, Jordache discloses wherein the stop material comprises a light absorbing material (aperture stop 158 is created from chromium and may be either absorb or reflect light, with the thickness of the chromium layer 170 determining whether the stop absorbs or reflects; figures 5-6(4); column 3, line 39- column 4, line 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the stop material comprises a light absorbing material, as taught by Jordache, in order to minimize internal reflections from the aperture stop and prevent cross-talk between channels.

Claims 10-13, 24-27, 38-41, 52-55, 66-69, 75, 76 lack an inventive step under PCT Article 33(3) as being obvious over Cavanaugh in view of US 2016/0150963 A1 to Roukes, M. et al. (hereinafter 'Roukes').

As for claim 10, Cavanaugh discloses the micro-optical receiver channel of claim 1, but Cavanaugh fails to disclose wherein the pixel layer comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel layer comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel layer comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 11, Cavanaugh discloses the micro-optical receiver channel of claim 1, but Cavanaugh fails to disclose wherein the pixel layer comprises a plurality of single-photon avalanche diode detectors. However, Roukes discloses wherein the pixel layer comprises a plurality of single-photon avalanche diode detectors (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel layer comprises a plurality of single-photon avalanche diode detectors, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

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As for claim 12, Cavanaugh discloses the micro-optical receiver channel of claim 1, but Cavanaugh fails to disclose wherein the pixel layer comprises at least one resonant cavity photodiode. However, Roukes discloses wherein the pixel layer comprises at least one resonant cavity photodiode (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel layer comprises at least one resonant cavity photodiode, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 13, Cavanaugh discloses the micro-optical receiver channel of claim 1, but Cavanaugh fails to disclose wherein the pixel layer comprises a plurality of resonant cavity photodiodes. However, Roukes discloses wherein the pixel layer comprises a plurality of resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel layer comprises a plurality of resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 24, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the pixel comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 25, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of single-photon avalanche diode detectors. However, Roukes discloses wherein the pixel comprises a plurality of single-photon avalanche diode detectors (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises a plurality of single-photon avalanche diode detectors, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 26, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the pixel comprises at least one resonant cavity photodiode. However, Roukes discloses wherein the pixel comprises at least one resonant cavity photodiode (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises at least one resonant cavity photodiode, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 27, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of resonant cavity photodiodes. However, Roukes discloses wherein the pixel comprises a plurality of resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises a plurality of resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 38, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein the pixel comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 39, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of single-photon avalanche diode detectors. However, Roukes discloses wherein the pixel comprises a plurality of single-photon avalanche diode detectors (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises a plurality of single-photon avalanche diode detectors, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 40, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein the pixel comprises at least one resonant cavity photodiode. However, Roukes discloses wherein the pixel comprises at least one resonant cavity photodiode (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]) .It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises at least one resonant cavity photodiode, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

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As for claim 41, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of resonant cavity photodiodes. However, Roukes discloses wherein the pixel comprises a plurality of resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide wherein the pixel comprises a plurality of resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 52, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the pixel comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh the pixel comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 53, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of single-photon avalanche diode detectors. However, Roukes discloses wherein the pixel comprises a plurality of single-photon avalanche diode detectors (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh the pixel comprises a plurality of single-photon avalanche diode detectors, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 54, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the pixel comprises at least one resonant cavity photodiode. However, Roukes discloses wherein the pixel comprises at least one resonant cavity photodiode (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises at least one resonant cavity photodiode, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 55, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of resonant cavity photodiodes. However, Roukes discloses wherein the pixel comprises a plurality of resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises a plurality of resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 66, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the pixel comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 67, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of single-photon avalanche diode detectors. However, Roukes discloses wherein the pixel layer comprises a plurality of single-photon avalanche diode detectors (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors; figure 13; paragraphs [0027, 0030, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises a plurality of single-photon avalanche diode detectors, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 68, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the pixel comprises at least one resonant cavity photodiode. However, Roukes discloses wherein the pixel comprises at least one resonant cavity photodiode (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises at least one resonant cavity photodiode, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 69, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose wherein the pixel comprises a plurality of resonant cavity photodiodes However, Roukes discloses wherein the pixel comprises a plurality of resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide wherein the pixel comprises a plurality of resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

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As for claim 75, Cavanaugh discloses the optical channel of claim 73 but Cavanaugh fails to disclose wherein the pixel comprises at least one single-photon avalanche diode detector. However, Roukes discloses wherein the pixel comprises at least one single-photon avalanche diode detector (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide wherein the pixel comprises at least one single-photon avalanche diode detector, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

As for claim 76, Cavanaugh discloses the optical channel of claim 73 but Cavanaugh fails to disclose wherein the pixel comprises at least one resonant cavity photodiodes. However, Roukes discloses wherein the pixel comprises at least one resonant cavity photodiodes (an array of optical detectors comprises an array of Single-Photo Avalanche Diode Detectors using resonant cavities; figure 13; paragraphs [0027, 0030, 0032, 0070]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide wherein the pixel comprises at least one resonant cavity photodiodes, as taught by Roukes, in order to provide the ability to detect very low level signals for spectrographic purposes.

Claims 15, 16, 29, 30, 43, 44, 57, 58, 71, 72, 74 lack an inventive step under PCT Article 33(3) as being obvious over Cavanaugh in view of US 2015/0292948 A1 to Verifood, LTD. (hereinafter 'Verifood').

As for claim 15, Cavanaugh discloses the micro-optical receiver channel of claim 1, but Cavanaugh fails to disclose further comprising a diffuser between the optical filter layer and the pixel layer. However, Verifood discloses a diffuser between the optical filter layer and the pixel layer (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a diffuser between the optical filter layer and the pixel layer, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 16, Cavanaugh, in view of Verifood, discloses the micro-optical receiver channel of claim 15, but Cavanaugh fails to disclose further comprising a third aperture layer between the optical filter layer and the diffuser. However, Verifood discloses a third aperture layer between the optical filter layer and the diffuser (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and a aperture array 172; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a third aperture layer between the optical filter layer and the diffuser, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 29, Cavanaugh discloses the micro-optical receiver channel of claim 17, but Cavanaugh fails to disclose further comprising a diffuser between the optical filter and the pixel . However, Verifood discloses a diffuser between the optical filter and the pixel (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a diffuser between the optical filter and the pixel, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 30, Cavanaugh, in view of Verifood, discloses the micro-optical receiver channel of claim 29, but Cavanaugh fails to disclose further comprising a third aperture between the optical filter and the diffuser. However, Verifood discloses a third aperture between the optical filter and the diffuser (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and a aperture array 172; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a third aperture between the optical filter layer and the diffuser, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 43, Cavanaugh discloses the micro-optical receiver channel of claim 31, but Cavanaugh fails to disclose further comprising a diffuser between the optical filter and the pixel . However, Verifood discloses a diffuser between the optical filter and the pixel (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a diffuser between the optical filter and the pixel, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 44, Cavanaugh, in view of Verifood, discloses the micro-optical receiver channel of claim 43, but Cavanaugh fails to disclose further comprising a third aperture between the optical filter and the diffuser. However, Verifood discloses a third aperture between the optical filter and the diffuser (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and a aperture array 172; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the micro-optical receiver channel of Cavanaugh to provide a third aperture between the optical filter layer and the diffuser, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

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As for claim 57, Cavanaugh discloses the method of claim 45, but Cavanaugh fails to disclose further comprising a diffuser between the optical filter and the pixel . However, Verifood discloses a diffuser between the optical filter and the pixel (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide a diffuser between the optical filter and the pixel, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 58, Cavanaugh, in view of Verifood, discloses the method of claim 57, but Cavanaugh fails to disclose further comprising a third aperture between the optical filter and the diffuser. However, Verifood discloses a third aperture between the optical filter and the diffuser (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and a aperture array 172; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide a third aperture between the optical filter layer and the diffuser, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 71, Cavanaugh discloses the method of claim 59, but Cavanaugh fails to disclose further comprising a diffuser between the optical filter and the pixel . However, Verifood discloses a diffuser between the optical filter and the pixel (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide a diffuser between the optical filter and the pixel, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 72, Cavanaugh, in view of Verifood, discloses the method of claim 71, but Cavanaugh fails to disclose further comprising a third aperture between the optical filter and the diffuser. However, Verifood discloses a third aperture between the optical filter and the diffuser (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and a aperture array 172; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the method of Cavanaugh to provide a third aperture between the optical filter layer and the diffuser, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

As for claim 74, Cavanaugh discloses the optical channel of claim 73, and Cavanaugh futher discloses whereby the pixel can detect incident photons across its full width and height to increase the dynamic range of the system (the super pixel receives a full image of the imaged object across the super pixel (across its full width and height) to create a larger color range with 16 wavelengths possible per super pixel; figures 1 and 3; column 4, lines 6-19, 27-51; column 4 line 59-column 5, line 8). But Cavanaugh fails to disclose further comprising a diffuser that spreads light rays passed from the aperture layer through the optical filter across an area of a corresponding pixel, However, Verifood discloses a diffuser that spreads light rays passed from the aperture layer through the optical filter across an area of a corresponding pixel (a stopper mounting 178 comprises a diffusive material and is between the filter array 170 and detector 190 made of a plurality of pixels; figure 5; paragraphs [0160, 0163]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide a diffuser that spreads light rays passed from the aperture layer through the optical filter across an area of a corresponding pixel, as taught by Verifood, in order to provide the advantage of a removing any specular component and providing uniform light across a subpixel.

Claims 79, 81-84 lack an inventive step under PCT Article 33(3) as being obvious over Cavanaugh in view of WO 2016/125165 A2 to Vertifood, LTD. (hereinafter 'Vertifood 2').

As for claim 79, Cavanaugh discloses the set of optical channels of claim 78 but Cavanaugh fails to disclose wherein multiple sets of optical channels are fabricated on the same wafer and diced to yield multiple sets of optical channels. However Vertifood 2 discloses multiple sets of optical channels are fabricated on the same wafer and diced to yield multiple sets of optical channels (lens and filters may be assembled on the same substrate and then cut into multiple individual assemblies; figure 20; paragraphs [0218]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channels of Cavanaugh to provide multiple sets of optical channels are fabricated on the same wafer and diced to yield multiple sets of optical channels, as taught by Verifood 2, in order to provide the advantage of being able to assemble the resulting device using wafer level packaging techniques, allowing for cheaper and easier mass production of the optical channels, as well as a compact shape suitable for portable use such as a within a phone for mobile applications.

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US17/39306

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As for claim 81, Cavanaugh discloses the set of optical channels with the bulk imaging optic of claim 80 but Cavanaugh fails to disclose further comprising a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels, and operating at a same wavelength as the set of optical channels and a controller to form an active illumination optical sensor. However Verifood 2 discloses a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels (the illumination module 140 may comprise an array of LEDs 210 (set of optical emitters) while the spectrometer module 160 comprises multiple photodiodes 263 sharing lens 225 (bulk transmitter optic) able to detect the light from the LEDs 210 being reflected off an object (overlapping field of view); figures 11-13; paragraphs [0170, 0172, 0181]), and operating at a same wavelength as the set of optical channels (the photodiodes 263 are responsive to the illumination from the LEDs across a broad set of wavelengths; figures 11 and 12; paragraphs [0173, 0184]) and a controller to form an active illumination optical sensor (control board 105 and processor 106 may control the LEDs and modulate the light to form a spectrometer (active illumination optical sensor); figure 11; paragraphs [0170, 0184-0186]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channels of Cavanaugh to provide a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels, as taught by Verifood 2, in order to provide the advantage of being able to control the light emitted to ensure sufficient illumination across a broad band of wavelengths to properly image targets, and because Vertifood 2 teaches a compact shape suitable for portable use such as a within a phone for mobile applications.

As for claim 82, Cavanaugh, in view of Verifood 2, discloses the active illumination optical sensor of claim 81 and Cavanaugh further discloses wherein the bulk imaging optic is image space telecentric (objective lens 140 is preferably a telecentric lens, and in various embodiments may be telecentric; figures 1 and 10; column 4, lines 6-27; column 7, lines 24-30).

As for claim 83, Cavanaugh, in view of Verifood 2, discloses the active illumination optical sensor of claim 81 but Cavanaugh fails to disclose wherein the set of optical emitters are arranged on a single semiconductor die. However, Verifood 2 discloses wherein the set of optical emitters are arranged on a single semiconductor die (light sources may be a flip chip mounted LED die which may be mounted in an array ; figure 12-13; paragraphs [0136, 0172, 0174]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channels of Cavanaugh to provide wherein the set of optical emitters are arranged on a single semiconductor die, as taught by Verifood 2, in order to provide the advantage of being able to assemble the resulting device using wafer level packaging techniques, allowing for cheaper and easier mass production of the optical channels, as well as a compact shape suitable for portable use such as a within a phone for mobile applications.

As for claim 84, Cavanaugh, in view of Verifood 2, discloses the active illumination optical sensor of claim 81 but Cavanaugh fails to disclose wherein the set of optical emitters are lasers. However, Verifood 2 discloses wherein the set of optical emitters are lasers (either in combination or alternatively to the LEDs, the light sources 140 may comprise lasers; figure 12; paragraph [0172]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channels of Cavanaugh to provide wherein the set of optical emitters are lasers, as taught by Verifood 2, in order to provide the advantage of being able to assemble the resulting device using wafer level packaging techniques, allowing for cheaper and easier mass production of the optical channels, as well as a compact shape suitable for portable use such as a within a phone for mobile applications.

Claims 81-82, and 84-86 lack an inventive step under PCT Article 33(3) as being obvious over Cavanaugh in view of US 2010/0008588 A1 to Feldkhun, D. et al. (hereinafter 'Feldkhun').

As for claim 81, Cavanaugh discloses the set of optical channels with the bulk imaging optic of claim 80 but Cavanaugh fails to disclose further comprising a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels, and operating at a same wavelength as the set of optical channels and a controller to form an active illumination optical sensor. However Feldkhun discloses a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels (system 100 (bulk transmitter optic) includes a pattern projector 101, comprising a set of radiation sources 107 (optical emitters), which illuminates a sample object 103 (projecting light into a field defining transmitter fields of view) which is images via multi-channel imaging system 102 with lenses 103 (overlapping with fields of view defined by a set of optical channels); figure 1; paragraphs [0038-0040]), and operating at a same wavelength as the set of optical channels (the projector 101 emits light that imaging system 102 comprising the channels is able to image; figure 1; paragraphs [0038-0040]) and a controller to form an active illumination optical sensor (a controller 115 may coordinate the emission and imaging of the light such as to detect depth in three dimensions ; figures 1 and 12; paragraphs [0031, 0038-0040, 0120]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide a bulk transmitter optic having a set of optical emitters at a focal plane projecting light into a field defining transmitter fields of view that are overlapping with the fields of view defined by the set of optical channels, and operating at a same wavelength as the set of optical channels and a controller to form an active illumination optical sensor, as taught by Feldkhun, in order to provide the advantage of a reference pattern which may be measured to perform 3D depth measurements using off the shelf optics suitable for use in a phone, providing a further advantage of allowing both depth measurements and color discrimination for augmented reality applications.

As for claim 82, Cavanaugh, in view of Feldkhun, discloses the active illumination optical sensor of claim 81 and Cavanaugh further discloses wherein the bulk imaging optic is image space telecentric (objective lens 140 is preferably a telecentric lens, and in various embodiments may be telecentric; figures 1 and 10; column 4, lines 6-27; column 7, lines 24-30).

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As for claim 84, Cavanaugh, in view of Feldkhun, discloses the active illumination optical sensor of claim 81 but Cavanaugh fails to disclose wherein the set of optical emitters are lasers. However Feldkhun discloses wherein the set of optical emitters are lasers (a pattern projector 101, comprising a set of radiation sources 107 may use laser diodes; figure 1; paragraphs [0039]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide wherein the set of optical emitters are lasers, as taught by Feldkhun, in order to provide the advantage of a reference pattern which may be measured to perform 3D depth measurements using off the shelf optics suitable for use in a phone, providing a further advantage of allowing both depth measurements and color discrimination for augmented reality applications.

As for claim 85, Cavanaugh, in view of Feldkhun, discloses the active illumination optical sensor of claim 81 but Cavanaugh fails to disclose wherein the active illumination optical sensor is configured to measure the distance to an object in the scene for each transmit receiver pair. However Feldkhun discloses wherein the active illumination optical sensor is configured to measure the distance to an object in the scene for each transmit receiver pair (the system is able to estimate the location and distance by sequentially emitting patterns from the projector with each emitter and detector array working individually to record separate patterns (each pair) and then using that to measure the location (measure the distance to an object); figure 1; paragraphs [0038-0040]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide wherein the active illumination optical sensor is configured to measure the distance to an object in the scene for each transmit receiver pair, as taught by Feldkhun, in order to provide the advantage of a reference pattern which may be measured to perform 3D depth measurements using off the shelf optics suitable for use in a phone, providing a further advantage of allowing both depth measurements and color discrimination for augmented reality applications.

As for claim 86, Cavanaugh, in view of Feldkhun, discloses the active illumination optical sensor of claim 85 but Cavanaugh fails to disclose wherein the active illumination optical sensor is a 3D depth sensor. However Feldkhun discloses wherein the active illumination optical sensor is a 3D depth sensor (the system 100 may be used to project and imaging of the light such as to detect depth in three dimensions; figures 1 and 12; paragraphs [0031, 0038-0040, 0120]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the optical channel of Cavanaugh to provide wherein the active illumination optical sensor is a 3D depth sensor, as taught by Feldkhun, in order to provide the advantage of a reference pattern which may be measured to perform 3D depth measurements using off the shelf optics suitable for use in a phone, providing a further advantage of allowing both depth measurements and color discrimination for augmented reality applications.

Claims 1-86 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Jennifer L. Hayes
Nixon Peabody LLP
300 South Grand Avenue
Suite 4100
Los Angeles, California 90071-3151
United States of America

PCT

INVITATION TO PAY ADDITIONAL FEES
AND, WHERE APPLICABLE, PROTEST FEE

(PCT Article 17(3)(a) and Rules 40.1 and 40.2(e))

Applicant's or agent's file reference 78715-001WO0	Date of mailing *(day/month/year)* 31 AUG 2017 **PAYMENT DUE** within **ONE MONTH** from the above date of mailing
International application No. PCT/US17/39306	International filing date *(day/month/year)* 26 June 2017 (26.06.2017)
Applicant OUSTER, INC.	

1. This International Searching Authority

(i) considers that there are 2 *(number of)* inventions claimed in the international application covered by the claims indicated below/on an extra sheet:

Group I: Claims 1-72; Group II: Claims 1-16 and 73-86

(ii) therefore considers that **the international application does not comply with the requirement of unity of invention** (Rules 13.1, 13.2 and 13.3) for the reasons indicated below/on an extra sheet:

-***-Continued within extra sheet-***-

(iii) ☐ has carried out a partial international search (see Annex) ☒ will establish the international search report on those parts of the international application which relate to the invention first mentioned in claims Nos.:

Group I: Claims 1-72

(iv) will establish the international search report on the other parts of the international application only if, and to the extent to which, additional fees are paid.

2. Consequently, the applicant is hereby **invited to pay**, within the time limit indicated above, additional fees in the amount indicated below:

$2080.00 (Fee per additional invention) x 1 (number of additional inventions) = $2080.00 (See Item 2 of annex) (total amount of additional fees/currency)

3. The applicant is informed that, according to Rule 40.2(c), **the payment of any additional fees may be made under protest**, that is, a reasoned statement to the effect that the international application complies with the requirement of unity of invention or that the amount of the required additional fees is excessive, where applicable, subject to the payment of a protest fee.

Where the applicant pays additional fees under protest, the applicant is hereby invited, within the time limit indicated above, to pay a protest fee (Rule 40.2(e)) in the amount of _____ *(amount/currency)*

Where the applicant has not, within the time limit indicated above, paid the required protest fee, the protest will be considered not to have been made and the International Searching Authority will so declare.

4. ☐ Claim(s) Nos. _____ have been found to be unsearchable under Article 17(2)(b) because of defects under Article 17(2)(a) and therefore have not been included with any invention.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Shane Thomas PCT Helpdesk: 571-272-4300

Form PCT/ISA/206 (April 2005)

INVITATION TO PAY ADDITIONAL FEES
AND, WHERE APPLICABLE, PROTEST FEE

International application No.
PCT/US17/39306

Item 2 (continued). For International Applications filed on or after 01 January 2014, Applicant is reminded that the search fee per additional invention indicated in item 2 is the undiscounted fee per additional invention. An Applicant may pay the search fee per additional invention fee reduced by 50% (small entity assertion) or 75% (micro entity certification), as appropriate. See 37 CFR 1.27 and 1.29.

-***-Continued from 1.(ii)-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-72 are directed towards a micro-optical receiver channel, an image sensor, and a method.
Group II: Claims 1-16 and 73-86 are directed towards an optical channel for receiving photons and detecting the photons.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include at least wherein the aperture accepts an input cone of light containing a wide range of wavelengths, and the optical filter filters out all but a narrow band of the wavelengths centered at an operating wavelength, and wherein the pixel is configured to detect photons within the narrow band of wavelengths, which are not present in Group II.

The special technical features of Group II include at least a bulk imaging optic; an aperture layer located at an imaging plane of the bulk optic; a collimating lens layer behind the aperture layer and separated therefrom by a focal length of the collimating lens layer; an optical filter behind the collimating lens layer; and a pixel offset from the optical filter opposite the collimating lens layer, and responsive to photons incident on the pixel, which are not present in Group I.

The common technical features shared by Groups I-II are an optical channel comprising: an aperture; an optical lens adjacent the aperture; an optical filter adjacent the optical lens; and a pixel adjacent the optical filter.

However, these common features are previously disclosed by US 2012/0320164 A1 (LIPTON). Lipton discloses an optical channel comprising: an aperture (polarizing aperture 306; Fig. 3 and para [0046]); an optical lens adjacent the aperture (lens 302 adjacent to aperture 306; Fig. 3 and para [0046]); an optical filter adjacent the optical lens (a patterned polarizer (optical filter) adjacent lens 302; Fig. 3 and para [0046]); and a pixel adjacent the optical filter (a pixel image sensor 309 adjacent to the polarizer 308; Fig. 3, paras [0032], [0046]).

Since the common technical features are previously disclosed by the Lipton reference, these common features are not special and so Groups I-II lack unity.

Form PCT/ISA/206 (extra sheet) (April 2005)

Electronic Patent Application Fee Transmittal					
Application Number:					
Filing Date:					
Title of Invention:	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS				
First Named Inventor/Applicant Name:	Angus Pacala				
Filer:	William Leland Shaffer/La Renda Meyer				
Attorney Docket Number:	103033-P001USC2-1096583				
Filed as Small Entity					
Filing Fees for Utility under 35 USC 111(a)					
Description	**Fee Code**	**Quantity**	**Amount**	**Sub-Total in USD($)**	
Basic Filing:					
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	75	75	
UTILITY SEARCH FEE	2111	1	330	330	
UTILITY EXAMINATION FEE	2311	1	380	380	
Pages:					
Claims:					
CLAIMS IN EXCESS OF 20	2202	6	50	300	
Miscellaneous-Filing:					
Petition:					

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	1085

Electronic Acknowledgement Receipt	
EFS ID:	33272323
Application Number:	16046643
International Application Number:	
Confirmation Number:	1720
Title of Invention:	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS
First Named Inventor/Applicant Name:	Angus Pacala
Customer Number:	20350
Filer:	William Leland Shaffer
Filer Authorized By:	
Attorney Docket Number:	103033-P001USC2-1096583
Receipt Date:	26-JUL-2018
Filing Date:	
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Application Type:	Utility under 35 USC 111(a)

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37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	ADS_P001USC2-1096583.pdf	111933 8b471cfb91cfc32a0f9a3b05ad457c48548a8504	no	9
Warnings:					
Information:					
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2		ContinuationPatentApplication_P001USC2-1096583.pdf	225907 6d73a47f433e57fa000023fdbecface31b4bd6c0	yes	31

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Abstract	31	31
Claims	26	30
Specification	1	25

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3	Drawings-only black and white line drawings	Drawings_P001USC2-1096583.pdf	983370 f82e2296501a1736acf96ea1e95079b10a0458bd	no	8
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4	Transmittal Letter	IDS_Transmittal_P001USC2-1096583.pdf	110398 494ef4b6b5d48e62c58459f7cb8d14d88c20ee09	no	2
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5	Information Disclosure Statement (IDS) Form (SB08)	PTOSB08A_P001USC2-1096583.pdf	193564 220702b336bb72fa792366da93c2b4524c2ba2a0	no	11
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6	Foreign Reference	Foreign_WO2016125165A2_Part1.pdf	24464206 797083145ae4a0dacca20f206e259294db0fa59d	no	20
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7	Foreign Reference	Foreign_WO2016125165A2_Part2.pdf	26164850 e12572004905 9f3c12c9d6e999004eb8de7f7ab4	no	20
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12	Foreign Reference	Foreign_WO2016125165A2_Part7.pdf	6577599 5289d6ff0350fd1825b18fd6842b0473eff9fda1	no	9
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13	Foreign Reference	Foreign_JP2007049417.PDF	645596 58eaf0b965dcbceaef0ce5738961e78d4c6724a0	no	15
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14	Foreign Reference	EP2124069.pdf	855824 0035751c441d49f4b6afd34ba200e1b4450b6df5	no	15
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16	Foreign Reference	EP3002548.pdf	723120 720235988e6eafacd599817cf0e19c8a8088b094	no	16
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18	Foreign Reference	WO2016116733.pdf	1443915 a982df6c2f020af9cea8e41913aaf5fb4160add e	no	41
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22	Non Patent Literature	NPL_InvitationToPayAdditionalFees_with_PartialSearch_103033-1059680.PDF	111241 4cca7ee95b48d0322ca01a5fa030c6f0367bb928	no	2
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23	Non Patent Literature	Cova.pdf	569343 56d76bc672f942c5d8d23450cdc3cfe4c937d8b5	no	5
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24	Non Patent Literature	Ex_Kilpela_Reviews_Scientific_Instruments_April_2001.pdf	9734984 7f8734e55fe86df6b3786afb8136998edfd3bc24	no	13
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26	Non Patent Literature	NPL_100_000_Frames_64_32_Single-Photon-Detector_Array_for_2-D_Imaging_and_3-D_Ranging.PDF	10865433 0e431052b86ba408622cbcf9728cf8423c6892fa	no	10
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27	Non Patent Literature	NPL_IEEE_Photonics_Journal_TwoDimensional_SPAD_Imaging_Camera_for_Photon_Counting.PDF	3458258 f6be4736e2f13fe79567e50bdf8ec7c94d721881	no	17
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28	Non Patent Literature	NPL_SPAD-Based_Sensors_Edoardo_Charbon.PDF	1608039 a3c6681b74df227d08918797296fd0cd9e5fb6ee	no	29
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29	Non Patent Literature	Velodyne_Lidar_HDL-32E_datasheet2010.pdf	900080 62c5b52ba02b57f8d4dcc5f5289515b918756c64	no	2
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31	Non Patent Literature	HDL-32E_webpage12-2017.pdf	2052396 eddf4a4ddc5a2a16fa951d80a8738e8f2d121383	no	5
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33	Non Patent Literature	VelodyneLidarPuckUsersManualandProgrammingGuide.pdf	3746167 0550fcc14f134f936ed06c7e60f1a5090b833bfc	no	49
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38	Non Patent Literature	NPL_Puck_Hi-Res_Data_Sheet_Sept2016.pdf	511359 ae3aa2b93e83ef750cf9444c0c858f4e5ba2a741	no	2
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39	Non Patent Literature	NPL_Puck_Hi-Res_User_Manual_Sept2016.pdf	6903338 31c21782c0d3260422bc34300ada96fee2b2d2dc	no	49
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40	Non Patent Literature	NPL_Puck_LITE_Data_Sheet_Feb2016.pdf	494889 51ff47c273fa705d819cb9d1e84d2805ecefac01	no	2
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41	Non Patent Literature	NPL_Puck_LITE_User_Manual_Feb2016.pdf	6903349 97c6dda6f438aeb1fddac40d7ff5ef01c550c30f	no	49
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42	Non Patent Literature	VelodyneLidarPuckLiteOurLighttestSensorEver.pdf	901637 d75683a378498463ee1d4d3331628d5e063af3de	no	2
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43	Non Patent Literature	VelodyneLidarUltraPuckVLP32C.pdf	1585669 27ca824ea5841f6cdadfb23a5862ca6fb771bbb7	no	4
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44	Fee Worksheet (SB06)	fee-info.pdf	36833 271f3f03fb82184a76bdeeb84c4c133335002921	no	2
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Information:					
		Total Files Size (in bytes):	213324978		

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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.

PTO/AIA/14 (11-15)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC2-1096583
	Application Number	
Title of Invention	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS	

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:

☐ 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
	Angus		PACALA	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	San Francisco	State/Province	CA	Country of Residence	US

Mailing Address of Inventor:

Address 1	2741 16th Street		
Address 2			
City	San Francisco	State/Province	CA
Postal Code	94103	Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Mark		FRICHTL	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	San Francisco	State/Province	CA	Country of Residence	US

Mailing Address of Inventor:

Address 1	2741 16th Street		
Address 2			
City	San Francisco	State/Province	CA
Postal Code	94103	Country	US

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

Correspondence Information:

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

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC2-1096583
	Application Number	
Title of Invention	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS	

☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	20350		
Email Address	ipefiling@kilpatricktownsend.com	Add Email	Remove Email

Application Information:

Title of the Invention	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS		
Attorney Docket Number	103033-P001USC2-1096583	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	8	**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:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC2-1096583
	Application Number	
Title of Invention	OPTICAL IMAGING SYSTEM WITH A PLURALITY OF SENSE CHANNELS	

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	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	15880491	2018-01-25
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
15880491	Continuation of	15276532	2016-09-26
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
15276532	Claims benefit of provisional	62232222	2015-09-24

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

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)[i] 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).

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Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

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