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(71) Applicants: **BOSCH CAR MULTIMEDIA PORTUGAL S.A.** [PT/PT]; R. Max Grundig, 35, 4705-820 Braga (PT). **UNIVERSIDADE DO MINHO** [PT/PT]; Largo do Paço, 4704-553 Braga (PT).

(72) Inventors: **HOLLECZEK, Annemarie**; Bosch Car Multimedia Portugal S.A. - R. Max Grundig, 35, 4705-820 Braga (PT). **ANTUNES DE CARVALHO ALBUQUERQUE,**

André; Bosch Car Multimedia Portugal S.A. - R. Max Grundig, 35, 4705-820 Braga (PT). **NUNES PEREIRA, Eduardo Jorge**; Universidade Do Minho - Escola De Ciências, Centro De Física, Gualtar, 4710 - 057 Braga (PT). **CORREIA, Alexandre**; Bosch Car Multimedia Portugal S.A. - R. Max Grundig, 35, 4705-820 Braga (PT). **CALDELAS, Pedro**; Bosch Car Multimedia Portugal S.A. - R. Max Grundig, 35, 4705-820 Braga (PT). **RODRIGUES, Ângela**; Universidade Do Minho - Largo Do Paço, 4704-553 Braga (PT). **PEREIRA PEIXOTO, Hélder Xavier**; Travessa do Monte, 121, SANTA MARIA OLIVEIRA, 4765-326 (PT).

(74) Agent: **SILVESTRE ALMEIDA FERREIRA, Luis Humberto**; Patentree, Rua de Salazares 842 - Edf. NET, 4149-002 Porto (PT).

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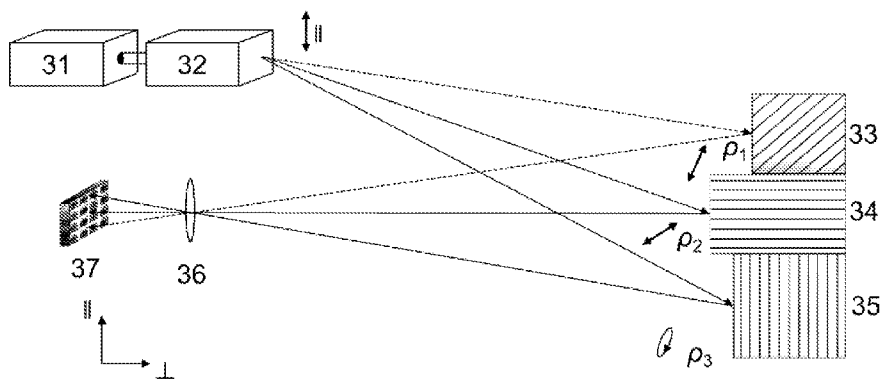


Fig. 4

(57) **Abstract:** Terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, comprising: a polarized laser light emitter having emitter optics for emitting polarized laser light over said field of view; an assembly of a photodetector array and of a polarizer array, for detecting backscattered polarized light and respective polarization over said field of view; an electronic data processor connected to said photodetector array and configured to calculate, from return time and the polarization of the detected backscattered polarized light, a 3D representation having light polarization properties. Method for operating a terrestrial vehicle range finder device, comprising: emitting a polarized laser light over said field of view by a laser emitter; detecting backscattered polarized light and respective polarization over said field of view; calculating, by an electronic data processor, from return time and the detected polarization, a 3D representation having light polarization properties.

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D E S C R I P T I O N

TERRESTRIAL VEHICLE RANGE FINDER DEVICE AND OPERATION METHOD THEREOF

Technical field

[0001] This disclosure relates to the field of LIDAR systems and, more specifically, to object identification in 3D images for terrestrial vehicle range finding devices. The disclosure describes a way to discriminate different types of target materials for autonomous or assisted driving systems based on LIDAR sensors for terrestrial vehicle range finding devices.

Background

[0002] Light Detecting and Ranging (LIDAR) systems are used in a wide range of practical applications requiring remote measurements. In general, LIDAR comprises a set of techniques that use laser light to measure the distance to a specific target. By using appropriate optical scanning elements or by illuminating/flashing a specific area of a target, it is possible to obtain 3D images with depth information and backscattering properties of the target. Such systems provide a 3D point cloud frame that can be processed by software in order to obtain additional information of the surrounding scene. Consequently, 3D LIDAR imaging has been widely recognized as an attractive possibility for vehicular applications such as hazard and collision avoidance and autonomous/assisted navigation.

[0003] Given a 3D point cloud frame, the obtained data still needs to be processed in order to recognize, discriminate and classify key elements such as vehicles, pedestrians, buildings or any other obstacle. This kind of classification is of uttermost relevance for autonomous and driving-assisted navigation when hazard avoidance and self-steering decisions need to be made. In order to do so, several object recognition and mapping techniques and methodologies have been proposed, e.g. patent documents US8244026B2 or EP2113437A2. These techniques use the 3D information to determine the geometrical shape and edges of different objects in the illuminated scene to discriminate different types of targets. However, object recognition based

solely on pure geometrical and dimensional properties is difficult, in particular when the resolution of the LIDAR cameras is not very high and when different types of targets have similar geometry.

[0004] In addition to 3D mapping, LIDAR sensors also provide information on the reflectivity properties of the illuminated targets by measuring the intensity of the reflected/backscattered light, as mentioned in patent document US9360554B2. This information can thus be used as an additional feature for object recognition and further improve the discrimination and classification of targets,. In addition, it is also possible to measure the velocity of a target by measuring the distance at different time instants.

[0005] For those skilled in the art, it is known that the polarisation properties of light may vary when interacting with matter. As an example, the state of polarisation of scattered light may be rotated or even become unpolarised at all (random polarization). The polarization of light backscattered from a “hard” target (e.g. wall, car, pedestrian) also depends on the type of material of the target and can thereby be used as an additional parameter and contrast mechanism for object identification and recognition in automotive LIDAR systems.

General Description

[0006] The problem to be solved includes object identification and recognition based on the data provided by a 3D LIDAR system, which is a complex multiparameter problem, given that current automotive LIDAR systems provide distance, velocity and intensity/reflectivity information. The improved performance of object recognition techniques relying on the disclosed LIDAR system, in particular due to enhanced input data, is also a matter addressed by the disclosure. It is noted that some properties of scattered light can be used to improve object identification and recognition by a 3D LIDAR system. Also, the discrimination of the type of materials of a target by measuring the polarization properties of the backscattered light, through a LIDAR system, is possible with the present disclosure.

[0007] It is an advantage of the disclosure, the simple evaluation of the polarization properties by a 3D LIDAR system of light backscattered/reflected from a target, wherein an embodiment of the disclosure includes:

Polarized laser diode as the light source;

Polarizing beam splitting element to separate two orthogonal states of polarization of the incoming light;

Two independent photodetectors or a photodetector array with integrated micropolarizers to measure the intensity of the two orthogonal states of polarization;

Single photodetector with rotating half wave plate and a polarizer.

[0008] It is an advantage of the disclosure, the compatibility with both scanning and flash LIDAR systems based on time-of-flight measurements. Another advantage includes the discrimination of materials such as fabrics, fur, wood, paints, metal and concrete. The disclosure also provides the combination with information on the intensity of backscattered light and image processing techniques for identification of people, vehicles, trees, traffic signs, buildings and animals. Also, there is a possibility of a multiple variable, also called 6D, analysis: 2D location in the image + depth + reflectivity + velocity + polarization.

[0009] It is disclosed a terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, comprising:

a polarized laser light emitter (12, 22, 31) having emitter optics (13, 23, 32) for emitting polarized laser light over said field of view (33, 34, 35);

an assembly (37) of a photodetector array and of a polarizer array, for detecting backscattered polarized light and respective polarization over said field of view;

an electronic data processor connected to said photodetector array and configured to calculate, from return time and the polarization of the detected backscattered polarized light, a 3D representation having light polarization properties over said field of view.

[0010] The polarized laser light emitter may be a linearly polarized, a circularly polarized or an elliptically polarized laser light emitter. In an aspect of the disclosure, the polarized laser light emitter is linearly polarized.

[0011] The emitted laser light is generally a pulsed laser light. The device is generally a light detection and ranging, LIDAR, device. The LIDAR may be scanning LIDAR, flash LIDAR, FMCW (Frequency Modulated Continuous Wave) LIDAR or a hybrid scanning-flash LIDAR, among others.

[0012] In an embodiment, the photodetector array and the polarizer array comprise, respectively, corresponding pixel photodetectors and pixel polarization filters.

[0013] In an embodiment, the polarizer array is arranged to discriminate the backscattered polarized light between, at least, two polarization directions such that each said pixel photodetector receives one and only one polarization direction, in particular said directions being orthogonal.

[0014] In an embodiment, said polarizer array comprises an array of pixel filters, each pixel polarization filter (39) having two or more subpixel filters (38) comprising two or more light polarization directions.

[0015] In an embodiment, each pixel photodetector corresponds to one, and only one, subpixel filter (38) of the polarizer array.

[0016] In an embodiment, the subpixel filters (38) of a pixel filter (39) comprise the following subpixel light polarization directions relative to the polarization direction of the polarized laser light emitter:

parallel and perpendicular; or

-45° and +45°; or

parallel, perpendicular, -45° and +45°.

[0017] In an embodiment, each pixel filter (39) has 4 subpixel filters (38).

[0018] In an embodiment, the polarized laser light emitter comprises emitter optics 13, 23, 32) for emitting linearly polarized laser light by scanning or flashing over said field of view, in particular the emitter optics comprising rotating mirrors, micro-electro-mechanical system mirrors, or optical phase arrays deflectors, or the emitter optics comprise a rotating housing.

[0019] In an embodiment, the emitter optics 13, 23, 32) comprise a polarization filter.

[0020] It is also disclosed a method for operating a terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, comprising: emitting a polarized laser light over said field of view by a laser emitter (12, 22, 31); detecting backscattered polarized light and respective polarization over said field of view by a polarizer setup (17, 27, 28, 37) and a cooperating photodetector (20, 30, 37); calculating, by an electronic data processor, from return time and the polarization of the detected backscattered polarized light, a 3D representation having light polarization properties over said field of view.

[0021] In an embodiment, said photodetector is a 2D image sensor photodetector array and said polarizer setup comprises a polarizer array, wherein said photodetector array and said polarizer array comprise, respectively, corresponding pixel photodetectors and pixel polarization filters, wherein the polarizer array is arranged to discriminate the backscattered polarized light between, at least, two polarization directions such that each said pixel photodetector receives one and only one polarization direction, in particular said directions being orthogonal.

[0022] In an embodiment, said polarizer array comprises an array of pixel filters, each pixel polarization filter (39) having two or more subpixel filters (38) comprising two or more light polarization directions, wherein each pixel photodetector corresponds to one, and only one, subpixel filter (38) of the polarizer array, and the subpixel filters (38) of a pixel filter (39) comprise the following subpixel light polarization directions relative to the polarization direction of the polarized laser light emitter:

parallel and perpendicular; or

-45° and +45°; or

parallel, perpendicular, -45° and +45°.

[0023] In an embodiment, the step of detecting backscattered polarized light and respective polarization comprises:

splitting by said polarizer setup (17) the backscattered polarized light according to two polarization directions into said photodetector (20) and an additional photodetector (21) such that each photodetector detects each of the polarization directions, in particular said directions being orthogonal.

[0024] In an embodiment, the step of detecting backscattered polarized light and respective polarization comprises:

rotating a rotatable half wave plate (27) to rotate the polarization of the backscattered polarized light conveyed through a polarizer (28) into the photodetector (30), such that two polarization directions are consecutively detected, in particular said directions being orthogonal.

[0025] It is also disclosed a non-transitory storage media including program instructions for implementing a method for operating a terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, the program instructions including instructions executable to carry out the method of any of the disclosed embodiments.

Brief Description of the Drawings

[0026] The following figures provide preferred embodiments for illustrating the description and should not be seen as limiting the scope of invention.

[0027] **Figure 1** is a schematic representation of two prior art LIDAR setups.

[0028] **Figure 2** is a schematic representation of an embodiment of the polarization-sensitive LIDAR with external polarizing beam splitter.

[0029] **Figure 3** is a schematic representation of an embodiment of the polarization-sensitive LIDAR using a rotating half wave plate and a polarizer.

[0030] **Figure 4** is a schematic representation of an embodiment of the polarization-sensitive LIDAR with integrated micropolarizers.

[0031] **Figure 5** is a schematic representation of an embodiment of the 4x4 photodetector array with integrated micropolarizers.

[0032] **Figure 6** is a schematic representation of the orthogonal polarization components of linearly and elliptical polarized light in a standard Cartesian coordinate system.

[0033] **Figure 7** is a graphical representation of results of a polarization degree of polarization retention from the back scattered radiation for several representative materials as a function of detection angle.

[0034] **Figure 8** is a photographic representation of polarization degree of polarization retention from the back scattered radiation for several representative materials.

Detailed Description

[0035] The disclosure describes a method and apparatus for measuring the variation of the state of polarization of light backscattered from a specific target for automotive LIDAR systems. The variation on the state of polarization of backscattered light provides additional information on the constituent material of a specific target, which can be used as additional information for object recognition and target discrimination in LIDAR systems.

[0036] In typical LIDAR systems for automotive applications, a 3D point cloud is obtained by either scanning or flashing a surrounding scene within a certain field of view, as - respectively - depicted on top and at the bottom of **Figure 1**. In the former case, light emitted by a pulsed laser source **1** (e.g. edge emitter or vertical-cavity surface-emitting laser diodes) scans the target scene using a scanner **2**, which may comprise rotating mirrors, micro-electro-mechanical system (MEMS) mirrors, or optical phase arrays deflectors, for instance. In addition, the scanner may consist of a rotating housing with the laser source **1**, imaging optics **3** and the photodetectors **4** inside. When light emitted by the laser source hits a specific target, such as trees **5**, cars **6** or pedestrians **7**, part of the light beam may be reflected or scattered back to the receiving part of the LIDAR system. The receiving part of the system comprises imaging optics **3** and a single photodetector or a photodetector array (shown as element **4** in **Figure 1**) to form an image of the scanned scene. The image depicted at the bottom of **Figure 1** illustrates a typical flash LIDAR system where the light beam emitted by laser source **8** is shaped using appropriate beam shaping optics **9** in order to illuminate a surrounding scene within a certain field of view. Light reflected or scattered back to the system is then collected by imaging optics **10** and a

photodetector array **11** to form an image. In both cases, range information can be obtained by measuring the time of flight between the emission and detection of the reflected pulse, whereas the intensity of the reflected/scattered light is given by the photocurrent generated in the photodetectors.

[0037] In one embodiment of the disclosure, illustrated in **Figure 2**, linearly-polarized light emitted by laser source **12** either scans or illuminates targets **14**, **15** and **16** by using a scanner or beam shaping optics, represented in **Figure 2** by element **13**. Note that element **13** may also be a rotating housing that contains the light sources and detectors within. Depending on the type of laser and the polarization properties of the emitted light, an additional polarizer may be required after laser source **12** in order to obtain a highly linearly-polarized beam. Let us consider the reference axis shown at the bottom left corner of **Figure 2**, with $\parallel$ and $\perp$ the directions parallel and perpendicular to the state of polarization of the laser source. When polarized light beam hits a specific target, the polarization properties of the reflected/scattered light are modified depending on the target's material, as exemplified in **Figure 2**.

[0038] Light reflected/scattered from targets **14**, **15** and **16**, whose polarization properties were altered depending on the specific target, is then led to polarizing beam splitter **17**. Polarizing beam splitter **17** then separates the incoming beams into two orthogonal polarizations components. For simplicity, it is assumed here that the two orthogonal axis of the polarizing beam splitter are aligned with directions $\parallel$ and $\perp$. Afterwards, the two orthogonal polarization components of the incoming light are respectively led to lenses **18** and **19**, which focus the received light on photodetectors **20** and **21** in order to form an image of the surrounding scene. It should be noted that elements **18** and **19** may be replaced by an optical system of lenses, prisms or mirrors rather than a single lens in order to correct for spherical aberrations, image distortions or to improve the field of view or the angular resolution of the system, for instance.

[0039] Photodetector **20** and **21** respectively generates electrical currents $I_{\parallel}$ and $I_{\perp}$, which are proportional to the intensity of the parallel and perpendicular polarization components of the incoming light. Hence, the sum of the electrical currents generated by each detector of the arrays, $I_{\perp} + I_{\parallel}$, provides the total intensity of light backscattered/reflected from the target (reflectivity information). Depending on the

architecture and type of LIDAR system, a single photodetector or a photodetector array can be used to detect the scattered light and to generate an image of the surrounding scene. In the former case, which is commonly used in scanning LIDAR systems, the field of view angle of the scattered light reaching the detector is determined by the deflection angle of the scanner. In the second case, each detector of the arrays can be sensitive only to light coming from a specific angle, thus providing a 2D image with the additional depth information from time-of-flight measurements. Hereinafter, the architecture and embodiments of the disclosure are described assuming a detection scheme based on a photodetector array. Nonetheless, the architectures described in this disclosure are also valid for detection schemes based on a single detector, with only a few or even no modifications on the detection design.

[0040] Several quantities/parameters can be defined in order to quantify the modification on the polarization properties of the reflected/scattered light. The coefficients defined in Eq. 1, Eq. 2, Eq. 3 and Eq. 4 are some possibilities, though many other possibilities can be used using the same apparatus/method in this disclosure. Coefficient ρ represents the current ratio between the perpendicular and parallel polarization components of the incoming light, whereas coefficient χ gives the ratio between the perpendicular and total current. Coefficient κ is related to the degree of polarization of the detected light and coefficient r is the so-called fluorescence anisotropy, which is a very common parameter for fluorescence microscopy applications.

$$\rho = \frac{I_{\perp}}{I_{\parallel}}, \quad \text{Eq. 1}$$

$$\chi = \frac{I_{\perp}}{I_{\parallel} + I_{\perp}} = \frac{\rho}{1 + \rho} \quad \text{Eq. 2}$$

$$\kappa = \frac{I_{\perp} - I_{\parallel}}{I_{\parallel} + I_{\perp}} = \frac{\rho - 1}{1 + \rho}. \quad \text{Eq. 3}$$

$$r = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + 2I_{\perp}} = \frac{1 - \rho}{1 + 2\rho}. \quad \text{Eq. 4}$$

[0041] All the previous quantities can be used to evaluate the variation of the polarization properties of the reflected/scattering light, without having to modify the detection architecture. Note that the information contained in all the quantities defined above is equivalent, as χ , κ and r can all be expressed in terms of ρ .

[0042] Similarly to the intensity measurements, different values of the previous coefficients can be obtained for each field of view angle, thus enabling to obtain a 2D image with the polarization information (e.g. coefficients ρ_1 , ρ_2 and ρ_3). The generated image can be used as complementary information to range and intensity measurements for target discrimination and object recognition.

[0043] The embodiment of this disclosure represented in **Figure 2** requires an additional external element (polarizing beam splitter **17**) in order to separate the two orthogonal polarization components, but it also requires two independent photodetector arrays. In addition, the extinction ratio of the polarizing beam splitters, defined as the ratio of the unwanted polarization component transmitted to the wanted component, depends on the angle of incidence, which may hamper the performance of the system and the reliability of the obtained polarization information. Furthermore, if the two photodetector arrays are not perfectly aligned, the images formed by the two arrays do not exactly coincide, becoming “blurry”. In another embodiment of the disclosure, illustrated in **Figure 3**, the additional external polarizing beam splitter and photodetector array are replaced by a half wave plate **27** and polarizer **28**. As in the previous embodiment of the disclosure, polarized light emitted by laser source **22** either scans/flushes targets **24**, **25** and **26**, using scanner/beam shaping optics **23**. In this case, however, the backscattered/reflected light passes through half wave plate **27** and polarizer **28**, before focusing lens **29** and photodetector array **30**.

[0044] The principle of operation of this embodiment is as follows. Polarizer **28** acts as a polarization filter as it lets only one of the polarization components reaching the photodetector. For simplicity, it is assumed that the polarization axis of the polarizer is aligned with direction $\parallel$, but other configurations are possible. If the fast axis of the half wave plate is aligned with the axis of the polarizer, the perpendicular polarization component of the incoming light is blocked by polarizer **28**, and only the parallel

polarization component reaches photodetector array **30**. On the other hand, if the fast axis of half wave plate **27** is aligned at 45° with respect to the parallel direction, the perpendicular and parallel polarization components are rotated by 90° . By doing so, only the perpendicular component of the incoming light passes through the polarizer and reaches the photodetector array, as the half wave plate rotates the perpendicular polarization component to the parallel direction. Hence, it is possible to consecutively measure the parallel and perpendicular polarization components by rotating half wave plate **27** between 0° and 45° . Note that the rotation of the polarization vector is proportional to twice the rotation angle of the half wave plate and that the photodetectors are only sensitive to the intensity of the light. Hence, the effects of rotating the half wave plate by 0° , 90° , 180° and 270° , or alternatively by 45° , 135° , 225° or 315° are equivalent. In the embodiment described above, the rotating halfwave plate can be replaced by any other polarization-rotating element, including liquid crystal polarization rotators or Faraday rotators, for instance.

[0045] The embodiment of the disclosure illustrated in **Figure 3** eliminates the need for an external polarizing beam splitter and an additional photodetector array. The performance of the polarizer and half wave plate may be sensitive to the angle of incidence of light reaching the detector. In a different embodiment of the disclosure, illustrated in **Figure 4**, a single photodetector array with integrated micropolarizers is disclosed in order to overcome the aforementioned issue. Not only it avoids the additional polarizing beam splitters, photodetector array, polarizer or half wave plate but it also solves the dependence on the angle of incidence. Compared to the previous embodiments of the disclosure, the emitting part of the LIDAR system remains unaltered, with polarized light being emitted by laser source **31**, which either scans or flashes targets **33**, **34** and **35**, using scanner or beam shaping optics **32**. In this case, however, light backscattered from the targets is directly led to lens **36**, which focuses the incoming light to the photodetector array with integrated micropolarizers, represented in **Figure 4** by element **37**.

[0046] **Figure 5** shows on the left (5a), a 4x4 photodetector array with integrated micropolarizers (polarizing grid **40**) oriented along the parallel ($\parallel$) and perpendicular ($\perp$) directions. On the right (5b), same as on the left, but with integrated

micropolarizers oriented at the parallel ($\parallel$) and perpendicular ($\perp$) directions and at 45° and -45° .

[0047] The photodetector array with integrated micropolarizers may comprise a solid state detector array with a polarizing assembly (e.g. a metal grid) formed directly on top of the detectors, as described in patent US7186968B2, which is herewith incorporated in its entirety, though other alternatives are possible. The photodetector array is composed of several detectors (pixels **39**), which in turn are divided into smaller subpixels **38**, each with a micropolarizer with the polarizing axis at a specific orientation, as illustrated in **Figure 5**. The micropolarizer is used to select the polarization component arriving at each subpixel, so different orientations of the micropolarizer enable detecting different polarization components in the same pixel. In **Figure 5**, on the left (5a), each pixel is divided into four subpixels, with two of them oriented along the parallel direction ($\parallel$) and the other two along the perpendicular direction ($\perp$).

[0048] **Figure 6** shows on the left (6a), a schematic representation of the orthogonal polarization components of linearly and elliptical polarized light in a standard Cartesian coordinate system. On the right (6b), same as on the left but using a Cartesian coordinate system oriented at 45° .

[0049] Note that other configurations of the micropolarizers are possible as exemplified in **Figure 5**, on the right (5b), where each pixel is divided into four subpixels with micropolarizers oriented at 0° (parallel direction), 45° , -45° and 90° (perpendicular direction). Such configuration can be used to further improve the sensibility of the LIDAR system to the polarization properties of the backscattered/reflected light. In order to understand the possible advantages of this latter configuration, let us consider two light beams, one with a linear state of polarization and another elliptically polarized, as illustrated in **Figure 6**. When considering the Cartesian coordinate system shown on the left of **Figure 6**, the amplitude of the two orthogonal components for both states of polarization is the same, i.e., $E_{\parallel}^L = E_{\parallel}^E$ and $E_{\perp}^L = E_{\perp}^E$, where superscripts L and E represent the linearly and elliptically polarized beams. Hence, it is not possible to distinguish the two states of polarization using the embodiments of this disclosure represented in **Figure 2** and

Figure 3 or even when using micropolarizers oriented only along the parallel and perpendicular directions. On the other hand, the amplitude of the orthogonal polarization components measured in a Cartesian reference system oriented at 45° is different, as $E_{45^\circ}^L \neq E_{45^\circ}^E$ and $E_{-45^\circ}^L \neq E_{-45^\circ}^E$. Hence, it is possible to distinguish the two different states of polarization by considering the micropolarizer configuration shown on the left of **Figure 5**, thus enhancing the sensitivity of the LIDAR system to the polarization properties of light backscattered from the different targets. The photocurrents generated by the sub-pixels with integrated micropolarizers at 45° and -45° enable to obtain new coefficients ρ , χ , κ and r , respectively given by Eq. 1, Eq. 2, Eq. 3 and Eq. 4, but considering the electrical currents I_{45° and I_{-45° , instead of $I_{\parallel}$ and $I_{\perp}$.

[0050] **Figure 7** illustrates a graphical representation of a polarization FOM (Figure-Of-Merit), computed from eq. 3 (degree of polarization retention, from the back scattered radiation), for several representative materials, as a function of detection angle. All cases have results for incidence angles from 0 to 24 degrees, in steps of 2 degrees. The FOM can assume values from 0 to 1. Metallic grey **41** (OPEL/VAUXHALL PEPPERDUST-MET) and green **42** (OPEL/VAUXHALL LEMON GRASS-MET) are samples of car paints. For the car paints, the FOM is very close to 1 (above 0.98) while for the other materials its value is always lower than 0.25. For the car paints **41** **42** and the polyester fabric **44** samples, the FOM is independent of both incident and detection angle. The wood **43** value depends on both angles (from left to right are results for increasing angles of incidence). The results were obtained with an Agilent Cary 7000 spectrometer with a spectral band width of 5nm, centred in 905nm.

[0051] **Figure 8** illustrates a photographic representation of a polarization FOM (Figure-Of-Merit), computed from eq. 3 (degree of polarization retention, from the back scattered radiation), for several representative materials. Results from a custom built scanning LiDAR using 785nm picosecond pulsed radiation with a target placed at an approximate distance of 5m. Metallic grey (OPEL/VAUXHALL PEPPERDUST-MET) is a sample of car paint. K-line (target material) is a diffusive white cardboard, a well-known material for arts and architecture physical models. The packing cardboard is a common cardboard sample. The metallic grey and packing cardboard materials were placed at two different heights from the target (20 and 30cm, respectively).

[0052] An additional test was conducted with a commercial LiDAR sensor. A LeddarTech Vu8 was selected and its receiving unit was covered with a linear polarizer. Samples of metallic grey (OPEL/VAUXHALL PEPPERDUST-MET) and grey polyester fabric were set at an approximate distance of 5m from the LiDAR sensor. The polarization FOM, eq. 3, was computed and values either above 0.98 (metallic grey OPEL/VAUXHALL PEPPERDUST-MET) or below 0.2 (polyester fabric) were obtained.

[0053] The term "comprising" whenever used in this document is intended to indicate the presence of stated features, integers, steps, components, but not to preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

[0054] The disclosure should not be seen in any way restricted to the embodiments described and a person with ordinary skill in the art will foresee many possibilities to modifications thereof. The above described embodiments are combinable. The following claims further set out particular embodiments of the disclosure.

C L A I M S

1. Terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, comprising:
a polarized laser light emitter (12, 22, 31) having emitter optics (13, 23, 32) for emitting polarized laser light over said field of view (33, 34, 35);
an assembly (37) of a photodetector array and of a polarizer array, for detecting backscattered polarized light and respective polarization over said field of view;
an electronic data processor connected to said photodetector array and configured to calculate, from return time and the polarization of the detected backscattered polarized light, a 3D representation having light polarization properties over said field of view.
2. Range finder device according to the previous claim wherein the polarized laser light emitter is linearly polarized, circularly polarized or elliptically polarized, in particular linearly polarized.
3. Range finder device according to any of the previous claims wherein the photodetector array and the polarizer array comprise, respectively, corresponding pixel photodetectors and pixel polarization filters.
4. Range finder device according to the previous claim wherein the polarizer array is arranged to discriminate the backscattered polarized light between, at least, two polarization directions such that each said pixel photodetector receives one and only one polarization direction, in particular said directions being orthogonal.
5. Range finder device according to any of the previous claims wherein said polarizer array comprises an array of pixel filters, each pixel polarization filter (39) having two or more subpixel filters (38) comprising two or more light polarization directions.

6. Range finder device according to the previous claim wherein each pixel photodetector corresponds to one, and only one, subpixel filter (38) of the polarizer array.
7. Range finder device according to the previous claim wherein the subpixel filters (38) of a pixel filter (39) comprise the following subpixel light polarization directions relative to the polarization direction of the polarized laser light emitter:
parallel and perpendicular; or
-45° and +45°; or
parallel, perpendicular, -45° and +45°;
in particular, wherein each pixel filter (39) has 4 subpixel filters (38).
8. Range finder device according to any of the previous claims wherein the polarized laser light emitter comprises emitter optics (13, 23, 32) for emitting polarized laser light by scanning or flashing over said field of view, in particular the emitter optics comprising rotating mirrors, micro-electro-mechanical system mirrors, or optical phase arrays deflectors, or the emitter optics comprise a rotating housing.
9. Range finder device according to any of the previous claims wherein the emitter optics (13, 23, 32) comprise a polarization filter or polarization optics for causing rotation of the plane of polarization or change in the polarization state.
10. Method for operating a terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, comprising:
emitting a polarized laser light over said field of view by a laser emitter (12, 22, 31);
detecting backscattered polarized light and respective polarization over said field of view by a polarizer setup (17, 27, 28, 37) and a cooperating photodetector (20, 30, 37);
calculating, by an electronic data processor, from return time and the polarization of the detected backscattered polarized light, a 3D representation having light polarization properties over said field of view.

11. Method according to the previous claim wherein said photodetector is a 2D image sensor photodetector array and said polarizer setup comprises a polarizer array, wherein said photodetector array and said polarizer array comprise, respectively, corresponding pixel photodetectors and pixel polarization filters, wherein the polarizer array is arranged to discriminate the backscattered polarized light between, at least, two polarization directions such that each said pixel photodetector receives one and only one polarization direction, in particular said directions being orthogonal.
12. Method according to the previous claim wherein said polarizer array comprises an array of pixel filters, each pixel polarization filter (39) having two or more subpixel filters (38) comprising two or more light polarization directions, wherein each pixel photodetector corresponds to one, and only one, subpixel filter (38) of the polarizer array, and the subpixel filters (38) of a pixel filter (39) comprise the following subpixel light polarization directions relative to the polarization direction of the polarized laser light emitter:
parallel and perpendicular; or
-45° and +45°; or
parallel, perpendicular, -45° and +45°.
13. Method according to any of the claims 10 - 12 wherein the step of detecting backscattered polarized light and respective polarization comprises:
splitting by said polarizer setup (17) the backscattered polarized light according to two polarization directions into said photodetector (20) and an additional photodetector (21) such that each photodetector detects each of the polarization directions, in particular said directions being orthogonal.
14. Method according to any of the claims 10 - 12 wherein the step of detecting backscattered polarized light and respective polarization comprises:
rotating a rotatable half wave plate (27) to rotate the polarization of the backscattered polarized light conveyed through a polarizer (28) into the

photodetector (30), such that two polarization directions are consecutively detected, in particular said directions being orthogonal.

15. Non-transitory storage media including program instructions for implementing a method for operating a terrestrial vehicle range finder device for monitoring a terrestrial field of view from a terrestrial vehicle, the program instructions including instructions executable to carry out the method of any of the claims 10-14.

D R A W I N G S

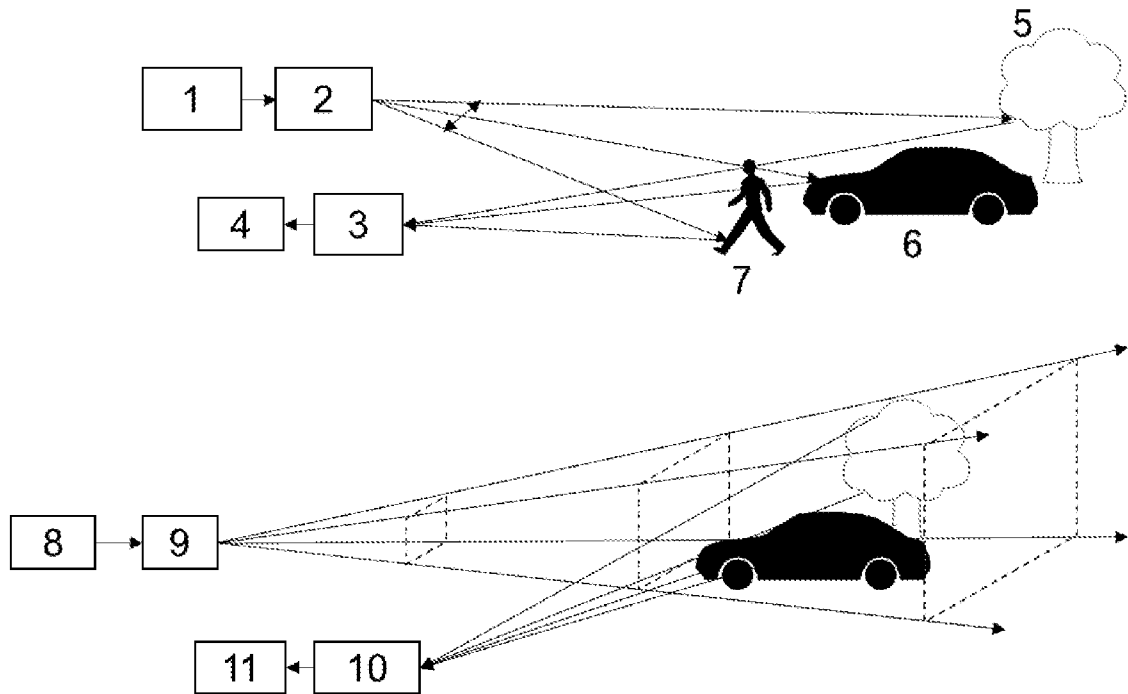


Fig. 1

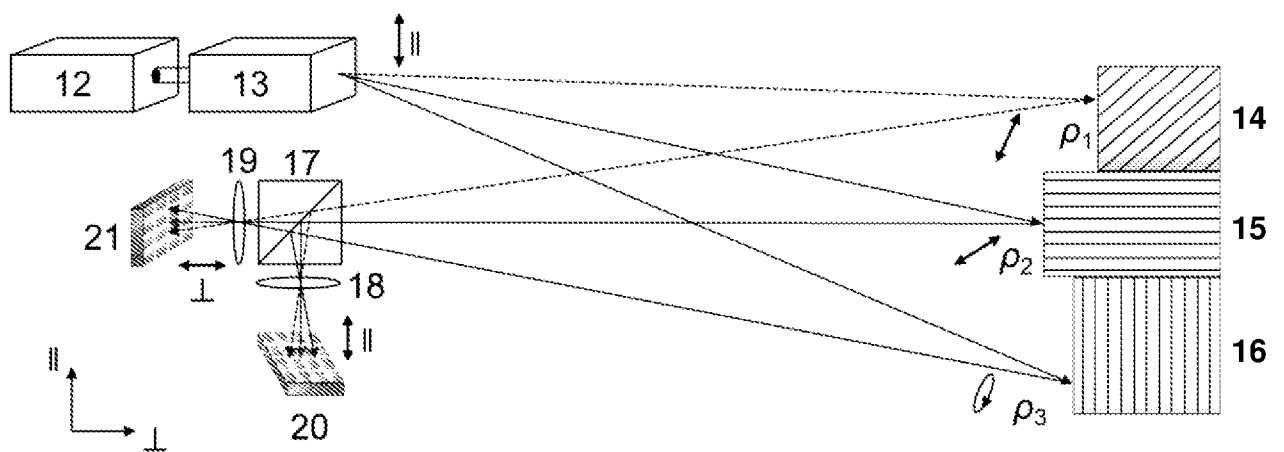


Fig. 2

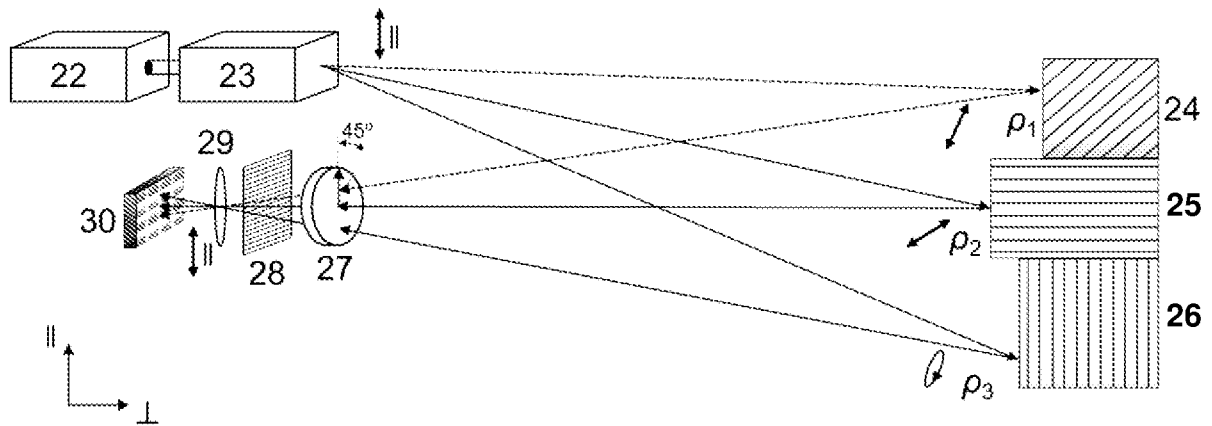


Fig. 3

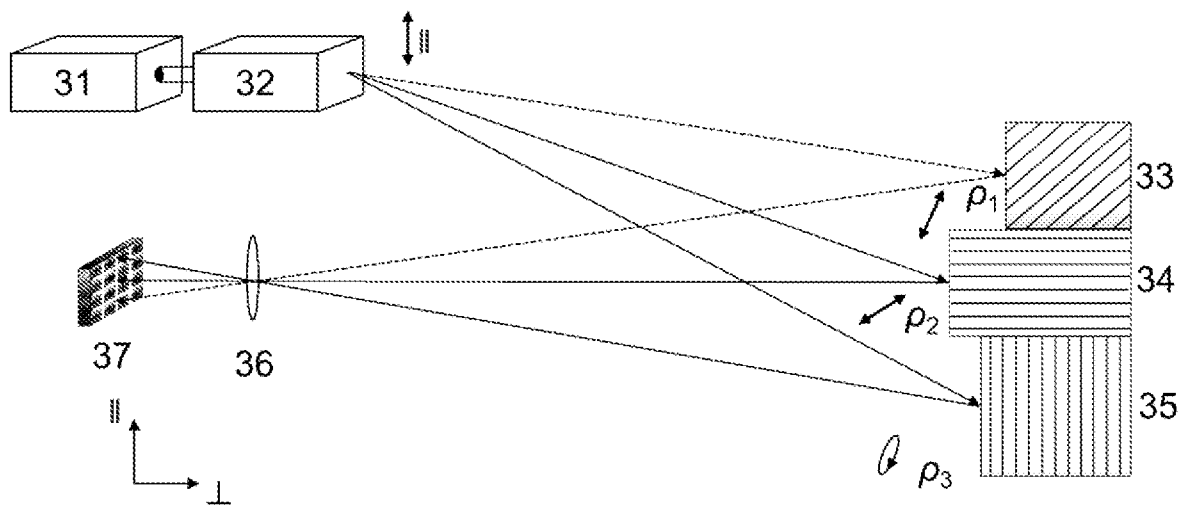


Fig. 4

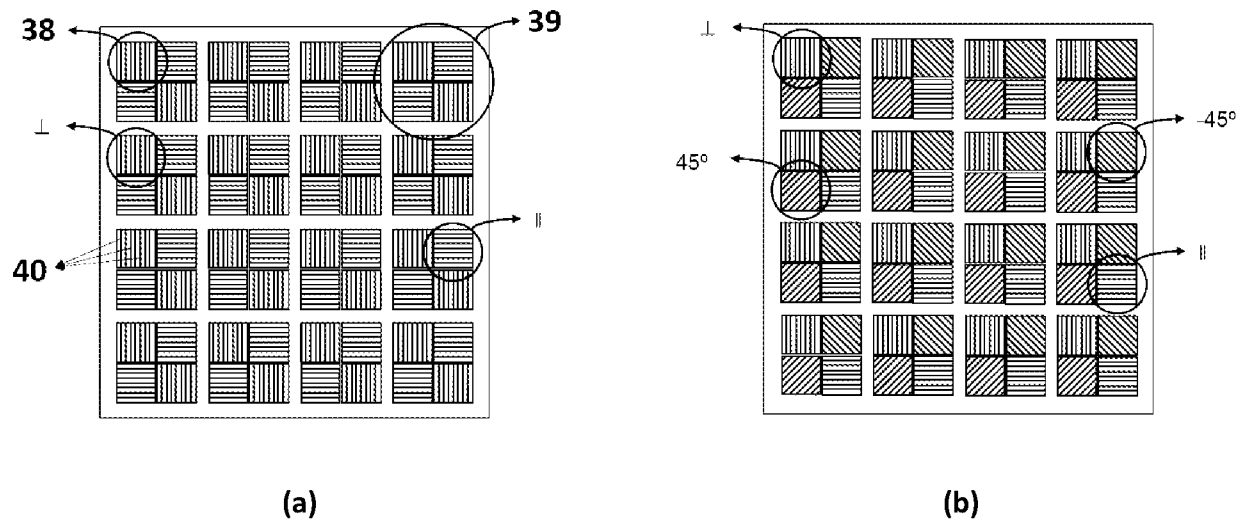


Fig. 5

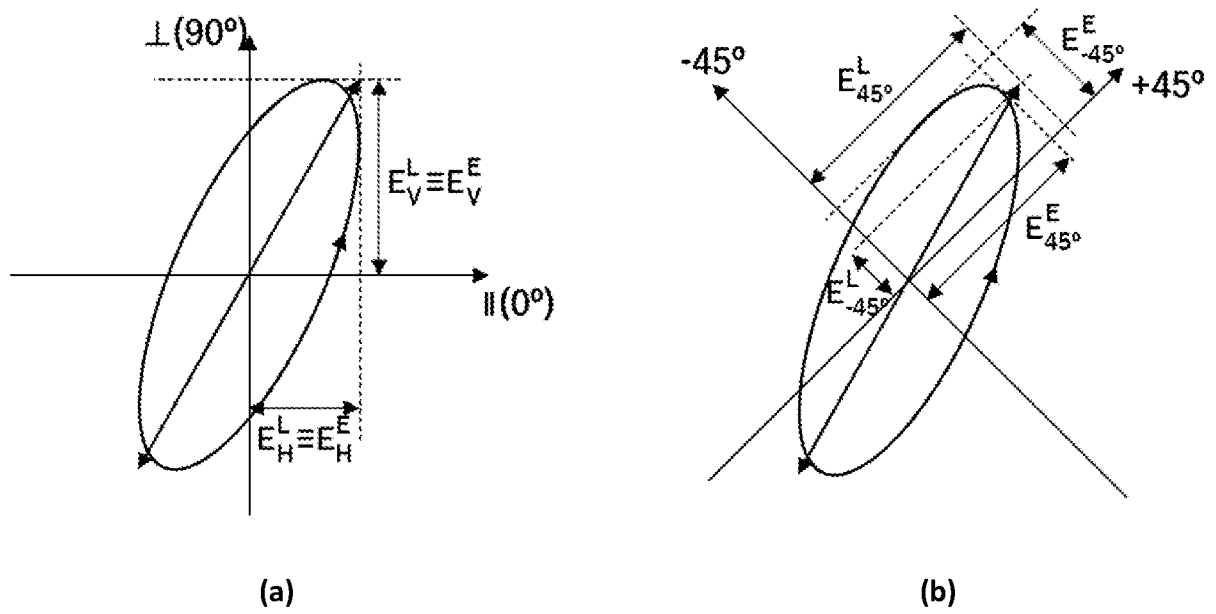


Fig. 6

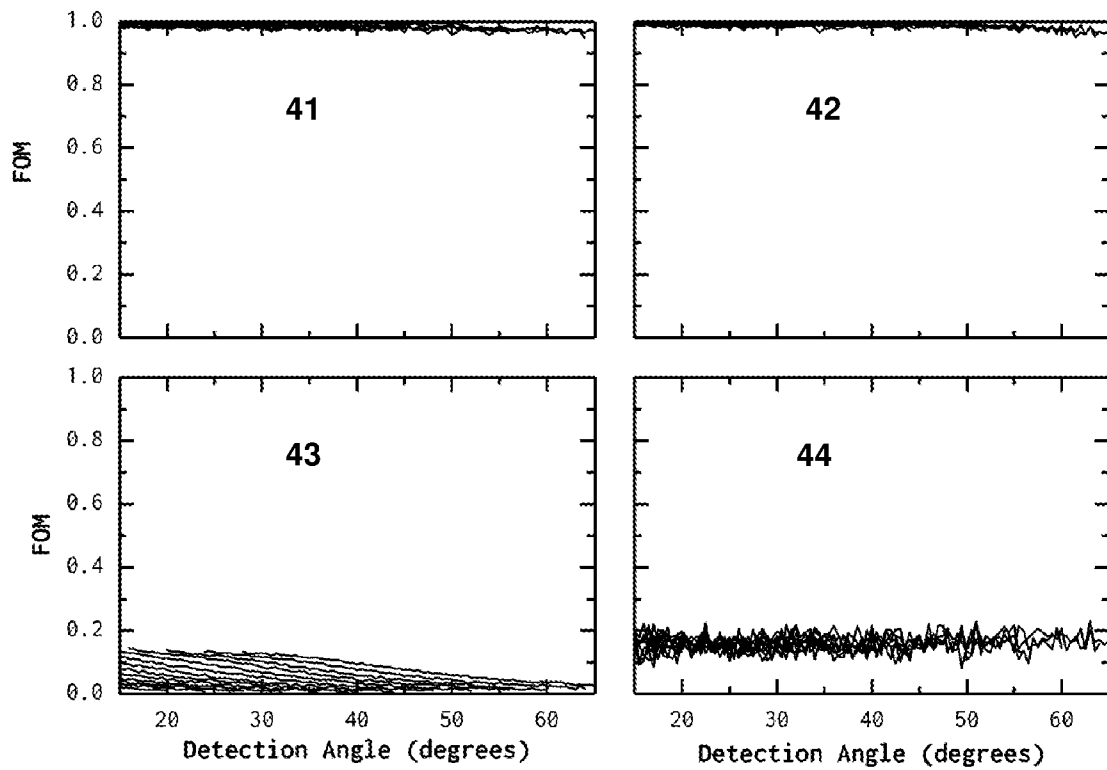


Fig. 7

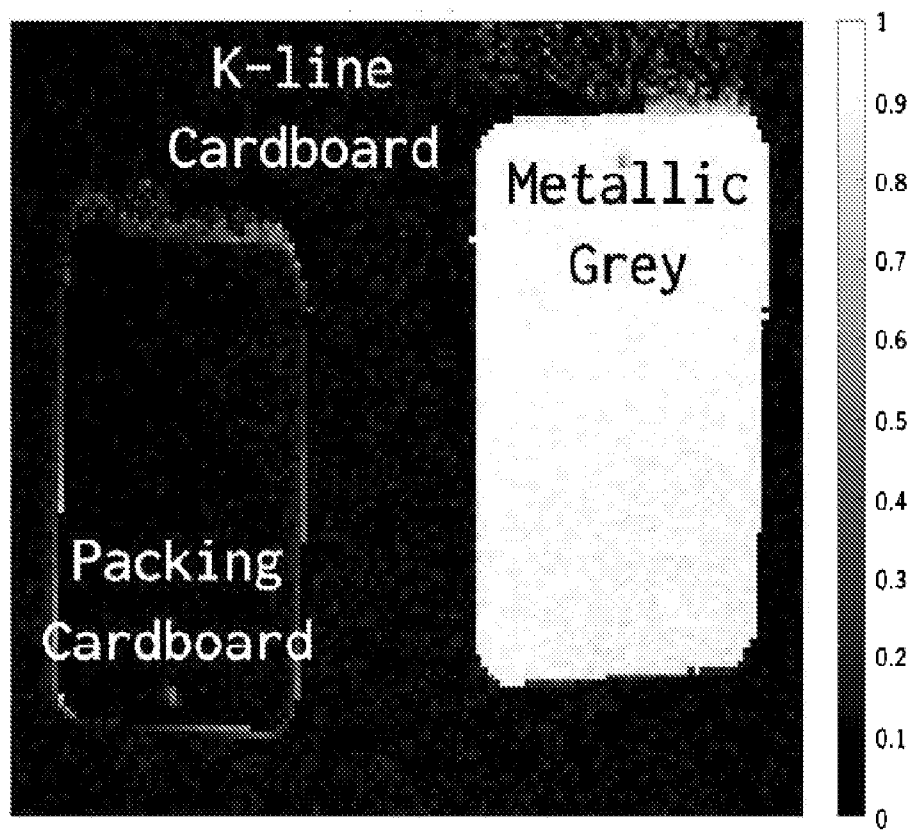


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/055588

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S17/10 G01S17/42 G01S17/89 G01S17/93 G01S7/48
G01S7/481 G01S7/499

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

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 3 182 158 A1 (STMICROELECTRONICS LTD [GB]) 21 June 2017 (2017-06-21) abstract; figures 1, 12 paragraphs [0020] - [0022], [0028] paragraphs [0031], [0049], [0059] paragraphs [0060], [0061], [0062] -----	1-12, 15
X	US 9 116 243 B1 (BROWN ROBERT G [US]) 25 August 2015 (2015-08-25) abstract; figure 5 column 5, line 39 - line 60 column 6, line 44 - line 51 column 6, line 58 - column 7, line 37 ----- -/--	10, 13, 15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

21 March 2019

Date of mailing of the international search report

29/03/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Knoll, Bernhard

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2018/055588

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2016 115277 A1 (BERLOW JULIAN [DE]) 22 February 2018 (2018-02-22) abstract; figures 1 - 3 paragraphs [0009], [0028], [0029] paragraphs [0034], [0041], [0042] paragraph [0044] - paragraph [0047] paragraphs [0050], [0051] -----	10, 14, 15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2018/055588

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			CN 205809294 U	14-12-2016
			EP 3182158 A1	21-06-2017
			US 2017176184 A1	22-06-2017

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DE 102016115277	A1	22-02-2018	DE 102016115277 A1	22-02-2018
			WO 2018033446 A1	22-02-2018
