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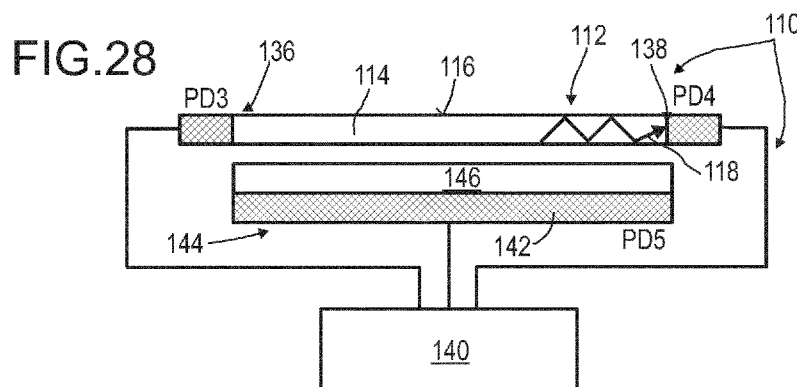
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(54) Title: OPTICAL DETECTOR COMPRISING AT LEAST ONE OPTICAL WAVEGUIDE



(57) Abstract: The present invention refers to an optical detector (110) comprising at least one optical waveguide (112), the optical waveguide (112) having at least one transparent matrix material (120) and at least one fluorescent colorant (122) embedded into the matrix material (120), wherein the fluorescent colorant (122), in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, the optical waveguide (112) being configured for waveguiding fluorescence light generated by the fluorescent colorant (122), the optical waveguide (112) further having at least one light-sensitive area (116) configured for being illuminated by at least one light beam (174), the optical detector (110) further comprising at least one photosensitive element (124, 126, 128, 130) configured for detecting fluorescence light generated by the fluorescent colorant (122), excited by the light beam (174), waveguided by the optical waveguide (112) and coupled out from the optical waveguide (112).

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Optical detector comprising at least one optical waveguideField of the invention

5 The invention relates to an optical detector comprising at least one optical waveguide, a method for manufacturing an optical waveguide and to various uses of the optical detector. The invention further relates to a detector system, a human-machine interface for exchanging at least one item of information between a user and a machine, an entertainment device, a tracking system, and a camera. The devices and methods according to the present invention
10 specifically may be employed for example in various areas of daily life, gaming, traffic technology, production technology, photography such as digital photography or video photography for arts, documentation or technical purposes, medical technology or in the sciences. Further, the invention specifically may be used for scanning one or more objects and/or for scanning a scenery, such as for generating a depth profile of an object or of a
15 scenery, e.g. in the field of architecture, metrology, archaeology, arts, medicine, engineering or manufacturing. However, other applications are also possible.

Prior art

20 Various optical detectors are known from the prior art. While photovoltaic devices are generally used to convert electromagnetic radiation, for example, ultraviolet, visible or infrared light, into electrical signals or electrical energy, optical detectors are generally used for picking up image information and/or for detecting at least one optical parameter, for example, a brightness.

25 Optical detectors which can be based generally on the use of inorganic and/or organic sensor materials are known from the prior art. Examples of such detectors are disclosed in US 2007/0176165 A1, US 6,995,445 B2, DE 2501124 A1, DE 3225372 A1 or else in numerous other prior art documents. To an increasing extent, in particular for cost reasons and for reasons of large-area processing, detectors comprising at least one organic sensor material are being
30 used, as described for example in US 2007/0176165 A1.

Further, generally, for various other detector concepts and uses of the detector, reference may be made to WO 2014/097181 A1, WO 2014/198626 A1, WO 2014/198629 A1, WO 2014/198625 A1, and WO 2015/024871 A1, the full content of which is herewith included by
35 reference. Further, referring to potential materials and optical detectors which may also be employed in the context of the present invention as well as to their uses, reference may be made to WO 2016/120392 A1, WO 2016/169871 A1, WO 2017/012964 A1, WO 2017/025567 A1, WO 2017/046121 A1, WO 2017/089540 A1, WO 2017/089553 A1, WO 2017/093453 A1, the full content of all of which is herewith also included by reference.

40 Further, P. Bartu, R. Koeppe, N. Arnold, A. Neulinger, L. Fallon, and S. Bauer, *Conformable large-area position-sensitive photodetectors based on luminescence collecting silicone waveguides*, J. Appl. Phys. 107, 123101 (2010), describe a kind of position sensitive detector (PSD) device which might be suitable for large areas and on curved surfaces. This kind of PSD

device is based on a planar silicone waveguide with embedded fluorescent dyes used in conjunction with small silicon photodiodes, which may be arranged in a regular pattern, such as at the edges of the device or distributed over the device. Impinging laser light may be absorbed by the dye in the PSD device and re-emitted as fluorescence light at a larger wavelength. Due to a predominantly isotropic emission from the fluorescent dye molecules, the re-emitted light may at least partially be coupled into the planar silicone waveguide and directed to the silicon photodiodes, wherein the light signals may be detected via the silicon photodiodes. By using algorithms as known from global positioning systems (GPS), the position of light spots may be determined. For further details and for information about later developments which are related to this kind of PSD device reference may be made to WO 2009/105801 A1, WO 2010/118409 A2, WO 2010/118450 A1, WO 2013/090960 A1, WO 2013/ 116883 A1, and WO2015/081362 A1. However, this kind of PSD device is not adapted for 3D-sensing such that further development is required to provide an optical detector well-suited for this purpose.

Further, Goetzberger A et al, *Solar Energy Conversion With Fluorescent Collectors*, Applied Physics, Springer Verlag, Heidelberg, DE, Vol. 14, 1977, pages 123-139; Wilhelm Stahl et al, *Fluoreszenzkollektoren*, Physik in unserer Zeit, VCH, Weinheim, DE, Vol. 16, No. 6; and WO 2012/050059 A1 describe solar cells comprising fluorescence collectors. For this purpose, collection and concentration of direct and diffuse radiation is achieved by using a stack of transparent sheets of a material doped with fluorescent dyes. Hereby, the efficiency of light collection can be increased by light guiding and an appropriate design of the collectors.

Despite the advantages implied by the above-mentioned devices and detectors, several technical challenges remain. Thus, there still is a need for improvements with respect to a simple, cost-efficient and, still, reliable spatial detector, in particular, for the visual and infrared spectral range.

Problem addressed by the invention

It is therefore an object of the present invention to provide devices and methods facing the above-mentioned technical challenges of known devices and methods. Specifically, it is an object of the present invention to provide devices and manufacturing methods a simple, cost-efficient and, still, reliable optical detector, in particular, for the visual and infrared spectral range.

Summary of the invention

This problem is solved by the invention with the features of the independent patent claims. Advantageous developments of the invention, which can be realized individually or in combination, are presented in the dependent claims and/or in the following specification and detailed embodiments.

As used in the following, the terms “have”, “comprise” or “include” or any arbitrary grammatical variations thereof are used in a non-exclusive way. Thus, these terms may both refer to a situation in which, besides the feature introduced by these terms, no further features are present in the entity described in this context and to a situation in which one or more further features are present. As an example, the expressions “A has B”, “A comprises B” and “A includes B” may both refer to a situation in which, besides B, no other element is present in A (i.e. a situation in which A solely and exclusively consists of B) and to a situation in which, besides B, one or more further elements are present in entity A, such as element C, elements C and D or even further elements.

Further, it shall be noted that the terms “at least one”, “one or more” or similar expressions indicating that a feature or element may be present once or more than once typically will be used only once when introducing the respective feature or element. In the following, in most cases, when referring to the respective feature or element, the expressions “at least one” or “one or more” will not be repeated, notwithstanding the fact that the respective feature or element may be present once or more than once.

Further, as used in the following, the terms “preferably”, “more preferably”, “particularly”, “more particularly”, “specifically”, “more specifically” or similar terms are used in conjunction with optional features, without restricting alternative possibilities. Thus, features introduced by these terms are optional features and are not intended to restrict the scope of the claims in any way. The invention may, as the skilled person will recognize, be performed by using alternative features. Similarly, features introduced by “in an embodiment of the invention” or similar expressions are intended to be optional features, without any restriction regarding alternative embodiments of the invention, without any restrictions regarding the scope of the invention and without any restriction regarding the possibility of combining the features introduced in such a way with other optional or non-optional features of the invention.

The optical detector

In a first aspect, the present invention relates to an optical detector, comprising at least one optical waveguide as described below in more detail, the optical waveguide having at least one light-sensitive area configured for being illuminated by at least one light beam, the optical detector further comprising at least one photosensitive element configured for detecting fluorescence light generated by the fluorescent colorant, excited by the light beam, waveguided by the optical waveguide and coupled out from the optical waveguide. In particular contrast to solar cells comprising fluorescence collectors which comprise a set of transparent sheets of material which is doped with appropriate fluorescent molecules in order to allow incoming light to interact with the fluorescent molecules in a manner that the captured light may be guided within the transparent sheet in order to increase solar cell efficiency for power generation, where it does not matter whether the light may be collected within an absorption maximum of the fluorescent molecule or outside the absorption maximum, the optical detector according to the present invention comprises one or, preferably, more photosensitive elements which are

configured for detecting fluorescence light that has been generated by the fluorescent colorant and travelled, from the origin of generation, to one of the photosensitive elements.

In a particular embodiment, the optical detector, thus, comprises at least two of the photosensitive elements which are located at different positions. Herein, the optical detector may further comprise at least one evaluation device, the evaluation device being configured for determining at least one transversal coordinate of the light spot generated by the light beam on the light-sensitive area.

As further used herein, the term "light-sensitive area" generally refers to a two-dimensional or three-dimensional region of an element, specifically of the optical waveguide, which is sensitive to external influences and, e.g., produces at least one reaction in response to an external stimulus. In this case, specifically, the light-sensitive area may be sensitive to an optical excitation. The light-sensitive area specifically may be a part of a surface or the volume of the optical waveguide, such as the whole surface of the optical waveguide or a part thereof.

As further used herein, the term "light beam" generally refers to an amount of light, specifically an amount of light traveling essentially in the same direction, including the possibility of the light beam having a spreading angle or widening angle.

As further used herein, the term "total power of the fluorescence light" generally refers to the integral over the light intensities of the fluorescence light over all spatial directions. As example, the total power may be determined as a surface integral over the intensities of the fluorescence light over the surface of a sphere enclosing the whole fluorescent area, i.e. the area of the light-sensitive area in which fluorescence takes place. The total power of fluorescence, as an example, may be measured by using an integrating sphere. The term "intensity of the illumination" generally refers to the power of illumination per unit area, as the skilled person will recognize.

As further used herein, the term "photosensitive element" generally refers to an element which is sensitive against illumination in one or more of the ultraviolet, the visible or the near infrared spectral range. Specifically, the photosensitive element may be or may comprise at least one element selected from the group consisting of a photodiode, a photocell, a photoconductor, a phototransistor or any combination thereof. Any other type of photosensitive element may be used. Herein, the photosensitive element generally may fully or partially be made of inorganic materials and/or may fully or partially be made of organic materials. Most commonly, one or more photodiodes may be used, such as commercially available photodiodes, e.g. inorganic semiconductor photodiodes.

As indicated above, the photosensitive element is configured for detecting fluorescence light generated by the fluorescent colorant, excited by the light beam, waveguided by the optical waveguide and coupled out from the optical waveguide. For this purpose, the photosensitive element may be fully or partially located in the same plane as the fluorescent waveguiding sheet

and/or may be fully or partially be located in a different plane. In the latter case, as will be outlined in further detail below, as an example, an optical coupling between the fluorescent waveguiding sheet and the photosensitive element may take place, by using at least one optical coupling element. Further, in case more than one photosensitive element may be present, a first photosensitive element may be located in the same plane as the fluorescent waveguiding sheet while a further photosensitive element may be located outside the plane of the fluorescent waveguiding sheet. Further, a direction of view of the photosensitive element may be parallel to the plane of the fluorescent waveguiding sheet or may be directed otherwise, such as perpendicular to the plane. Therein, when talking about a “plane” of the fluorescent waveguiding sheet, this term does not necessarily imply that the fluorescent waveguiding sheet is fully planar. Thus, as an example, the fluorescent waveguiding sheet may also be curved or bent, and the plane of the fluorescent waveguiding sheet at the location of the respective photosensitive element may be a local tangential plane.

As already outlined above, in order to improve feeding fluorescence light guided from the light spot towards the photosensitive element into the photosensitive element, at least one optical coupling may take place, in particular, by using at least one optical coupling element in between the fluorescent waveguiding sheet and the photosensitive element. Thus, the photosensitive element may be optically coupled to the fluorescent waveguiding sheet by the at least one optical coupling element configured for at least partially coupling the fluorescence light guided by the fluorescent waveguiding sheet out of the fluorescent waveguiding sheet and, preferably, at least partially into the photosensitive element. As used herein, the term “optical coupling element” generally refers to an arbitrary element which is configured for one or more of disturbing, diminishing or interrupting an internal total reflection within the fluorescent waveguiding sheet which takes place during waveguiding within the fluorescent waveguiding sheet. Thus, as an example, the optical coupling element may be an arbitrary transparent element having an index of refraction in between an index of refraction of the fluorescent waveguiding sheet and the photosensitive element and/or the ambient atmosphere, such as air. Thus, as an example, in case an index of refraction of the fluorescent waveguiding sheet is denoted by n_1 , and an index of refraction of the photosensitive element is denoted by n_2 , an index of refraction n_3 of the optical coupling element may be $n_1 < n_3 < n_2$ or $n_1 > n_3 > n_2$. The optical coupling element may be in direct contact with the fluorescent waveguiding sheet, such as with at least one surface, such as a surface facing the object and/or a surface facing away from the object, of the fluorescent waveguiding sheet. Further, the optical coupling element may also be in direct contact with the photosensitive element. Further, in case more than one photosensitive element may be present, an independent optical coupling element may be provided for each photosensitive element, or alternatively, a plurality of photosensitive elements may share a common optical coupling element, or, alternatively, a plurality of optical coupling elements may be coupled to one photosensitive element.

Various ways of optical coupling are generally known to the skilled person and may also be used for coupling fluorescence light from the fluorescent waveguiding sheet into the respective photosensitive element. Thus, as an example, the at least one optical coupling element may

comprise at least one element selected from the group consisting of: a portion of transparent adhesive attaching the photosensitive element to the fluorescent waveguiding sheet; an etched portion within the fluorescent waveguiding sheet, such as within a surface of the fluorescent waveguiding sheet, such as a surface facing the object and/or facing away from the object; a scratch in the fluorescent waveguiding sheet, such as a scratch in the surface of the fluorescent waveguiding sheet, such as a surface facing the object and/or facing away from the object; a prism. Additionally or alternatively, other optical coupling elements are generally known and may also be used in the present invention. In a most simple case, the photosensitive element may simply be adhered or glued to a surface of the fluorescent waveguiding sheet, such as by at least one transparent glue or adhesive, e.g. a transparent epoxy. Other ways of optical coupling are feasible. Regarding the placement of the photosensitive element, a plurality of possibilities exists. Thus, as an example, the photosensitive element may be located at a partition of the fluorescent waveguiding sheet, such as a straight edge of the fluorescent waveguiding sheet, a straight rim portion, or a corner of the fluorescent waveguiding sheet. Other possibilities are generally given.

As used herein, a signal generally refers to an arbitrary memorable and transferable response which is generated by the photosensitive element, in response to the illumination. Thus, as an example, the signal may be or may comprise at least one electronic signal, which may be or may comprise a digital electronic signal and/or an analogue electronic signal. The signal may be or may comprise at least one voltage signal and/or at least one current signal. Further, either raw signals may be used, or the optical detector or any other element may be adapted to process or preprocess the signal, thereby generating secondary signals, which may also be used as signals, such as preprocessing by filtering or the like.

As further used herein, the term "evaluation device" generally refers to an arbitrary device adapted to perform the named operations, preferably by using at least one data processing device and, more preferably, by using at least one processor and/or at least one application-specific integrated circuit. Thus, as an example, the at least one evaluation device may comprise at least one data processing device having a software code stored thereon comprising a number of computer commands. Thus, as an example, one or more relationships may be implemented in software and/or hardware, such as by implementing one or more lookup tables. Thus, as an example, the evaluation device may comprise one or more programmable devices such as one or more computers, application-specific integrated circuits (ASICs) or Field Programmable Gate Arrays (FPGAs) which are configured to perform an evaluation of the signal. Additionally or alternatively, however, the evaluation device may also fully or partially be embodied by hardware. Herein, the optical waveguide and the evaluation device may fully or partially be integrated into one or more devices. The degree of integration may also have an impact on the speed of evaluation and the maximum frequency. Thus, the optical detector may also fully or partially be embodied as a camera and/or may be used in a camera, suited for acquiring standstill images or suited for acquiring video clips. Further, the optical detector may comprise one or more signal processing devices, such as one or more filters and/or analogue-digital-converters for processing and/or preprocessing the at least one signal. The one or more

signal processing devices may fully or partially be integrated into the optical detector and/or may fully or partially be embodied as independent software and/or hardware components.

- The light beam propagates from the object towards the optical detector. Herein, the light beam may originate from the object, such as by the object and/or at least one illumination source integrated or attached to the object emitting the light beam, or may originate from a different illumination source, such as from an illumination source directly or indirectly illuminating the object, wherein the light beam is reflected or scattered by the object and is, thereby, at least partially directed towards the optical detector. Herein, the at least one illumination source may, preferably, emit light in a wavelength range covering the range of 400 nm to 900 nm, more preferred the range of 550 nm to 850 nm, in particular, the range of 600 nm to 800 nm, where the fluorescent material, such as the fluorescent colorant, in particular the dye, may exhibit an absorption maximum.
- The optical detector according to one or more of the above-mentioned embodiments may be modified and improved or even optimized in various ways, which will be briefly discussed in the following and which may also be implemented in various arbitrary combinations, as the skilled person will recognize.
- Further optional details may refer to the light-sensitive area. Thus, as an example, the light-sensitive area specifically may be a homogeneous light-sensitive area. Thus, the light-sensitive area may not be subdivided physically into partial areas, such as pixels. Contrarily, the light-sensitive area may be one homogeneous area which forms a uniform fluorescence.
- The light-sensitive area specifically may be a large light-sensitive area. Thus, as an example, the light-sensitive area may have a surface of at least 5 mm², preferably of at least 10 mm², more preferably of at least 100 mm², more preferably of at least 400 mm². As an example, the light-sensitive area may have a surface of 5 mm² to 10,000 mm², such as 100 mm² to 2500 mm². The large-area design of the light-sensitive area is advantageous in many ways. Thus, specifically, by increasing the surface of the light-sensitive area, a resolution of the determination of the transversal coordinates may be increased. Further, the field of view of the optical detector, e.g. the viewing angle, may be widened by using a large light-sensitive area.
- The optical detector may comprise a single optical waveguide or a plurality of optical waveguides. In case a plurality of optical waveguides is used, the optical waveguides may be located in one and the same beam path or at least two of the optical waveguides may be positioned in different partial beam paths of the optical detector. Thus, the beam path of the optical detector may be split into two or more partial beam paths, such as by using one or more beam splitting elements, specifically one or more semi-transparent mirrors and/or beam splitting cubes. Other embodiments are feasible. Further, the optical waveguides may have identical spectral sensitivities. Alternatively, at least two of the optical waveguides may have differing spectral sensitivities, wherein the evaluation device, in the latter case, may be adapted to determine a wavelength-dependent property of the light beam by comparing signals of the

optical waveguides having differing spectral sensitivities. This feature may, generally, be achieved by using different types of optical filters and/or different types of absorbing materials for the optical waveguides, such as different types of colorants or other absorbing materials.

Additionally or alternatively, differing spectral properties of the optical waveguides may be

generated by other means implemented into the optical detector, such as by using one or more wavelength-selective elements, such as one or more filters (such as color filters) in front of the optical waveguides and/or by using one or more prisms and/or by using one or more dichroitic mirrors. Thus, in case a plurality of optical waveguides is provided, at least one of the optical waveguides may comprise a wavelength-selective element such as a color filter, having a specific transmission or reflection characteristic, thereby generating differing spectral properties of the optical waveguides.

The optical detector may further comprise one or more additional optical elements. As an example, the optical detector may comprise one or more lenses and/or one or more flat or

curved reflective elements, as will be outlined in further detail below in the context of the transfer device. Specifically, however, the optical detector may further comprise at least one wavelength selective element, also referred to as at least one optical filter or filter element. The at least one optical filter, as an example, may comprise at least one transmissive filter or absorption filter, at least one grating, at least one dichroitic mirror or any combination thereof.

Other types of wavelength selective elements may be used. Preferably, the at least one optical detector comprises at least one optical filter element having at least one optical short-pass filter. As an example, the optical short-pass filter may be located in a beam path behind the fluorescent waveguiding sheet, such that the light beam may, firstly, pass the fluorescent waveguiding sheet and may, preferably afterwards, secondly, pass the at least one short-pass filter. In the beam path behind the at least one short-pass filter, preferably, at least one further element may be placed, such as a reference photosensitive element.

Thus, generally, the optical detector may further comprise at least one reference photosensitive element, also referred to as a reference photosensor, a reference detector or a photosensitive

reference element. The reference photosensitive element generally may be an arbitrary photosensitive element which is configured and/or arranged to detect the light beam before or after passing the at least one fluorescent waveguiding sheet, or a part of this light beam. The photosensitive element specifically may be used for calibration and/or normalization purposes, in order to render the above-mentioned means and methods more or less independent of the total power of the light beam. The reference photosensitive element generally may be designed in a similar way as the photosensitive element and, as an example, may comprise one or more of a photodiode, a photocell, a photoconductor, a phototransistor or a combination thereof. The reference photosensitive element may, specifically, be selected from the group consisting of an organic photosensitive element and an inorganic photosensitive element. The reference photosensitive element specifically may be or may comprise a large-area photosensitive element, which, as an example, covers at least 10%, such as 10% to 100%, of the area of the fluorescent waveguiding sheet and/or of the light-sensitive area of thereof. The reference photosensitive element, specifically, may be designed to detect the light of the light beam after

passing the fluorescent waveguiding sheet and to generate at least one reference signal. The reference signal specifically may be used for normalizing the sum signal of the photosensitive elements. The evaluation device may, specifically, be adapted to take into account the reference signal.

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The optical detector may further comprise one or more additional elements such as one or more additional optical elements. Further, the optical detector may fully or partially be integrated into at least one housing. The optical detector specifically may comprise at least one transfer device, the transfer device being adapted to guide the light beam onto the optical waveguide. The transfer device may comprise one or more of: at least one lens, preferably at least one focus-tunable lens; at least one beam deflection element, preferably at least one mirror; at least one beam splitting element, preferably at least one of a beam splitting cube or a beam splitting mirror; at least one multi-lens system.

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The optical detector may further comprise one or more optical elements, such as one or more lenses and/or one or more refractive elements, one or more mirrors, one or more diaphragms or the like. These optical elements which are adapted to modify the light beam, such as by modifying one or more of a beam parameter of the light beam, a width of the light beam or a direction of the light beam, above and in the following, are also referred to as a "transfer element". Thus, the optical detector may further comprise at least one transfer device, wherein the transfer device may be adapted to guide the light beam onto the optical waveguide, such as by one or more of deflecting, focusing or defocusing the light beam. Specifically, the transfer device may comprise one or more lenses and/or one or more curved mirrors and/or one or more other types of refractive elements.

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In case the optical detector comprises one or more transfer devices, the at least one transfer device specifically may have at least one focal length. Therein, the focal length may be fixed or variable. In the latter case, specifically, one or more focused tunable lenses may be comprised in the at least one transfer device. In this context, as an example, reference may be made to WO2016/092452 A1, the full content of which is herewith included by reference. The focus-tunable lenses disclosed therein may also be used in the at least one optional transfer device of the optical detector according to the present invention.

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In a particular embodiment, the evaluation device may, further, be configured to determine at least one transversal coordinate x , y of an object by evaluating the signals of at least two of the photosensitive elements. For the purpose of determining the at least one transversal coordinate in one or more directions, the signals of the at least two photosensitive elements may be compared. Thus, as is evident to the skilled person, the signal of a respective photosensitive element, which represents the fluorescence light guided to the photosensitive elements by the fluorescent waveguiding sheet from the light spot and, thus, from the location of generation of the fluorescence light, depends on a distance between the light spot and the respective photosensitive element. Generally, with an increasing distance between the light spot and the photosensitive element, the signal of the respective photosensitive element will decrease, such

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as due to losses during waveguiding and/or due to spreading of the fluorescence light. By comparing the signals of the photosensitive elements located at different, known positions, the lateral or transversal position of the light spot on the fluorescent waveguiding sheet may, thus, be determined and, therefrom, by using e.g. a known or determinable relationship between the transversal position of the light spot and the transversal coordinate of the object, the transversal coordinate of the object. Again, empirical relationships and/or semi-empirical relationships and/or analytical relationships may be used, such as the lens equation which is generally known to the skilled person.

As an example, at least one difference signal between at least two signals of at least two photosensitive elements may be generated for comparing these signals and, thus, for determining the transversal coordinate. Consequently, the evaluation device may comprise at least one subtracting device configured to form at least one difference signal D between at least two signals generated by at least two of the photosensitive elements. The signals may comprise at least one first signal s_1 and at least one second signal s_2 , wherein the at least one difference signal D specifically may be proportional to $a \cdot s_1 - b \cdot s_2$, with a, b being real number coefficients, preferably with $a = 1$ and $b = 1$. In this simple example, the at least one difference signal D specifically may be derived according to Equation (1)

$$D = (a \cdot s_1 - b \cdot s_2) / (a \cdot s_1 + b \cdot s_2). \quad (1)$$

The subtracting device specifically may be configured to form at least one first difference signal D_x from which at least one first transversal coordinate x of the object is derived. The subtracting device may further be configured to form at least one second difference signal D_y from which at least one second transversal coordinate y of the object is derived. Thus, as an example, Cartesian coordinates of the object may be derived. It shall be noted, however, that other coordinate systems may be used, such as polar coordinate systems, depending on, e.g., a geometry of the overall setup.

The first difference signal D_x specifically may be generated from at least two signals s_{x1} , s_{x2} of at least two photosensitive elements located at opposing partitions of the waveguiding sheet in a first dimension, e.g. opposing straight rim portions, which may also be referred to as an x-direction or x-dimension. Similarly, the second difference signal D_y may be generated from at least two signals s_{y1} , s_{y2} of at least two photosensitive elements located at opposing partitions, e.g. opposing straight rim portions, of the waveguiding sheet in a second dimension, which may also be referred to as a y-direction or a y-dimension. Thus, the coordinate system may be defined, with an optical axis of the optical detector being a z-axis, and with two axes x and y in a plane of the fluorescent waveguiding sheet, e.g. in a plane perpendicular to the z-axis. Other coordinate systems, however, are feasible.

In this particular embodiment, at least two photosensitive elements may be located at opposing partitions of the optical waveguide, e.g. opposing straight rim portions of a sheet, foil or disc. As an example, the fluorescent waveguiding sheet may be or may comprise a rectangular

fluorescent waveguiding sheet, and at least two photosensitive elements may be located at opposing, parallel partitions, e.g. opposing straight rim portions, of the rectangular fluorescent waveguiding sheet. As an example, two parallel partitions, e.g. two parallel rim portions, may be located in an opposing fashion in an x-direction, each partition having at least one
5 photosensitive element, and/or two parallel partitions, e.g. two parallel rim portions, may be located in an opposing fashion in a y-direction, each partition having at least one photosensitive element. Thus, generally, the rim portions of the rectangular fluorescent waveguiding sheet may be oriented perpendicular to the axes of an x-y-coordinate system. The described Cartesian coordinate system, however, is fairly easy to implement from a technical point of view, and the
10 evaluation of the signals, such as by using Equation (1), is rather simple.

In a further embodiment, the optical detector may furthermore have at least one modulation device for modulating the illumination. Accordingly, the optical detector may be designed to detect at least two signals in case of different modulations, in particular at least two signals
15 comprising different modulation frequencies. In this case, the evaluation device may be configured to detect at least two transversal signals in case of different modulations, in particular at least two transversal signals comprising different modulation frequencies. In this case, the evaluation device may further be configured to determine the at least one transversal coordinate of the object by evaluating the at least two modulated transversal signals. Thus, the
20 optical detector may be designed in such a way that the at least one transversal signal may also be dependent on a modulation frequency of a modulation of the illumination. Hereby, the evaluation device may optionally be configured to take account of a modulation frequency with which the illumination may be modulated. Thus, a plurality of signals may be detected by the same optical detector by using different modulation frequencies. Thus, at least two transversal
25 signals may be acquired at different frequencies of a modulation of the illumination, wherein, from the at least two signals, for example by comparison with corresponding calibration curves, it may be possible to deduce a total power and/or geometry of the illumination, and/or again, to distinguish between two different objects or parts thereof which may be illuminated by light having different modulation frequencies.

Thus, the optical detector can, furthermore, comprise at least one modulation device for modulating the illumination, in particular for periodic modulation, in particular a periodic beam interrupting device. A modulation of the illumination should be understood to mean a process in which a total power of the illumination may be varied, preferably periodically, in particular with
35 one or a plurality of modulation frequencies, by way of example, with a frequency of 0.05 Hz to 1 MHz, such as 0.1 Hz to 100 kHz. In particular, a periodic modulation can be effected between a maximum value and a minimum value of the total power of the illumination. The minimum value can be 0, but can also exceed 0, such that, by way of example, a complete modulation does not have to be effected. The modulation can be effected for example in a beam path
40 between the illumination source and the optical detector, for example by the at least one modulation device being arranged in said beam path.

The at least one modulation device can comprise for example a beam chopper or some other type of periodic beam interrupting device, for example comprising at least one interrupter blade or interrupter wheel, which preferably rotates at constant speed and which can thus periodically interrupt the illumination. Alternatively or additionally, however, it may also be possible to use one or a plurality of different types of modulation devices, for example modulation devices based on an electro-optical effect and/or an acousto-optical effect. Once again alternatively or additionally, the at least one optional illumination source itself can also be designed to generate a modulated illumination, for example by said illumination source itself having a modulated intensity and/or total power, for example a periodically modulated total power, and/or by said illumination source being embodied as a pulsed illumination source, for example as a pulsed laser. Thus, by way of example, the at least one modulation device can also be wholly or partly integrated into the illumination source. Various other possibilities may also be feasible.

In a further aspect of the present invention, a human-machine interface for exchanging at least one item of information between a user and a machine is disclosed. The human-machine interface comprises at least one detector system according to the embodiments disclosed above and/or according to one or more of the embodiments disclosed in further detail below. Therein, at least one beacon device may be adapted to be at least one of directly or indirectly attached to the user or held by the user. The human-machine interface is designed to determine at least one position of the user by means of the detector system, wherein the human-machine interface is designed to assign to the position at least one item of information.

In a further aspect of the present invention, an entertainment device for carrying out at least one entertainment function is disclosed. The entertainment device comprises at least one human-machine interface according to the embodiment disclosed above and/or according to one or more of the embodiments disclosed in further detail below. The entertainment device is configured to enable at least one item of information to be input by a player by means of the human-machine interface. The entertainment device is further configured to vary the entertainment function in accordance with the information.

In a further aspect of the present invention, a tracking system for tracking a position of at least one movable object is disclosed. The tracking system comprises at least one detector system according to one or more of the embodiments referring to a detector system as disclosed above and/or as disclosed in further detail below. The tracking system further comprises at least one track controller. The track controller is adapted to track a series of positions of the object at specific points in time.

In a further aspect of the present invention, a camera for imaging at least one object is disclosed. The camera comprises at least one optical detector according to any one of the embodiments referring to an optical detector as disclosed above or as disclosed in further detail below.

The optical waveguide

As indicated above, the optical detector of the present invention comprises an optical waveguide having at least one transparent matrix material and at least one fluorescent colorant embedded into the matrix material, wherein the fluorescent colorant, in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, the optical waveguide being configured for waveguiding fluorescence light generated by the fluorescent colorant.

Herein, the term “waveguiding” generally refers to the property of an optical element or a plurality of optical elements to guide light in at least one of the ultraviolet and/or visible and/or the near infrared spectral ranges by internal reflection, specifically by internal total reflection. Consequently, the term “waveguide” relates an optical element to which exhibits a waveguiding property as described herein.

Further, the term “fluorescence” generally refers to the property of an element or a material to emit secondary light, also referred to as fluorescence light, in one or more of the ultraviolet, visible or the near infrared spectral range, in response to excitation by electromagnetic radiation, also referred to as primary radiation or excitation radiation, such as primary light or excitation light. In most cases, the emitted light, fluorescence light or secondary light has a longer wavelength and a lower energy than the primary radiation. The primary radiation typically induces the presence of excited states within the fluorescent material, such as so-called excitons. Typically, excited state decay times for photon emissions with energies from the UV to near infrared are within the range of 0.5 to 20 nanoseconds. However, within the present invention, electromagnetic radiation is, as described below in more detail, primarily absorbed in a wavelength range of 400 nm to 900 nm, where an absorption maximum occurs in the wavelength range of 500 nm to 850 nm, while the emitted light has a longer wavelength, i.e. in the visible spectral range or in the infrared spectral range, preferably in the infrared spectral range, in particular, in the range of 780 nm to 3.0 micrometers.

Similarly, as used herein, the term “fluorescent colorant” generally refers to a material having fluorescence properties. The term “fluorescence light” generally refers to the secondary light generated during the above-mentioned fluorescence process.

As will be outlined in further detail below, the optical waveguide specifically may be or may comprise a transparent material, specifically a transparent optical waveguide. In particular, the transparency of the optical waveguide with respect to an incident light beam may be a transparency of at least 50 %, preferably of at least 75%, most preferred of at least 85 %, in the visible spectral range and/or the near infrared spectral range or a part thereof, such as in a range of 400 nm to 900 nm. Other embodiments are feasible.

Further, the optical waveguide may, at least partially, assume at least one shape, wherein the shape may, in particular, be selected from a sheet, a foil, a disc, a bar, or a slab. As used herein, the terms “sheet”, “foil”, and “disc”, generally, refer to an element which has a lateral

extension, such as a diameter or an equivalent diameter, representing a two-dimensional area which significantly exceeds a thickness of the element, such as by at least a factor of 5, more preferably by at least a factor of 10 or even more preferably by at least a factor of 20, a factor of 50 or even a factor of 100. As generally used, the terms “sheet” and “foil” may be distinguished by their flexibility, wherein the foil is usually considered as flexible and, thus, easily deformable while the sheet is usually considered as rigid or at least less flexible. Further, the term “disc” is generally used when the lateral extension exhibits a form having a circular or oval rim or boundary. Thus, the optical waveguide specifically may comprise at least one planar fluorescent waveguiding sheet, foil or disc. Therein, however, slight curvatures still may be tolerated. In other embodiments, however, the optical waveguide sheet may also be embodied as a curved fluorescent waveguiding sheet, foil or disc, such as in order to provoke specific optical effects which might be desirable in certain applications. Thus, one of the advantages of the present optical detector may reside in the fact that the fluorescent waveguiding sheet, foil or disc specifically may be curved, flexible or having a specific geometry. Herein, the fluorescent waveguiding sheet, foil or disc may have a thickness of 10 μm to 3 mm, preferably a thickness of 100 μm to 1 mm, such as a thickness of 50 μm to 2 mm. The thickness of the fluorescent waveguiding sheet, foil or disc specifically may be adapted to improve or optimize waveguiding properties of the fluorescence light.

In contrast hereto, the terms “bar” and “slab”, generally, refer to a further element in which a single dimension, usually denoted as a “length” exceed an extension of the further two dimensions of the element, such as by at least a factor of 5, more preferably by at least a factor of 10 or even more preferably by at least a factor of 20, a factor of 50 or even a factor of 100. However, other kinds or shapes may also be conceivable.

The matrix material

The optical waveguide comprises at least one transparent matrix material. As used herein, the term “matrix material” generally refers to a material which forms the main part of the optical waveguide and which defines the main body of the optical waveguide.

In the at least one matrix, the at least one fluorescent colorant is embedded. The term “embedded” is denoted to mean that the fluorescent colorant is distributed, preferably substantially homogeneously, more preferably homogeneously, within the matrix. Distributed is denoted to mean the fluorescent colorant is mixed into the matrix material, dispersed into the matrix material, chemically bound to the matrix material or dissolved in the matrix material. The term “substantially homogeneous distribution” means in the present application that the colorant is substantially evenly, i.e. substantially uniformly, distributes throughout the matrix material. In particular, the at least one fluorescent colorant is dissolved or dispersed within the at least one matrix material.

As matrix material, in general, any matrix material known to those skilled in the art may be employed provided that the matrix material is transparent and in combination with at least one

fluorescent colorant embedded therein is capable of waveguiding the fluorescent light generated by the fluorescent colorant.

The term “transparent” is understood to mean a transmission of the emitted light T_L of at least 50 %, more preferably of at least 75 %, more preferably of at least 85 %, in the wavelength ranges between 500 nm and 950 nm. Herein, the transmission of the emitted light may, preferably, be determined by comparing an intensity of a light beam after and prior to traversing an explicit distance within the matrix material.

10 The matrix material specifically may be or may comprise at least one polymer material.

Preferably, the matrix material comprises at least one thermoplastic polymer. Preferably, the thermoplastic polymer is selected from

- homo- and copolymers which comprise at least one copolymerized monomer
- 15 selected from C2-C10-monoolefins, 1,3-butadiene, 2-chloro-1,3-butadiene, vinyl alcohol and its C2-C10-alkyl esters, vinyl chloride, vinylidene chloride, glycidyl acrylate, glycidyl methacrylate, acrylates
- and methacrylates of C1-C10- alcohols, vinylaromatics, (meth)acrylonitrile, maleic anhydride, and ethylenically unsaturated mono- and dicarboxylic acids,
- 20 - homo- and copolymers of vinyl acetals,
- polyvinyl esters,
- polyvinylchlorides
- polycarbonates,
- polyesters,
- 25 - polyethers,
- polyether ketones,
- thermoplastic polyurethanes,
- polysulfides,
- polysulfones,
- 30 - polyether sulfones,
- cellulose alkyl esters,
- polypropylenes
- polyethylene terephthalates
- and mixtures of two or more thereof.

35 Mention may be made by way of example of polyacrylates having identical or different alcohol moieties from the group of the C4-C8-alcohols (particularly of butanol, hexanol, octanol, and 2-ethylhexanol), polycarbonate, polymethyl methacrylate (PMMA), methyl methacrylate, butyl acrylate copolymers, acrylonitrile-butadiene-styrene copolymers (ABSs), ethylene-propylene

40 copolymers, ethylene-propylene-diene copolymers (EPDMs), polystyrene (PS), styrene-acrylonitrile copolymers (SANs), acrylonitrile-styrene-acrylate (ASA), styrene-butadiene-methyl methacrylate copolymers (SBMMAs), styrene-maleic anhydride copolymers, styrene-methacrylic acid copolymers (SMAs), polyoxymethylene (POM), polyvinyl alcohol (PVAL),

polyvinyl acetate (PVA), polyvinylbutyral (PVB), polycaprolactone (PCL), polyhydroxybutyric acid (PHB), polyhydroxyvaleric acid (PHV), polylactic acid (PLA), ethylcellulose (EC), cellulose acetate (CA), cellulose propionate (CP), and cellulose acetate/butyrate (CAB).

- 5 Preferably, the matrix material comprises, in particular consists of, a polymer selected from the group consisting of polyester, polycarbonate (PC), polystyrene (PS), polymethyl methacrylate (PMMA), polyvinylchloride, polyamide, polyethylene, polypropylene, styrene/acrylonitrile (SAN), acrylonitrile/butadiene/styrene (ABS) and mixtures of two or more thereof. Particular preference is given to polycarbonate or poly(methyl-methacrylate).

10

The matrix material may further comprise suitable stabilizers to stabilize the polymer. Such stabilizers are known to the skilled person and include antioxidants, UV absorbers, light stabilizers, hindered amine light stabilizers, antiozonants and the like, in particular hindered amine light stabilizers. The term "hindered amine light stabilizer" refers to sterically hindered amines of the class of compounds typically represented by 2,2,6,6 tetraalkyl piperidines.

15

In case the matrix material comprises a stabilizer, the matrix material preferably comprises the stabilizer in an amount of 0.001 % by weight to 10 % by weight, based on the total weight of the sum of all matrix materials.

20

According to one preferred embodiment, the matrix material consists of the polymeric material.

The fluorescent colorants:

- 25 As described above, the matrix material comprises at least one fluorescent colorant embedded into the matrix material. Preferably, the material comprises the at least one fluorescent colorant in an amount in the range of from 1 ppm to 5 % by weight, more preferably in an amount in the range of from 5 ppm to 0.5 % by weight, more preferably in an amount in the range of from 10 ppm to 0.1 % by weight, more preferably in an amount in the range of from 100 ppm to 0.05 %
- 30 by weight, based on the total weight of the waveguide.

- As fluorescent colorant, in principle, any fluorescent colorant which, in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be used. Thus, the invention is not limited to fluorescent colorants with a
- 35 high quantum yield and/or large extinction coefficient. Surprisingly, waveguiding of fluorescent light was even demonstrated with fluorescent colorants having an absorption maximum of up to 800 nm, although such colorants are known for their low fluorescence quantum yields.

- As generally used, the term "absorption" refers to an optical property of a substance, such as of
- 40 the fluorescent colorant, which is related to receiving and keeping a portion of an incident radiation, in particular, of a light beam impinging the substance, rather than reflecting or transmitting it. Disregarding reflection, a transmission of the incident radiation through the substance may, thus, be incomplete, which results in an attenuation of the impinging light beam.

In general, the absorption of the incident radiation by the substance, however, depends on a wavelength of the incident light beam, whereby the absorption of the substance may vary over an increasing or a decreasing wavelength. In this regard, the term "absorption maximum" may, thus, refer to one or more specific wavelengths or wavelength ranges in which the absorption of the incident radiation by the substance may assume a higher value compared to adjacent wavelengths or wavelength ranges over a course of absorption values with regard to the corresponding wavelength.

In a particularly preferred embodiment, the absorption maximum may be an absolute maximum over a predefined wavelength range, in particular, over the whole above-mentioned wavelength range of 400 nm to 900 nm. Consequently, the term "absolute maximum" describes a type of absorption of the substance which assumes the highest value within the predefined wavelength range, thus, exceeding the absorption of the substance at all other wavelengths within the predefined wavelength range. However, a "relative maximum" may also be feasible, i.e. it may not be required that the absorption maximum may assume the highest value of the colorant as such as long as the absorption at the specific wavelength exceeds the absorption at adjacent wavelength ranges.

With regard to the present invention, considering a wavelength range of 400 nm to 900 nm, the fluorescent colorant has an absorption characteristic exhibiting an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm. This feature is to be understood that the fluorescent colorant may, however, exhibit a further maximum absorption maximum which may occur in the wavelength range below 400 nm. Preferably, the absorption maximum which occurs in the wavelength range of 500 nm to 850 nm is an absolute maximum within the wavelength range of 400 nm to 900 nm, as outlined above. More preferably, the absorption maximum which occurs in the wavelength range of 500 nm to 850 nm is an absolute maximum over the range of from 350 to 900 nm, i.e. any possible additional maximum optionally occurring in the wavelength range below 400 nm is preferably a relative maximum.

Preferably, the fluorescent colorant may, in the range of 400 nm to 900 nm, exhibit an absorption maximum in the wavelength range of 550 nm to 850 nm, more preferably in the range of 600 nm to 800 nm, preferably measured with the colorant embedded into the matrix material. In principle, any fluorescent colorant known to those skilled in the art may be employed, provided that these colorants display the desired absorption maximum defined above. A particular advantage of using a fluorescent colorant which may exhibit a fluorescence within the near infrared spectral range may be that the fluorescence may, thus, occur in a wavelength region for which the human eye is not sensitive.

In general, the course of the absorption of the fluorescent colorant over the predefined wavelength range may be measured by using the fluorescent colorant only. However, in a preferred embodiment, the course of the absorption of the fluorescent colorant over the predefined wavelength range may be measured by using the fluorescent colorant embedded within the matrix material, thereby taking into account that the absorption characteristic of the

matrix material in which the fluorescent colorant is disposed in within the optical waveguide. This preferred embodiment, thus, allows determining the absorption properties of the optical waveguide which has, according to the present invention, at least one transparent matrix material and at least one fluorescent colorant embedded therein in total.

- 5 A wide variety of fluorescent colorants is generally known to the skilled person. The fluorescent colorant is preferably an organic fluorescent colorant.

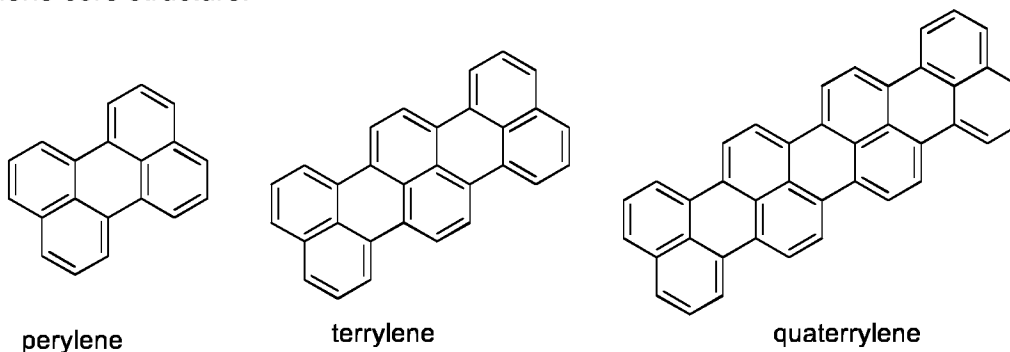
Preferably, the fluorescent colorant is selected from the group consisting of stilbenes, benzoxazoles, squaraines, bisdiphenylethylenes, coumarins, merocyanines, benzopyrans, 10 naphthalimides, rylene, phthalocyanines, naphthalocyanines, cyanines, xanthenes, oxazines, oxadiazols, squaraines, oxadiols, anthrachinones, acridines, arylmethanes, boron-dipyrromethenes, Aza-boron-dipyrromethenes, violanthrons, isoviolanthrons and diketopyrrolopyrrols.

- 15 More preferably, the fluorescent colorant is selected from the group consisting of rylene, phthalocyanines, naphthalocyanines, cyanines, xanthenes, oxazines, boron-dipyrromethenes, Aza-boron-dipyrromethenes and Diketopyrrolopyrrols, even more preferably from the group consisting of rylene, xanthenes and phthalocyanines.

- 20 It shall be noted, however, that other colorants may be used additionally or alternatively, as long as the colorant has, in the range of 400 nm to 900 nm, an absorption maximum in the wavelength range of 550 nm to 850 nm, more preferably in the range of 600 nm to 800 nm, preferably measured with the colorant embedded into the matrix material.

25 Rylene colorants

- The term rylene colorant as used herein refers to colorants comprising a rylene framework of naphthalene units linked in peri-positions. Such rylene frameworks include, but are not limited to perylene, terrylene and quaterrylene. Thus, the rylene colorant according to the invention, 30 comprises a core structure based on a rylene framework, in particular a perylene, terrylene or quaterrylene core structure.



- 35 The term "comprising a core structure" as used in the context of the present invention is denoted to mean that the shown structure may be suitably substituted.

Preferably, the rylene colorant comprises a polycyclic group Pr, wherein the polycyclic group comprises the rylene framework, in particular a perylene, terrylene or quaterrylene core structure being substituted with at least one group (radical) Rr, with Rr being selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, aryl, heteroaryl, cycloheteroalkyl, -O-alkyl, -O-aryl, -O-heteroaryl, -O-cycloalkyl and -O-cycloheteroalkyl. It is to be understood that, each residue Rr may be the same or may differ from each other. If, more than one group Rr is present, preferably all groups Rr are the same.

Within the meaning of the present invention, the term "alkyl" relates to non-branched alkyl residues and branched alkyl residues. The term also encompasses alkyl groups which are further substituted by one or more suitable substituents. The term "substituted alkyl" as used in this context of the present invention preferably refers to alkyl groups being substituted in any position by one or more substituents, preferably by 1, 2, 3, 4, 5 or 6 substituents, more preferably by 1, 2, or 3 substituents. If two or more substituents are present, each substituent may be the same or may be different from the at least one other substituent. There are in general no limitations as to the substituent. The substituents may be, for example, selected from the group consisting of aryl, heteroaryl, cycloalkyl, heterocycloalkyl, alkenyl, alkynyl, halogen, hydroxyl, alkylcarbonyloxy, arylcarbonyloxy, alkoxycarbonyloxy, aryloxy, carboxylate, alkylcarbonyl, arylcarbonyl, alkoxycarbonyl, aminocarbonyl, alkylaminocarbonyl, dialkylaminocarbonyl, alkylthiocarbonyl, alkoxy, phosphate, phosphonate, phosphinate, amino, acylamino, including alkylcarbonylamino, arylcarbonylamino, carbamoyl, ureido, amidino, nitro, imino, sulfhydryl, alkylthio, arylthio, thiocarboxylate, sulfates, alkylsulfinyl, sulfonate, sulfamoyl, sulfonamido, trifluoromethyl, cyano and azido. Preferred substituents of such organic residues are, for example, halogens, such as fluorine, chlorine, bromine or iodine, amino groups, hydroxyl groups, carbonyl groups, thiol groups and carboxyl groups.

The term "heteroalkyl" refers to alkyl residues comprising one or more heteroatoms or functional groups, such as, by way of example, -O-, -S-, -NH-, -NH-C(=O)-, -C(=O)-NH- and the like.

The term "cycloalkyl" refers to alkyl groups which form a ring, such as a 5-membered, 6-membered or 7-membered ring, e.g. cyclopentyl or cyclohexyl.

The term "heterocycloalkyl" refers to cycloalkyl groups comprising one or more heteroatoms or functional groups, such as, by way of example, -O-, -S-, -NH-, -NH-C(=O)-, -C(=O)-NH-, and the like, such as, e.g., morpholino, piperazinyl or piperidinyl, alkylaryl, arylalkyl and heteroaryl.

Within the meaning of the present invention, the term "aryl" refers to, but is not limited to, optionally suitably substituted 5- and 6-membered single-ring aromatic groups as well as optionally suitably substituted multicyclic groups, for example bicyclic or tricyclic aryl groups.

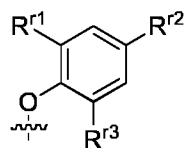
The term "aryl" thus includes, for example, optionally substituted phenyl groups or optionally suitably substituted naphthyl groups. Aryl groups can also be fused or bridged with alicyclic or

heterocycloalkyl rings which are not aromatic so as to form a polycycle, e.g. benzodioxolyl or tetraline.

The term “heteroaryl” as used within the meaning of the present invention includes optionally suitably substituted 5- and 6-membered single-ring aromatic groups as well as substituted or unsubstituted multicyclic aryl groups, for example tricyclic or bicyclic aryl groups, comprising one or more, preferably from 1 to 4, such as 1, 2, 3 or 4, heteroatoms, wherein in case the aryl residue comprises more than 1 heteroatom, the heteroatoms may be the same or different. Such heteroaryl groups including from 1 to 4 heteroatoms are, for example, benzodioxolyl, pyrrolyl, furanyl, thiophenyl, thiazolyl, isothiazolyl, imidazolyl, triazolyl, tetrazolyl, pyrazolyl, oxazolyl, isoxazolyl, pyridinyl, pyrazinyl, pyridazinyl, benzoxazolyl, benzodioxazolyl, benzothiazolyl, benzoimidazolyl, benzothiophenyl, methylenedioxyphe-nyl, naphthyridinyl, quinolinyl, isoquinolinyl, indolyl, benzofuranyl, purinyl, deazapurinyl, or indoliziny-
l.

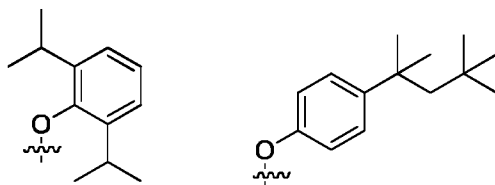
The term “optionally substituted aryl” and the term “optionally substituted heteroaryl” as used in the context of the present invention describes moieties having substituents replacing a hydrogen on one or more atoms, e.g. C or N, of an aryl or heteroaryl moiety. Again, there are in general no limitations as to the substituent. The substituents may be, for example, selected from the group consisting of alkyl, alkenyl, alkynyl, halogen, hydroxyl, alkylcarbonyloxy, arylcarbonyloxy, alkoxycarbonyloxy, aryloxy, carbonyloxy, carboxylate, alkylcarbonyl, arylcarbonyl, alkoxycarbonyl, aminocarbonyl, alkylaminocarbonyl, dialkylaminocarbonyl, alkylthiocarbonyl, alkoxy, phosphate, phosphonate, phosphinato, amino, acylamino, including alkylcarbonylamino, arylcarbonylamino, carbamoyl and ureido, amidino, nitro, imino, sulfhydryl, alkylthio, arylthio, thiocarboxylate, sulfates, alkylsulfinyl, sulfonate, sulfamoyl, sulfonamido, trifluoromethyl, cyano, azido, cycloalkyl, such as, e.g., cyclopentyl or cyclohexyl, heterocycloalkyl, such as, e.g., morpholino, piperazinyl or piperidinyl, alkylaryl, arylalkyl and heteroaryl. Preferred substituents of such organic residues are, for example, halogens, such as fluorine, chlorine, bromine or iodine, amino groups, hydroxyl groups, carbonyl groups, thiol groups and carboxyl groups.

Preferably the at least one group R^i is $-O$ -aryl or $-O$ -heteroaryl, more preferably $-O$ -alkyl, most preferably, the group has the following structure:



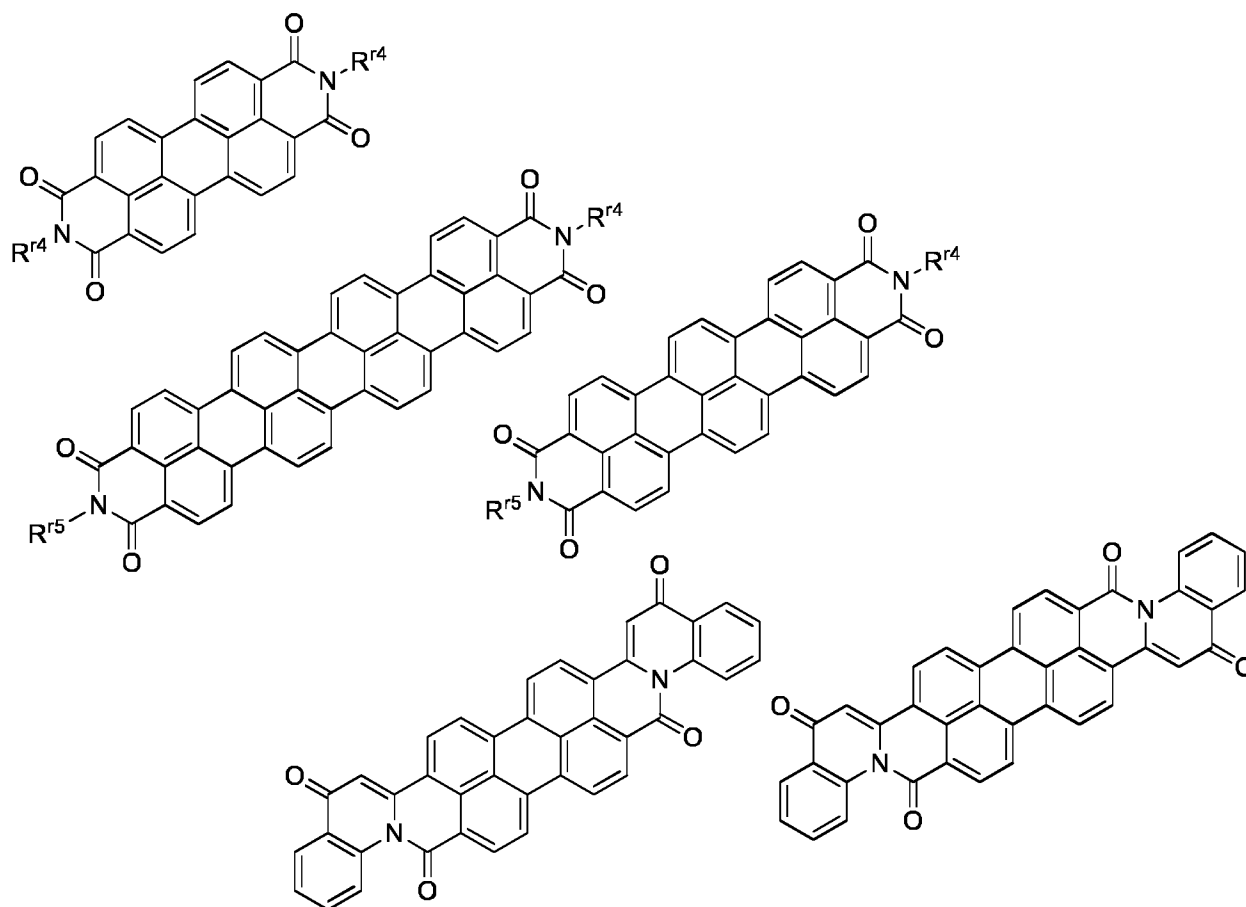
with R^1 , R^2 and R^3 , preferably being, independently of each other selected from the group consisting of, H, alkyl, heteroalkyl, aryl, heteroaryl, $-O$ -alkyl, O -aryl and O -heteroaryl, more preferably, wherein, R^1 , R^2 and R^3 , are, independently of each other selected from H and alkyl, more preferably H and C1-C8 alkyl.

Preferably, R^1 , R^2 and R^3 , are, independently of each other selected from the group consisting of, H, iso-propyl and $-C(CH_3)_2-CH_2-C(CH_3)_3$. Most preferably, R^1 is selected from the following radicals



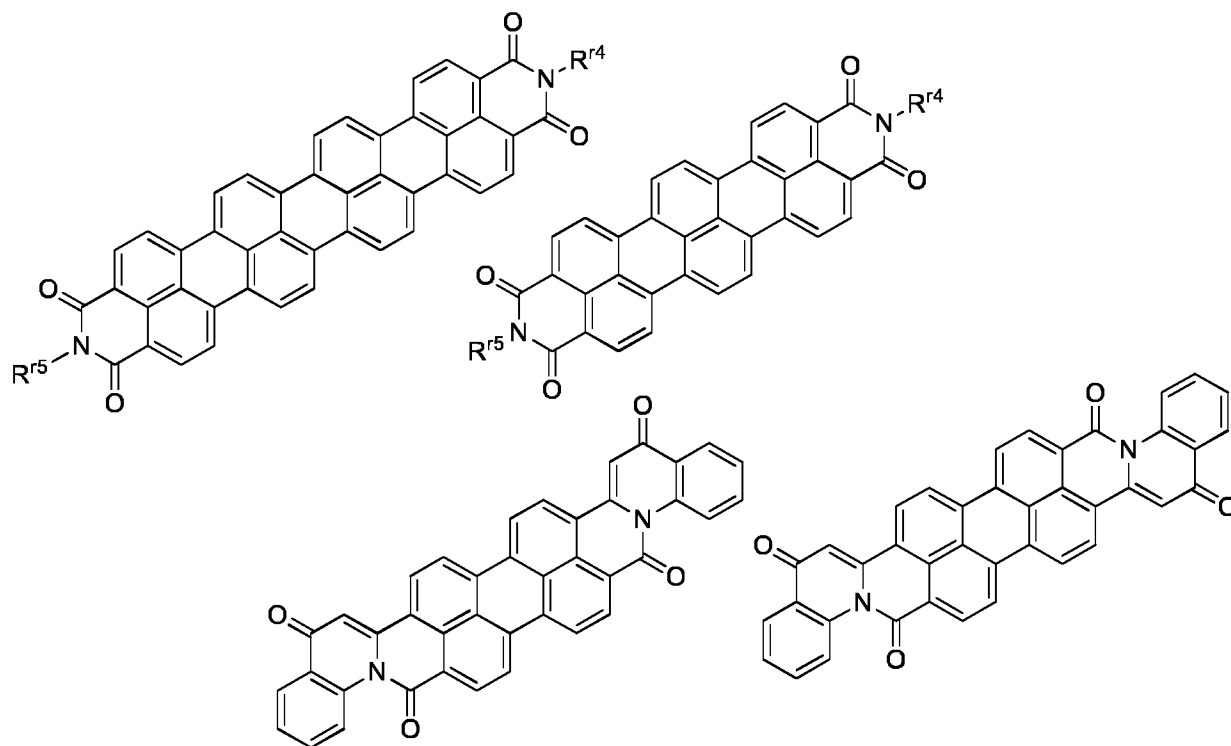
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The polycyclic group P^r preferably comprises one of the following core structures

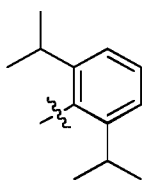


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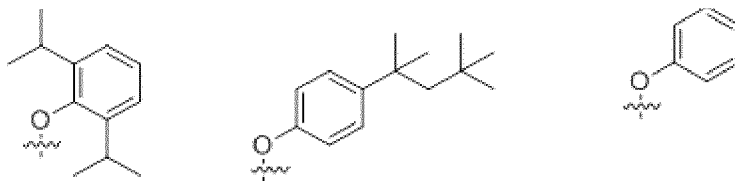
more preferably one of the following core structures



- wherein R^4 and R^5 , are, independently of each other, alkyl or aryl, preferably aryl, more preferably an alkyl substituted aryl, more preferably an alkyl substituted phenyl, more preferably an C1-C6 alkyl substituted phenyl, even more preferably an in ortho and meta position with an C1-C6 alkyl group substituted phenyl, most at least one of, preferably both of, R^4 and R^5 , are

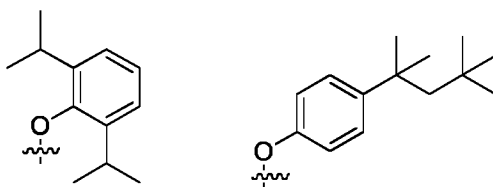


- and wherein the core structures are preferably substituted with at least one radical R^r , with R^r being as described above, preferably with R^r being selected from the following radicals

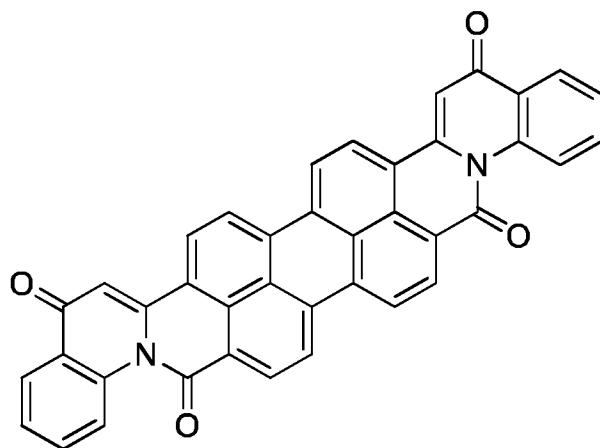


- or wherein the core structure comprises no additional substituents.

More preferably, the core structures are substituted with at least one radical R^r being selected from the following radicals

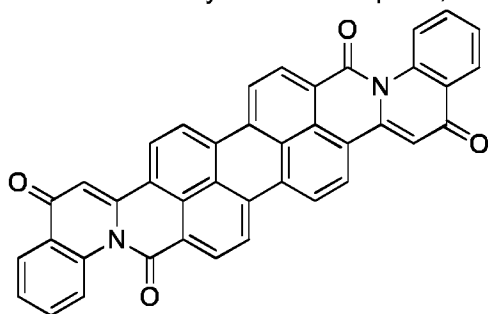


It is to be understood that in case, the colorant comprises the core structure

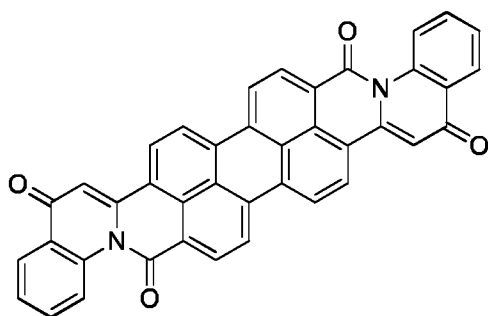


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the colorant may further comprise, the respective isomeric core structure

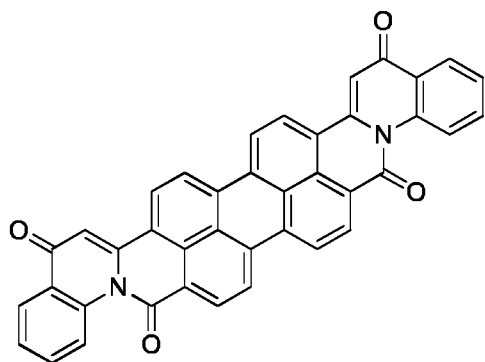


10 Similarly, in case the colorant comprises the core structure



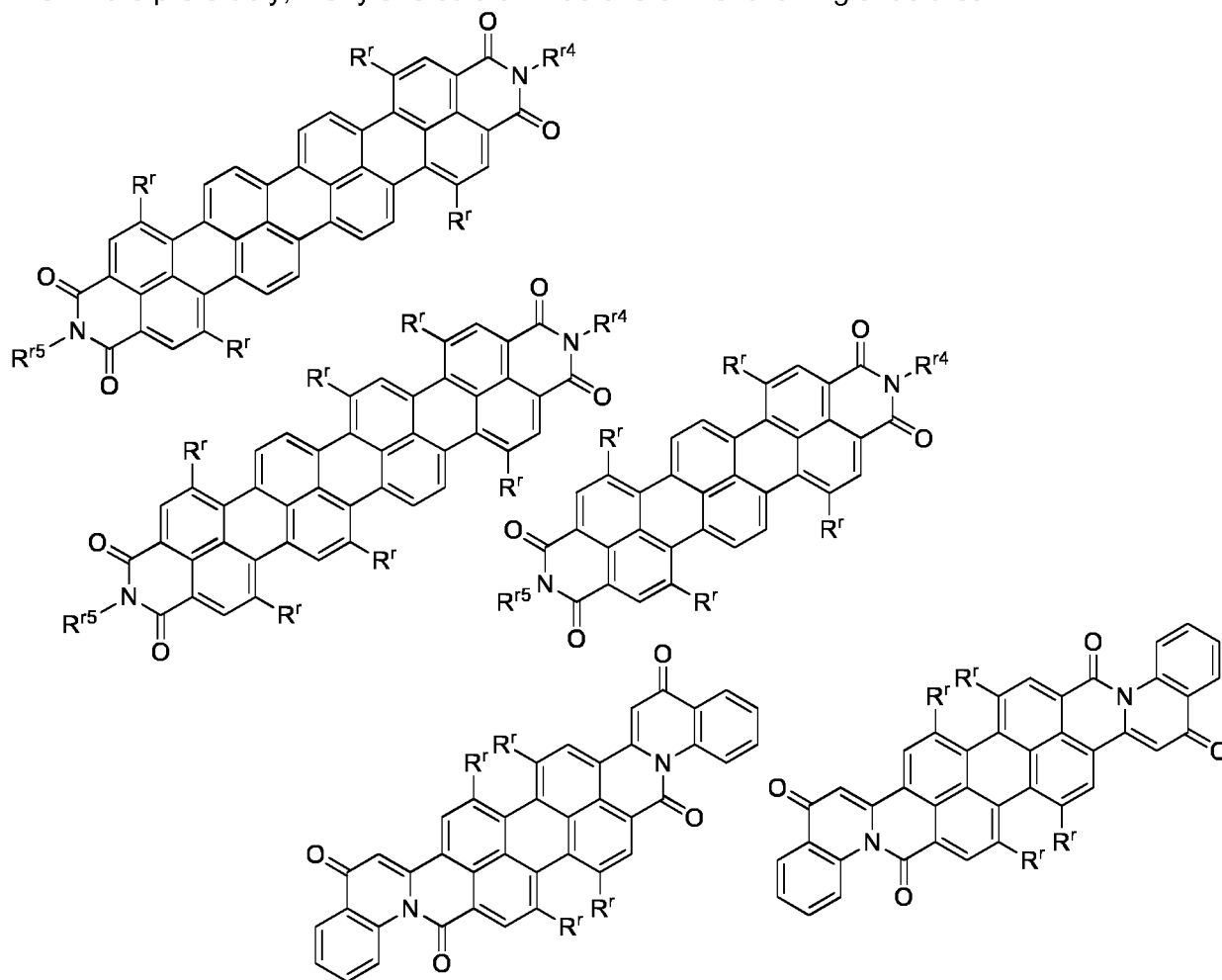
the colorant may further comprise, the respective isomeric core structure

15



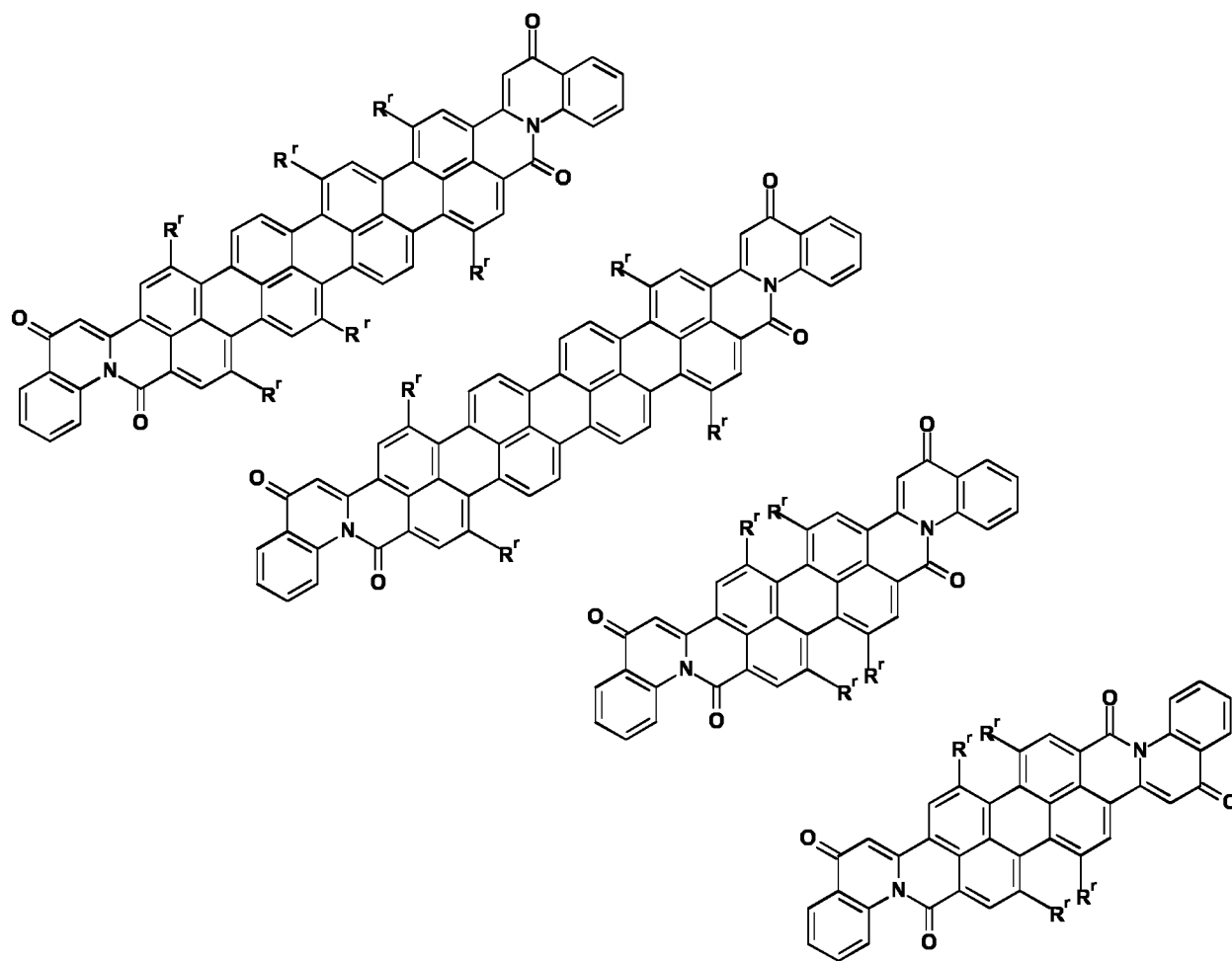
Thus, the colorant may be a mixture of both isomers. Alternatively, the colorant may be a pure isomer.

Even more preferably, the rylene colorant has one of the following structures:

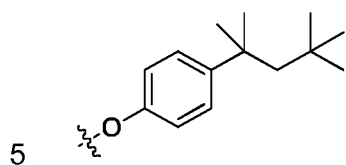


10

Especially preferably, the rylene fluorescent colorant according to the invention is selected from the group consisting of the following structures:



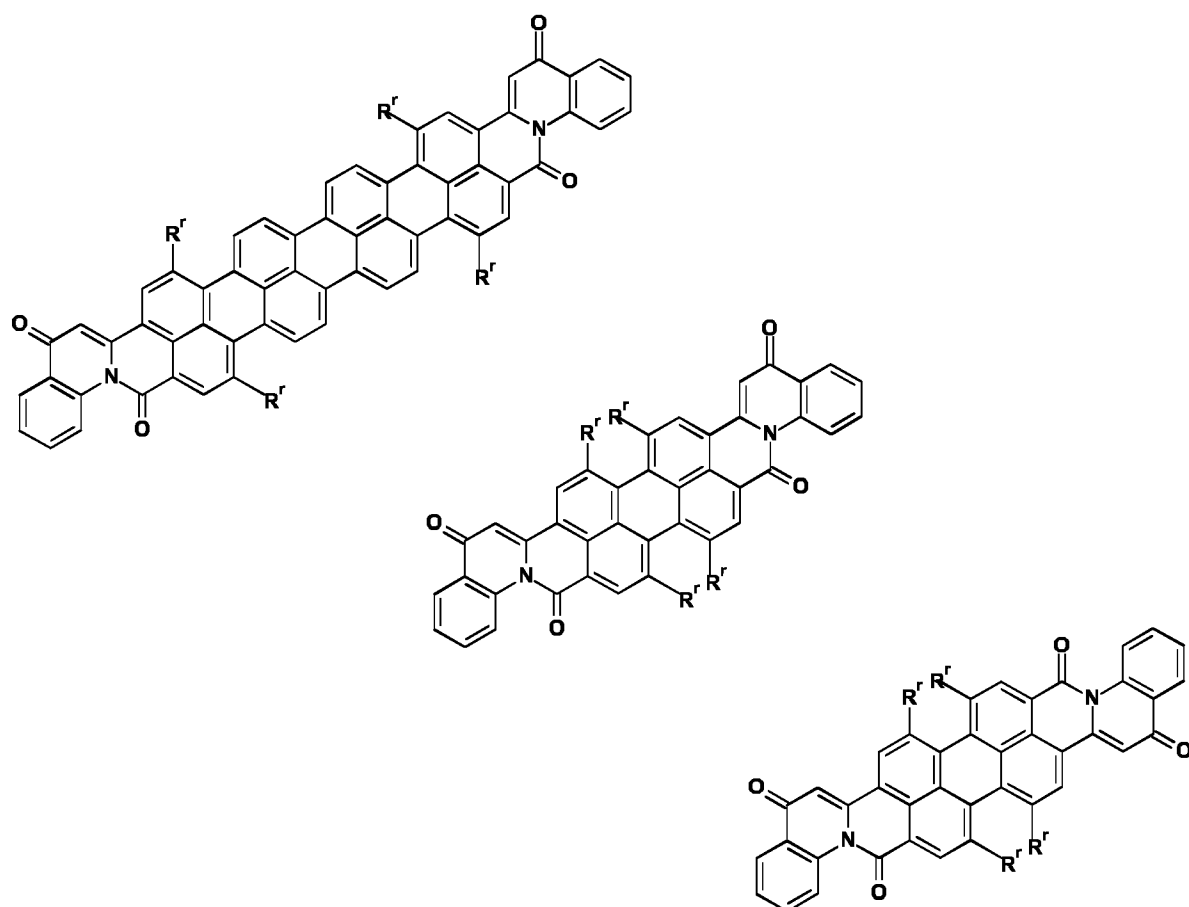
with R^r being



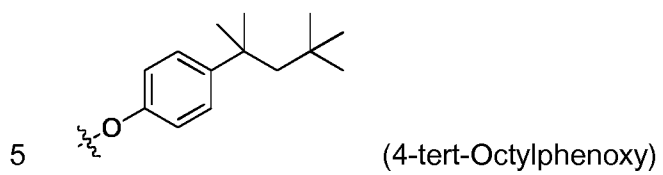
Thus, preferably, the rylene fluorescent colorant according to the invention is selected from the group consisting of compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, and compound 4 of Table 1.

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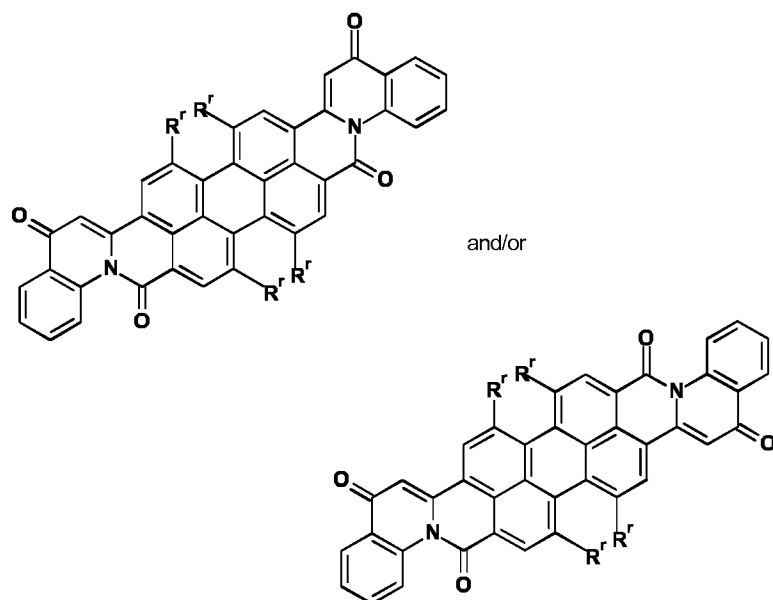
More preferably the rylene fluorescent colorant, even more preferably the fluorescent colorant, is



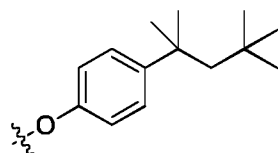
with R^r being



wherein



with R^r being



(4-tert-Octylphenoxy)

5

(2,13-Bis[2,6-bis(1-methylethyl)phenyl]-5,10,16,21-tetrakis[4-(1,1,3,3-tetramethylbutyl)phenoxy]anthra[9",1",2":6,5,10;10",5",6":6',5',10']dianthra[2,1,9-def:2',1',9'-d'e'f']diisoquinoline-1,3,12,14(2H,13H)-tetrone) is particularly preferred.

10 According to an alternative preferred embodiment, the rylene fluorescent colorant, even more preferably the fluorescent colorant, is selected from the group consisting of compound 15 of Table 1, compound 16 of Table 1 and compound 17 of Table 1.

Thus, preferred rylene colorants according to the invention are compound 1 of Table 1,
15 compound 2 of Table 1, compound 3 of Table 1, compound 4 of Table 1, compound 15 of Table 1, compound 16 of Table 1 and compound 17 of Table 1. More preferably, as already outlined above, the rylene fluorescent colorant according to the invention is however selected from the group consisting of compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, and compound 4 of Table 1, most preferred is compound 4.

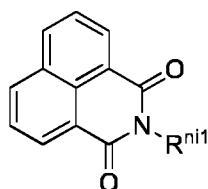
20

The preparation of the rylene colorants described above as well as further suitable rylene colorants and are known to the skilled person. Such preparations are, for example, described in EP 1373272 B1, US2006/0075585, WO2016/083914 and WO 2007/006717, which respective contents is herewith incorporated by reference. 2,13-Bis[2,6-bis(1-methylethyl)phenyl]-
25 5,10,16,21-tetrakis[4-(1,1,3,3-tetramethylbutyl)-phenoxy]anthra[9",1",2":6,5,10;10",5",6":6',5',10']dianthra[2,1,9-def:2',1',9'-d'e'f']diisoquinoline-1,3,12,14(2H,13H)-tetrone) (see Table 1, Compound 4) may e.g. be prepared according to example 4 of WO2016/083914, which contents is herewith incorporated by reference, and 2,11-Bis[2,6-bis(1-methylethyl)phenyl]-
30 5,8,14,17-tetra[2,6-bis(1-methylethyl)phenoxy] benzo[13,14]pentapheno[3,4,5-def:10,9,8-d'e'f']diisoquinoline-1,3,10,12(2H,11H)-tetrone (see Table 1, Compound 3), may e.g. be prepared according to example 2 of WO2007/006717, which contents is herewith incorporated by reference.

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Naphthalimide colorants

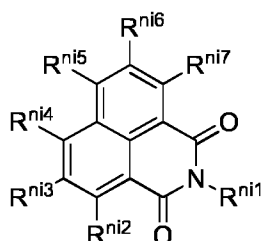
The term naphthalimide colorant as used herein refers to colorants comprising the naphthalimide core structure



wherein R^{ni1} is selected from the group consisting of alkyl, heteroalkyl, aryl, heteroaryl, cycloalkyl and cycloheteroalkyl.

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Preferably, the naphthalimide colorant according to the invention has a structure according to the following formula,



10

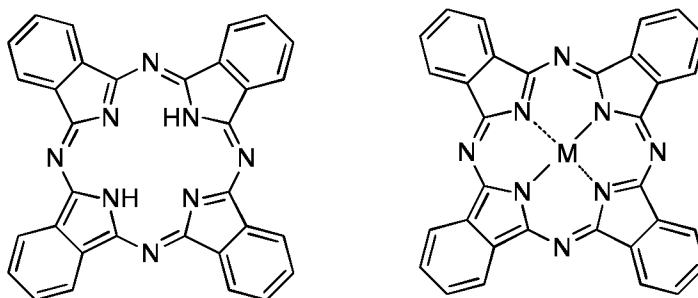
wherein R^{ni2} , R^{ni3} , R^{ni4} , R^{ni5} , R^{ni6} and R^{ni7} , are independently of each other, selected from the group consisting of H, alkyl, aryl, heteroalkyl, heteroaryl, alkoxy, cycloalkyl, heterocycloalkyl, alkylamin (Alkyl-NH-), arylamine (Aryl- NH-), alkylarylamine (Aryl-Alkyl-NH-), heteroarylamine (Heteroaryl- NH-) and heteroalkylarylamine (Heteroaryl-Alkyl-NH-), and wherein preferably at least one of R^{ni2} , R^{ni3} , R^{ni4} , R^{ni5} , R^{ni6} and R^{ni7} is selected from the group alkylamin (Alkyl-NH-), arylamine (Aryl- NH-), alkylarylamine (Aryl-Alkyl-NH-), heteroarylamine (Heteroaryl- NH-), heteroalkylarylamine and (Heteroaryl-Alkyl-NH-).

15

20 Phthalocyanine colorants

The term phthalocyanine colorant as used herein refers to metal free as well as to metal containing phthalocyanines, thus to colorants comprising one of the following structures, this structure preferably being suitably substituted.

25

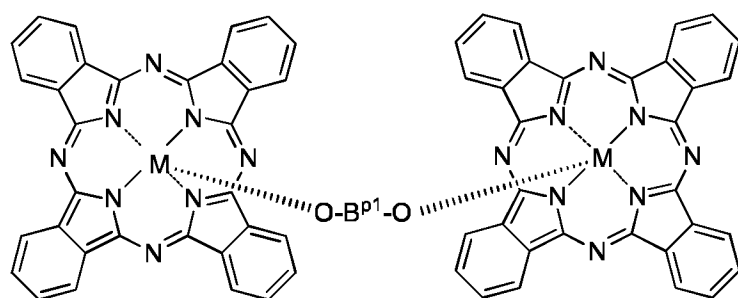


wherein M is metal or metallic component selected from the group consisting of M^1 , $M^2(R^{p1})$, $M^3(R^{p2})(R^{p3})$ and $M^4(=R^{p4})$, wherein M^1 is selected from the group consisting of Zn, Fe, Co, Ni, Pd, Pt and Mn, M^2 is selected from the group consisting of Al, In, La, and lanthanoids, M^3 is

30

selected from the group consisting of Ge, Si, Ti, and V, and M^4 is Ti or V, wherein R^{p1} is selected from the group consisting of halogen, OH, alkyl, -O-alkyl, -O-aryl, -S-alkyl, alkyl, -OSi(alkyl)₃, -O-alkoxy, such as preferably -O-(alkyl-O)₁₋₅-alkyl², and -O-B^{p1}-O-L, wherein B^{p1} is C₁-C₁₂alkylene, C₁-C₁₂alkylene which is interrupted by one or more oxygen atoms or C₁-C₁₂alkylene which is substituted by at least one OH group, and L is a further phthalocyanine colorant group, and wherein R^{p2} and R^{p3} are, independent of each other, selected from the group consisting of halogen, OH, -O-alkyl, -O-aryl, -O-alkoxy, such as preferably -O-(alkyl-O)₁₋₅-alkyl², and -M⁵(R^{p5})(R^{p6})(R^{p7}), wherein R^{p5} , R^{p6} and R^{p7} , are independently of each other, selected from the group consisting of alkyl, alkenyl, alkenyl, cycloalkyl, aryl, arylalkyl, trialkylsiloxy, -CO₂H, -SO₃H, -O-(alkyl-O)₁₋₅-alkyl² and trialkylammonium substituted alkyl, and wherein M^5 is selected from the group consisting of Ge, Si, Ti, and V, and wherein R^{p4} is O or S, preferably O, and wherein M^5 and M^3 are preferably the same.

In case, M is M²(R^{p1}) and R^{p1} is -O-B^{p1}-O-L, the colorant preferably has the structure



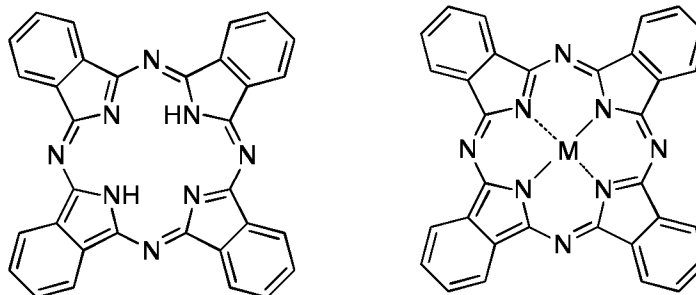
wherein, the aromatic rings may be suitably substituted.

In case the phthalocyanine is a metal containing phthalocyanine, M is preferably Si(R^{p2})(R^{p3}) or Ge(R^{p2})(R^{p3}), more preferably M is Si(R^{p2})(R^{p3}) with R^{p1} being -O-alkyl or -O-alkoxy, more preferably -O-(alkyl-O)₁₋₅-alkyl² with alkyl² being preferably methyl or ethyl, more preferably with R^{p1} being -O-(CH₂CH₂O)₃-CH₃, and with R^{p2} and R^{p3} being, independent of each other, selected from the group consisting of halogen OH, -O-alkyl, -O-aryl, -O-alkoxy, such as preferably -O-(alkyl-O)₁₋₅-alkyl², and -M⁵(R^{p5})(R^{p6})(R^{p7}), wherein R^{p5} , R^{p6} and R^{p7} , are independently of each other, selected from the group consisting of alkyl, alkenyl, alkenyl, cycloalkyl, aryl, arylalkyl, trialkylsiloxy, -CO₂H, -SO₃H, -O-(alkyl-O)₁₋₅-alkyl² and trialkylammonium substituted alkyl.

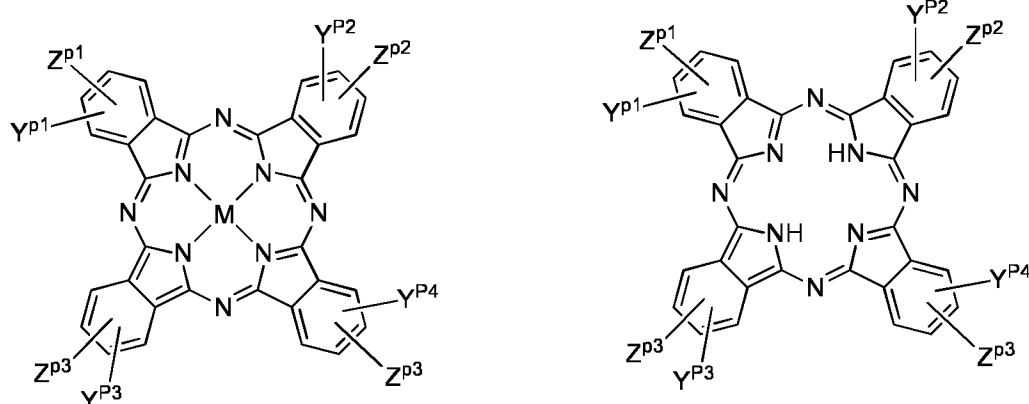
Preferably, the phthalocyanine colorant is a metal free colorant.

The phthalocyanine colorants described hereinabove and hereinunder as well as further suitable phthalocyanine colorants and their respective preparations are e.g described in WO 2008/122531 as well as in Dyes and Pigments 99 (2013), 613-619, which respective contents is herewith incorporated by reference. Further, suitable preparation methods are described in Hairong Li, Ngan Nguyen, Frank R. Fronczek, M. Graça H. Vicente, Tetrahedron 65 (2009) 3357-3363.

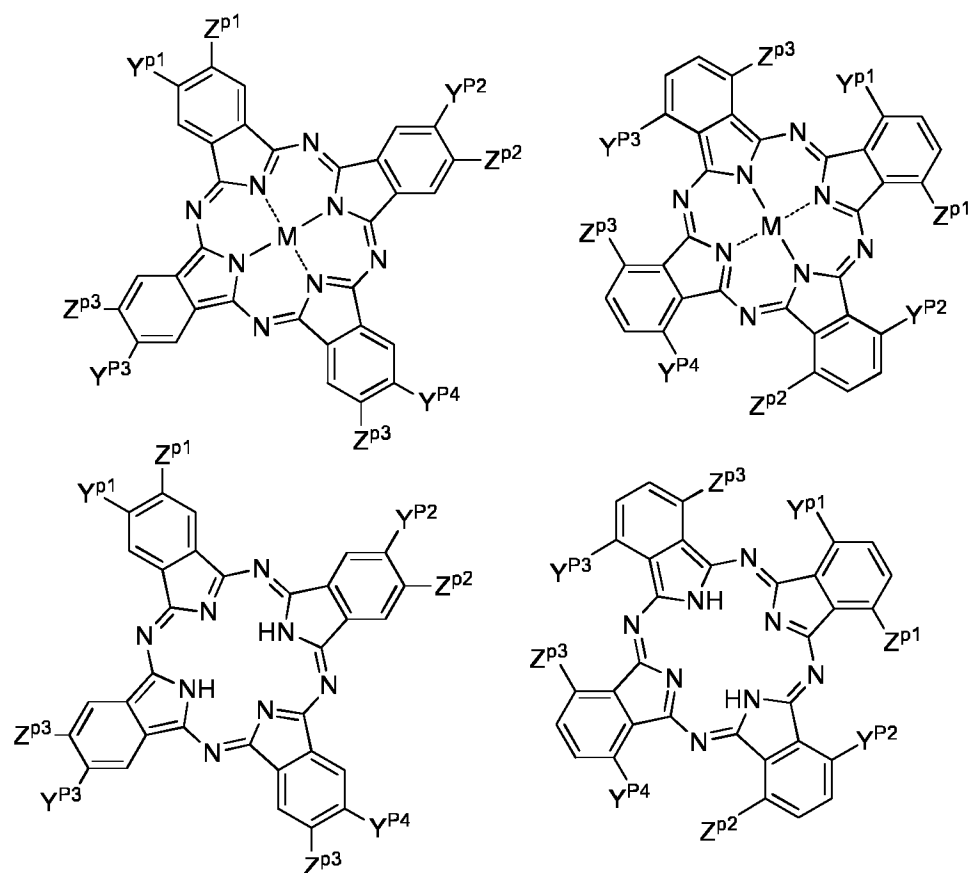
As described above, the structures



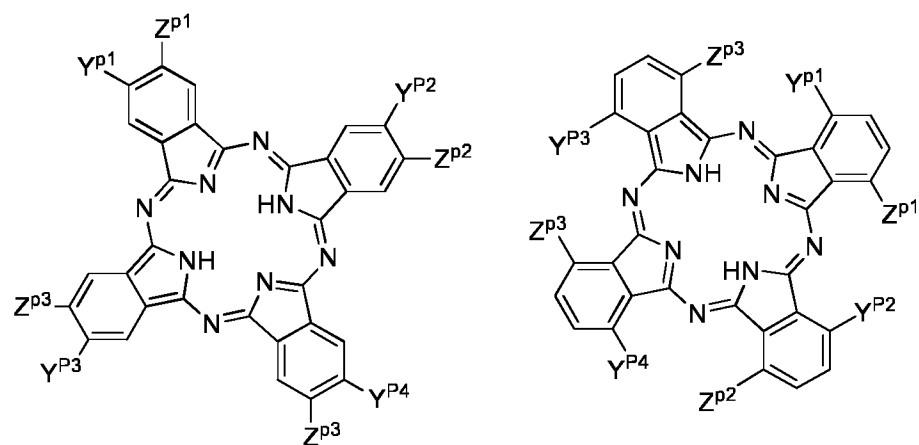
are preferably suitably substituted. Preferably, the phthalocyanine colorants according to the invention, have one of the following structures:



- 10 with Z^{P1} , Z^{P2} , Z^{P3} and Z^{P4} being, the same or being different, and being independently of each other selected from the group consisting of halogen, nitro, -OH, -CN, Amino, alkyl, alkenyl, alkynyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, -O-aryl, -O-heteroaryl, -O-cycloalkyl, -O-heterocycloalkyl, -O-alkyl, -S-alkyl, -S-aryl, -S-heteroaryl, -S-cycloalkyl, and -S-heterocycloalkyl, and with Y^{P1} , Y^{P2} , Y^{P3} and Y^{P4} being, the same or being different, and being independently of
- 15 each other selected from the group consisting of H, halogen, nitro, -OH, -CN, Amino, alkyl, alkenyl, alkynyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, -O-aryl, -O-heteroaryl, -O-cycloalkyl, -O-heterocycloalkyl, -O-alkyl, -S-alkyl, -S-aryl, -S-heteroaryl, -S-cycloalkyl and -S-heterocycloalkyl.
- 20 Preferably, the phthalocyanine colorants according to the invention, have one of the following structures:

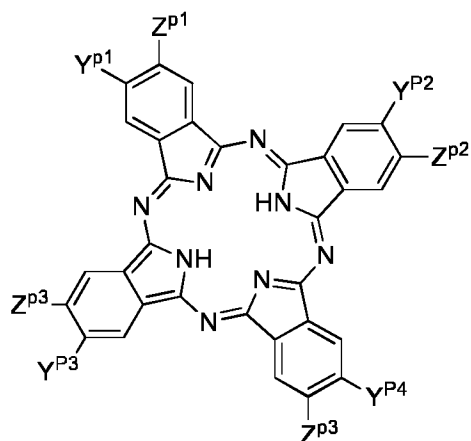


more preferably, one of the following structures

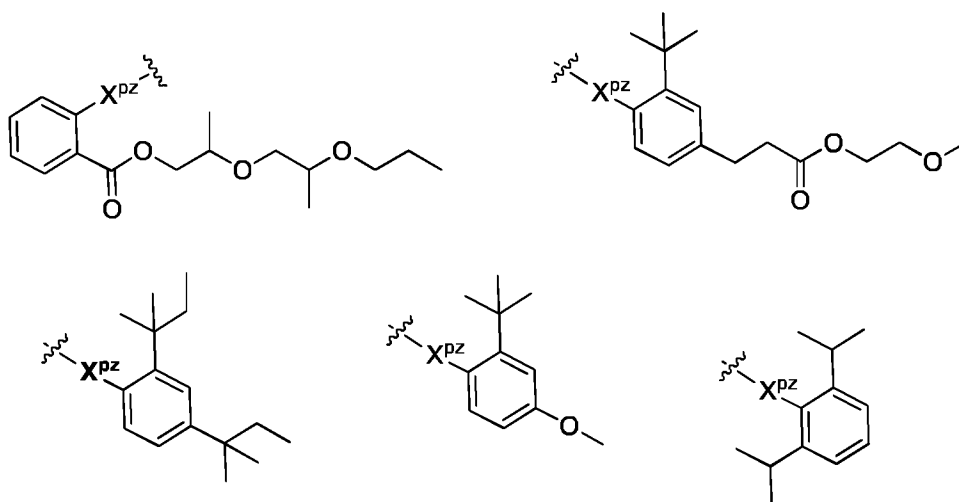


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and in particular, the following structure:



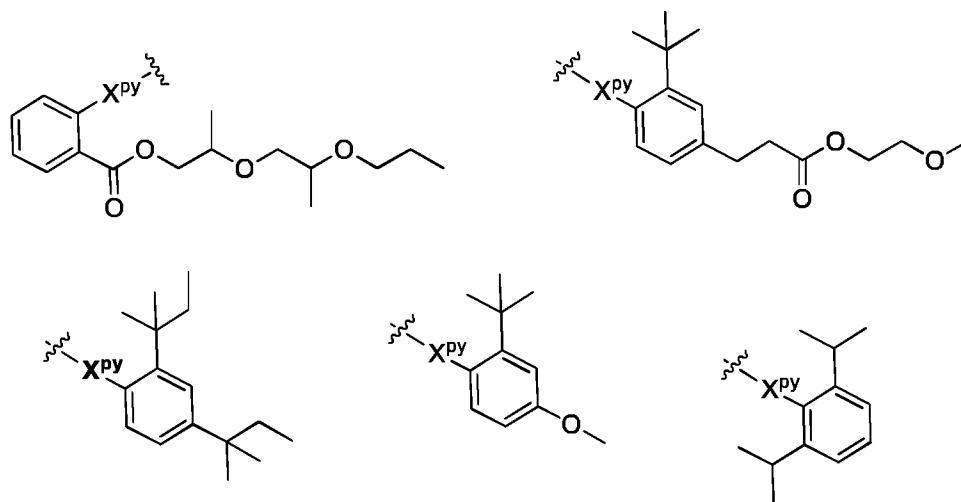
Preferably, Z^{P1}, Z^{P2}, Z^{P3} and Z^{P4}, are independently of each other, selected from the group consisting of -O-aryl, -O-heteroaryl, -S-aryl and -S-heteroaryl, more preferably, Z^{P1}, Z^{P2}, Z^{P3} and Z^{P4}, are independently of each other, selected from the group consisting of the following residues



with X^{pz} being O or S, preferably O.

Preferably, Z^{P1}, Z^{P2}, Z^{P3} and Z^{P4} are all the same.

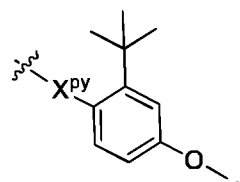
Preferably, Y^{P1}, Y^{P2}, Y^{P3} and Y^{P4}, are independently of each other, selected from the group consisting of H, -O-aryl, -O-heteroaryl, -S-aryl and -S-heteroaryl, more preferably, Y^{P1}, Y^{P2}, Y^{P3} and Y^{P4}, are independently of each other, selected from the group consisting of



with Y^{pz} being O or S, preferably O.

More preferably, Y^{P1} , Y^{P2} , Y^{P3} and Y^{P4} , are independently of each other, H or

5



Preferably, Y^{P1} , Y^{P2} , Y^{P3} and Y^{P4} are all the same.

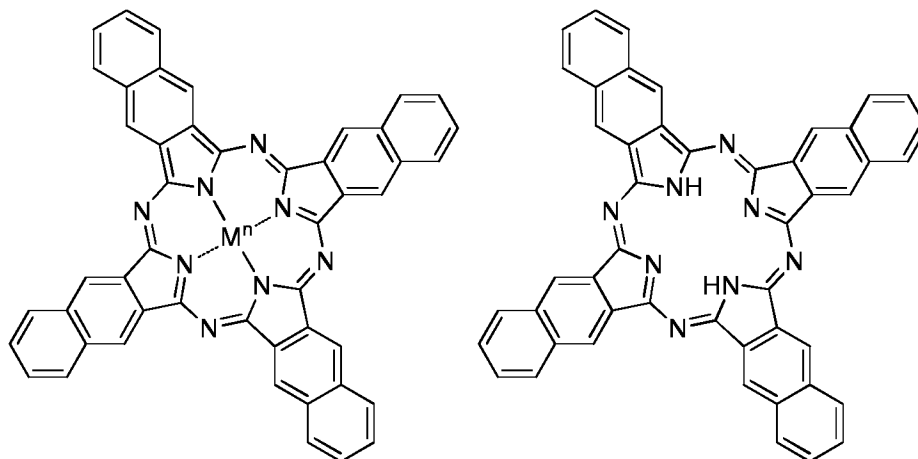
10 Most preferably Y^{P1} , Y^{P2} , Y^{P3} and Y^{P4} are H.

In particular, the phthalocyanine colorant, more preferably the fluorescent colorant, is selected from the group consisting of compound 5 of Table 1, compound 6 of Table 1, compound 7 of Table 1, compound 8 of Table 1, compound 9 of Table 1, compound 10 of Table 1 and
 15 compound 14 of Table 1, more preferably the phthalocyanine colorant is the compound 14 of Table 1 or compound 10 of Table 1, most preferably, the phthalocyanine colorant is the compound 14 of Table 1.

Suitable preparation methods for the preparation of such compounds are known to the skilled
 20 person and e.g. described in Hairong Li, Ngan Nguyen, Frank R. Fronczek, M. Graça H. Vicente, Tetrahedron 65 (2009) 3357–3363.

Naphthalocyanine colorants

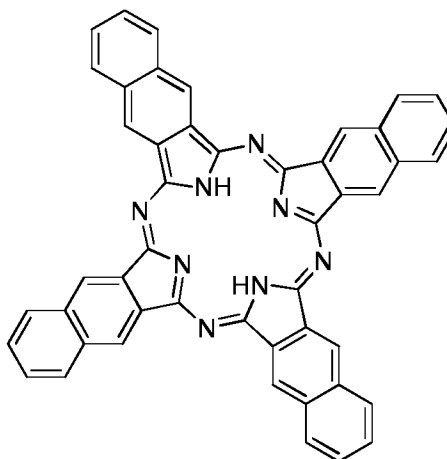
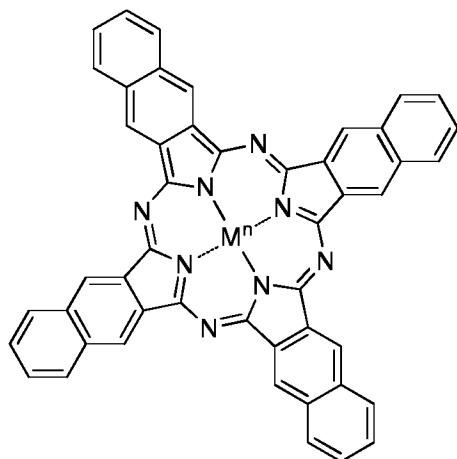
25 The term naphthalocyanine colorant as used herein refers to metal free as well as to metal containing naphthalocyanines, thus to colorants comprising one of the following core structures, wherein this structure may be suitably substituted.



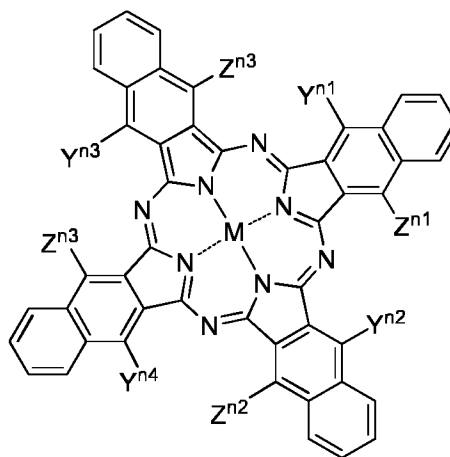
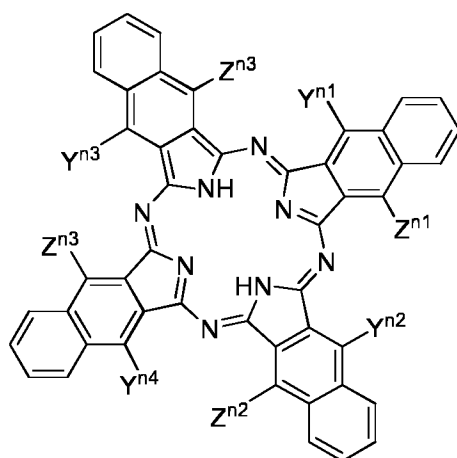
wherein M^n is metal or metallic component selected from the group consisting of M^{n1} , $M^{n2}(R^{p1})$, $M^{n3}(R^{n2})(R^{n3})$ and $M^{n4}(=R^{n4})$, wherein M^{n1} is selected from the group consisting of Zn, Fe, Co, Ni, Pd, Pt and Mn, M^{n2} is selected from the group consisting of Al, In, La, and lanthanoids, M^{n3} is selected from the group consisting of Ge, Si, Ti, and V, and M^{n4} is Ti or V, wherein R^{n1} is selected from the group consisting of halogen, OH, alkyl, -O-alkyl, -O-aryl, -S-alkyl, alkyl, -OSi(alkyl)₃, -O-alkoxy, such as preferably -O-(alkyl-O)₁₋₅-alkyl², and -O-Bⁿ¹-O-L, wherein Bⁿ¹ is C₁-C₁₂alkylene, C₁-C₁₂alkylene which is interrupted by one or more oxygen atoms or C₁-C₁₂alkylene which is substituted by at least one OH group, and L is a further naphthalocyanine colorant group, and wherein R^{n2} and R^{n3} are, independent of each other, selected from the group consisting of halogen, OH, -O-alkyl, -O-aryl, -O-alkoxy, such as preferably -O-(alkyl-O)₁₋₅-alkyl², and $M^{n5}(R^{n5})(R^{n6})(R^{n7})$, wherein R^{n5} , R^{n6} and R^{n7} , are independently of each other, selected from the group consisting of alkyl, alkenyl, alkenyl, cycloalkyl, aryl, arlyalkyl, trialkylsiloxy, -CO₂H, -SO₃H, -O-(alkyl-O)₁₋₅-alkyl² and trialkylammonium substituted alkyl, and wherein M^{n5} is selected from the group consisting of Ge, Si, Ti, and V, wherein R^{p4} is O or S, preferably O, and wherein M^{n5} and M^{n3} are preferably the same.

The naphthalocyanine colorants described hereinabove and hereinunder as well as further suitable naphthalocyanine colorants and there respective preparations are known to the skilled person.

As described above, the structures



may be suitably substituted. The naphthalocyanine colorants according to the invention may thus have one of the following structures:



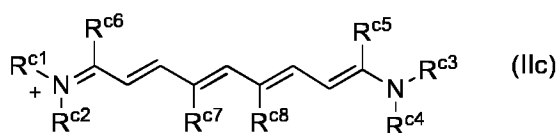
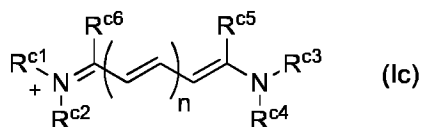
with Z^{n1} , Z^{n2} , Z^{n3} and Z^{n4} being, the same or being different, and being independently of each other selected from the group consisting of H, halogen, nitro, -OH, -CN, Amino, alkyl, alkenyl, alkynyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, -O-aryl, -O-heteroaryl, -O-cycloalkyl, -O-heterocycloalkyl, -O-alkyl, -S-alkyl, -S-aryl, -S-heteroaryl, -S-cycloalkyl and -S-heterocycloalkyl,, wherein Z^{P1} , Z^{P2} , Z^{P3} and Z^{P4} are preferably all the same. Most preferably, Z^{n1} , Z^{n2} , Z^{n3} and Z^{n4} are H.

Y^{n1} , Y^{n2} , Y^{n3} and Y^{n4} being, the same or being different, and being independently of each other selected from the group consisting of H, halogen, nitro, -OH, -CN, Amino, alkyl, alkenyl, alkynyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, -O-aryl, -O-heteroaryl, -O-cycloalkyl, -O-heterocycloalkyl, -O-alkyl, -S-alkyl, -S-aryl, -S-heteroaryl, -S-cycloalkyl and -S-heterocycloalkyl.. Preferably, Y^{n1} , Y^{n2} , Y^{n3} and Y^{n4} are all the same. Most preferably, Y^{P1} , Y^{P2} , Y^{P3} and Y^{P4} are H.

Cyanine colorants

The term cyanine colorant as used herein refers to colorants comprising a polymethine group, thus comprising at least three methine groups (CH) bound together by alternating single and double bonds. Such cyanine colorants include, e.g., indocarbocyanine, oxacarbocyanine, thiocarbocyanine, merocyanine, or derivatives of any one of the aforementioned compounds.

Preferably, the cyanine colorant according to the invention has the structure (Ic) or (IIc),

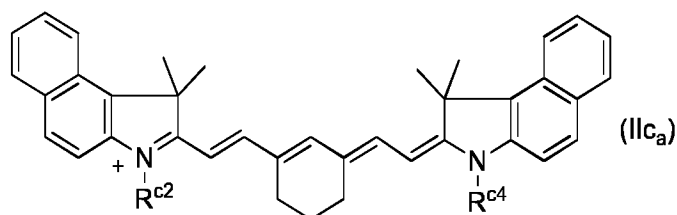
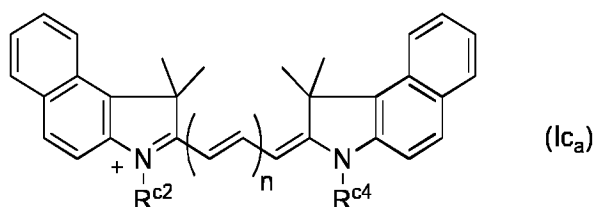


- wherein R^{c2} and R^{c4} , are independently of each other selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl, and wherein R^{c1} is selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with R^{c6} an, optionally substituted, cyclic ring, such as cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein R^{c3} is selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with R^{c4} an, optionally substituted, cyclic ring, such as a cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein R^{c6} is selected from the group consisting of H, alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with R^{c1} an, optionally substituted, cyclic ring, such as a cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein R^{c5} is selected from the group consisting of H, alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with R^{c5} an, optionally substituted, cyclic ring, such as an cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring and wherein R^{c2} and R^{c4} , are, independently of each other, selected from the group consisting of H, alkyl and cycloalkyl or form a cyclic ring with one another, and wherein n is an interger in the range of from 1 to 10, preferably 1 to 10, more preferably 1 to 5, most preferably n is 2.
- Such colorants are known in the art, and e.g. commercially available under the trademark names, Cy3, Cy5, Cy7, Cy3.5, Cy5.5, Cy7.5, S 0315 (3-Butyl-2-[5-(3-butyl-1,3-dihydro-1,1-dimethyl-2H-benzo[e]indol-2-ylidene)-penta-1,3-dienyl]-1,1-dimethyl-1H-benzo[e]indolium perchlorate) and S 0944 (1,3,3-Trimethyl-2-[5-(1,3,3-trimethyl-1,3-dihydro-indol-2-ylidene)-penta-1,3-dienyl]-3Hindolium chloride). S 0315 and S 0944 are e.g. commercially available from FEW Chemicals GmbH Deutschland.

Further suitable compounds and their preparation are described, e.g. in Ullmann's Encyclopedia of Industrial Chemistry, Vol. 23 (2012), Chapter "Methine Dyes and Pigments".

More preferably, the cyanine colorant according to the invention has the structure (Ic), wherein R^{c2} and R^{c4} , are, independently of each other an, optionally substituted, alkyl group, wherein the alkyl group may be different or the same, preferably C1-C10alkyl, more preferably selected from the group consisting of, optionally substituted, methyl, ethyl, propyl, butyl, pentyl and hexyl, more preferably wherein the alkyl group is methyl, butyl or pentyl, wherein the methyl, butyl or pentyl group may be suitably substituted such as with a Carboxy group $-COOH$, and wherein R^{c1} forms together with R^{c6} an, optionally substituted, cyclic ring, and wherein R^{c3} r forms together with R^{c4} an, optionally substituted, cyclic ring, and wherein n is preferably an integer from 1 to 10, more preferably 1 to 5, most preferably n is 2.

- 10 More preferably, the cyanine colorant according to the invention has a structure according formula (Ic_a) or (IIc_b), more preferably according to (Ic_a).



- wherein R^{c2} and R^{c4} , are, independently of each other an, optionally substituted, alkyl group, wherein the alkyl group may be different or the same, preferably C1-C10alkyl, more preferably selected from the group consisting of, optionally substituted, methyl, ethyl, propyl, butyl, pentyl and hexyl, more preferably wherein the alkyl group is methyl, butyl or pentyl, wherein the methyl, butyl or pentyl group may be suitably substituted such as with a Carboxy group $-COOH$, more preferably, wherein R^{c4} is methyl or butyl, and wherein R^{c2} is butyl or $-C_5H_{10}-COOH$, more preferably wherein both, R^{c2} and R^{c4} are butyl, with n being preferably of from 1 to 5, more preferably 2.

- Most preferably the cyanine colorant is S 0315 (Compound 12 of Table 1; 3-Butyl-2-[5-(3-butyl-1,3-dihydro-1,1-dimethyl-2H-benzo[e]indol-2-ylidene)-penta-1,3-dienyl]-1,1-dimethyl-1H-benzo[e]indolium perchlorate) or S0944 (Compound 13 of Table 1, 1,3,3-Trimethyl-2-[5-(1,3,3-trimethyl-1,3-dihydro-indol-2-ylidene)-penta-1,3-dienyl]-3H-indolium chloride), more preferably S 0315.

Xanthene colorants:

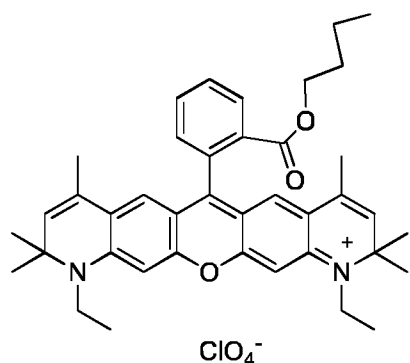
The term xanthene colorant as used herein refers to derivatives of xanthene, thus colorants comprising the following core structure, which is suitably substituted.

Such colorants include, but are not limited to rhodamine colorants, such as Pyrano[3,2-g:5,6-g']diquinolin-13-ium, 6-[2-(butoxycarbonyl)phenyl]-1,11-diethyl-1,2,10,11-tetrahydro-2,2,4,8,10,10-hexamethyl-, perchlorate, rhodamine B, Rhodamine 6G, rhodamine 123, sulfon-rhodamine colorants derivatives of any component thereof.

Further, suitable compounds are described in WO2003098617 A2 as well as in Appl. Mater. Interfaces 2016, 8, 22953-62, which respective contents is hereby incorporated by reference.

Such compounds are commercially available or their synthesis is well known to the skilled person. Suitable methods to prepare such compounds are e.g. described in E. Noeltling, K. Dziewonski, *Berichte der deutschen chemischen Gesellschaft*. Band 38, 1905, S. 3516–3527 as well as in T. Nedelcev, D. Racko, I. Krupa, *Dyes and Pigments*. Band 76, 2008, S. 550–556.

Preferably, the xanthene colorant according to the invention is Pyrano[3,2-g:5,6-g']diquinolin-13-ium, 6-[2-(butoxycarbonyl)phenyl]-1,11-diethyl-1,2,10,11-tetrahydro-2,2,4,8,10,10-hexamethyl-, perchlorate having the structure (compound 11 of Table 1):



Oxazine colorants

The term oxazine colorant refers to any colorant comprising an oxazine ring, provided that this colorant has, in the range of 400 nm to 900 nm, an absorption maximum in the wavelength range of 500 nm to 850 nm, preferably measured with the colorant embedded into the matrix material. Such compounds are commercially available or their synthesis is well known to the skilled person.

Boron-dipyrromethene colorants and Aza-boron-dipyrromethene colorants

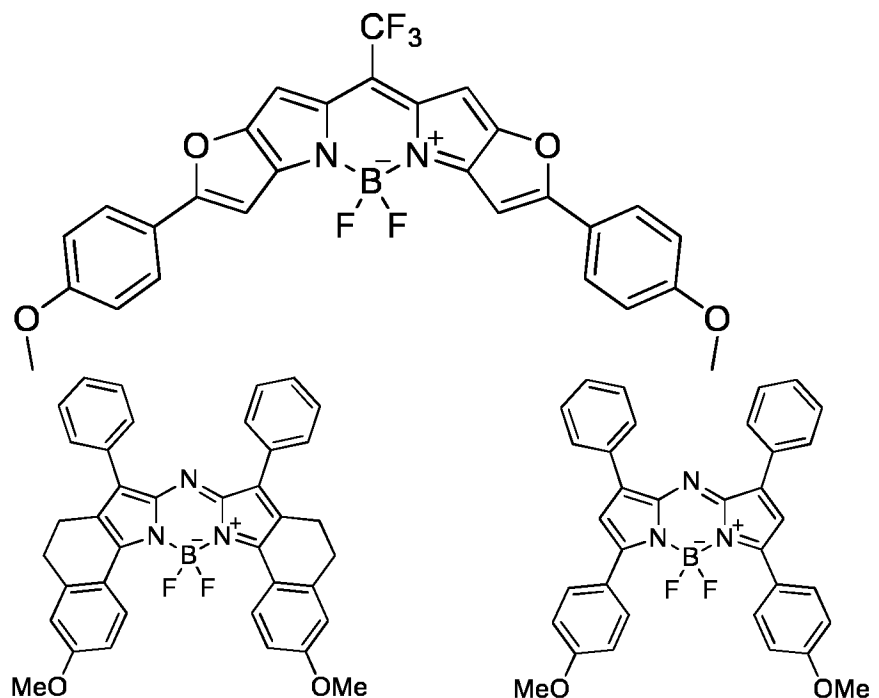
The term Boron-dipyrromethene colorants refers to colorants comprising a dipyrromethene complexed with a disubstituted boron atom, such as BF_2 unit. Preferably, the colorant comprises a BODIPY core, i.e. a 4,4-difluoro-4-bora-3a,4a-diaza-s-indacene core structure, this structure preferably being suitably substituted.

The term Aza-boron-dipyrromethene colorants refers to colorants comprising a difluoro-bora-1,3,5,7-tetraphenyl-aza-dipyrromethene core structure, this structure preferably being suitably substituted.

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Various Boron-dipyrromethene colorants and Aza-boron-dipyrromethene colorants are known to the skilled person, and are e.g. described in Loudet et al., Chem. Rev. 2007, 107, 4891-4932, which contents is herewith incorporated by reference.

10 By way of example the following suitable Boron-dipyrromethene colorants and Aza-boron-dipyrromethene colorants are mentioned



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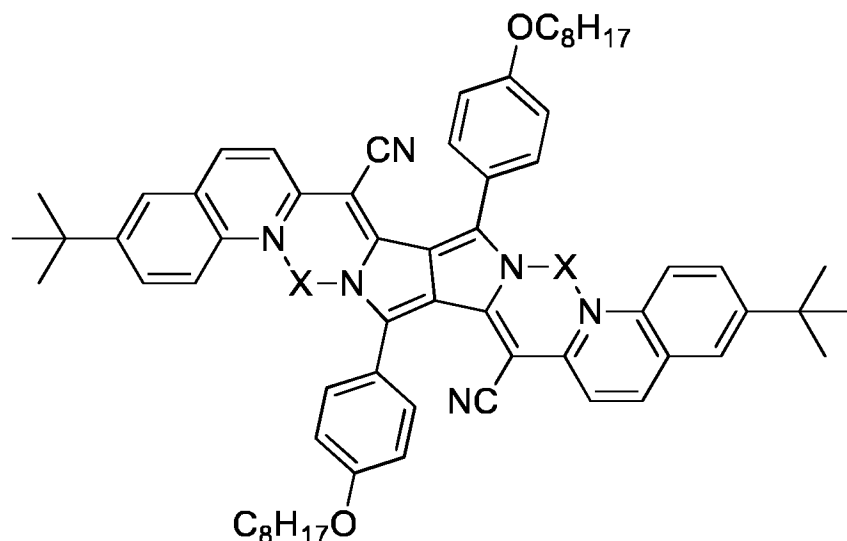
Such compounds and their preparation are e.g. described in WO 2008/145172 A1 and W. Zhao et al, Angew. Chem. Int. Ed. 2005, 44, 1677-79, which contents is hereby incorporated by reference.

20 Diketopyrrolopyrrol colorants

The term diketopyrrolopyrrol colorants (DPP colorants) according to the invention refers to colorants based on the bicyclic heterocyclic compound diketopyrrolopyrrole, i.e. on 2,5-Dihydropyrrolo[3,4-c]pyrrol-1,4-dione, or on any derivative thereof. Such colorants and ways to

25 prepare them are known to the skilled person.

It is to be understood that the term diketopyrrolopyrrol colorants also includes colorants based on heterocyclic derivatives of diketopyrrolopyrrole, such as, e.g., the following colorants which are mentioned by way of example:



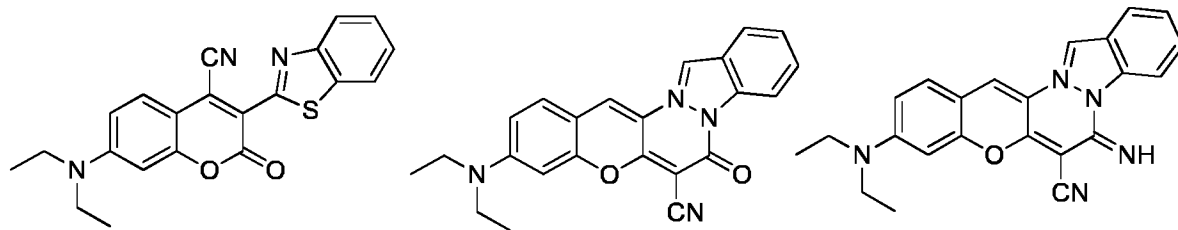
wherein X is selected from the group consisting of H, BF₂ and BPH₂. Such colorants are described e.g. in E Daltrozso, A. Zumbusch et al, Angew. Chem. Int. Ed. 2007, 46, 3750-3753, which contents is hereby incorporated by reference.

Further suitable colorants

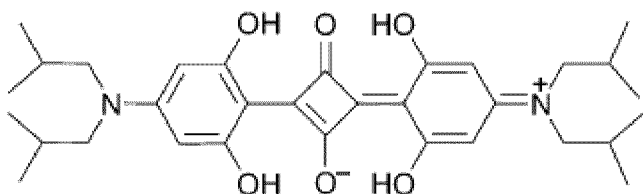
- 10 As mentioned above, besides the colorants discussed above in detail also stilbenes, benzoxazoles, coumarins and benzopyrans, squaraines, oxadiols, anthrachinones, acridines, arylmethanes, violanthrons and isoviolanthrons, and oxazines should be mentioned as preferred colorants according to the invention.
- 15 As preferred stilbenes, any stilbene colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be used. In this context, divinyl stilbenes, triazine stilbines, stilbene triazoles and stilbene benzoxazoles are mentioned by way of example.
- 20 Preferred benzoxazoles, which in a wavelength range of 400 nm to 900 nm, have an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, are, e.g. naphthalene benzoxazoles, bis-benzoxazoles, benzoxazole thiophenes and the like.

As arylmethanes, any arylmethane colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be conceivable. Such compounds are known to the skilled person.

As merocyanines, coumarins and benzopyrans colorant, any merocyanine, coumarin or benzopyran, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be used. By way of example, the following preferred colorants are mentioned:

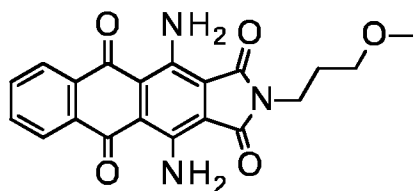


As squaraine colorant, any squaraine, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be used. This includes squaraine derivatives or ring-substituted squaraines, such as, e.g.,



Such squaraine colorants and their preparation is known to the skilled person and e.g. described in Angew. Chem. Int. Ed. 2012, 51, 2020-2068, which contents is hereby incorporated by reference.

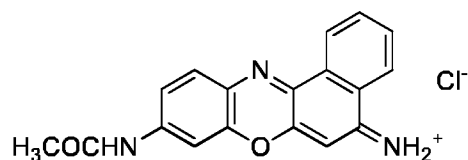
As suitable anthraquinone colorant, by way of example, Disperse Blue 60 (4,11-diamino-2-(3-methoxypropyl)naphtho[2,3-f]isoindole-1,3,5,10-tetrone)



may be mentioned. However, any other anthraquinone colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be conceivable.

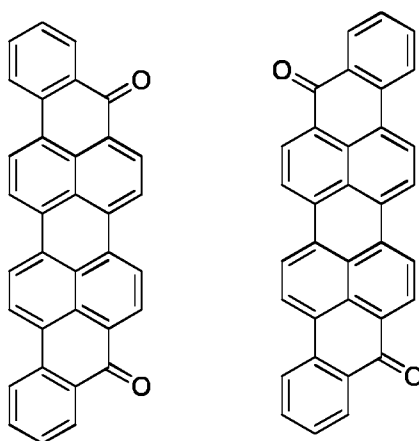
As acridines, neutral red (3-Amino-7-dimethylamino-2-methylphenazine hydrochloride, CAS 553-24-2) and Safranin O (3,7-Diamino-2,8-dimethyl-5-phenyl-phenaziniumchlorid, CAS 477-73-6) are mentioned, by way of example. However, any other acridine colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be conceivable.

As suitable oxazine colorant, by way of example, Darrow Red (CAS 15391-59-0), having the structure

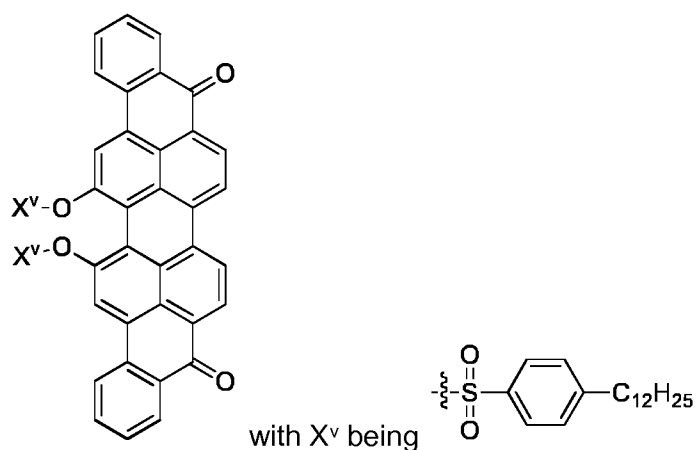


is mentioned. However, any other oxazine colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be conceivable.

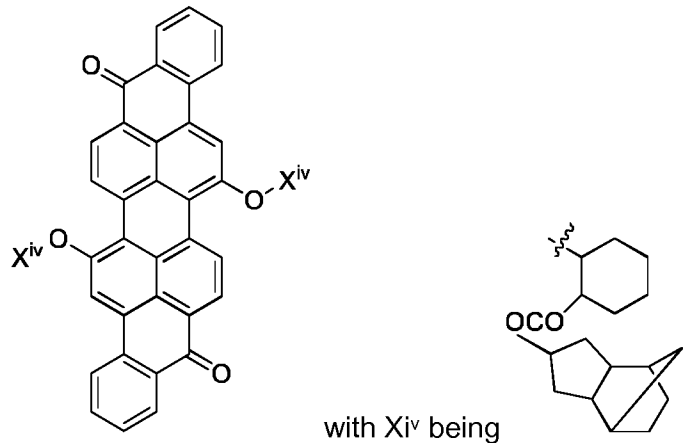
Besides the above mentioned, colorants, violanthron and isoviolanthron colorants, are also particularly preferred. These colorants comprise one of the following core structures or a mixture thereof, the core structures being suitably substituted.



As preferred violanthron colorant, a colorant having the following structure is mentioned:



As preferred isoviolanthron colorant, a colorant having the following structure is mentioned:



Such colorants, are e.g. described in Dyes and Pigments 11 (1989) 303-317 (in particular on page 309-311), which contents is hereby incorporated by reference. It is, however, to be understood, that, any other violanthron or isoviolanthron colorant, which in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, may be conceivable.

According to one embodiment of the invention, the fluorescent colorant is not texas red, DRAQ5, DRAQ7, CyTRAK orange, nile red, nile blue, cresyl violet, oxazine 170, acridine orange, auramine, crystal violet (((4-(4,4'-Bis(dimethylaminophenyl) benzhydryliden)cyclohexa-2,5-dien-1-yliden)dimethylammoniumchloride) or malachite green (4-[[4-(dimethylamino)phenyl](phenyl)methylidene]-*N,N*-dimethylcyclohexa-2,5-dien-1-iminium chloride), more preferably not eosin, texas red, SeTa, SeTau, DRAQ5, DRAQ7, CyTRAK orange, nile red, nile blue, cresyl violet, oxazine 170, acridine orange, auramine, crystal violet (((4-(4,4'-Bis(dimethylaminophenyl) benzhydryliden)cyclohexa-2,5-dien-1-yliden)dimethylammoniumchloride) or malachite green (4-[[4-(dimethylamino)phenyl](phenyl)methylidene]-*N,N*-dimethylcyclohexa-2,5-dien-1-iminium chloride).

Method for manufacturing the optical waveguide

Further, the present invention relates to a method for manufacturing an optical waveguide, the method comprising providing at least one transparent matrix material, the method further comprising embedding at least one fluorescent colorant in the transparent matrix material, the method further comprising shaping the transparent matrix material with the fluorescent colorant into the optical waveguide, wherein the fluorescent colorant, in the range of 400 nm to 900 nm, has an absorption maximum in the wavelength range of 500 nm to 850 nm, the optical waveguide being configured for waveguiding fluorescence light generated by the fluorescent colorant.

Preferably the fluorescent colorant is embedded in the matrix material by distributing the colorant, preferably substantially homogenously, more preferably homogenously, within the matrix or a precursor of the matrix material. Precursor of the matrix material is denoted to refer to a material, which after one or more process steps is transformed into matrix material. Thus, in

case the matrix e.g. consists of a polymer, this term e.g. refers to monomer compounds which after a suitable polymerization form the final polymeric matrix.

The distributing is preferably achieved by mixing the colorant into the matrix material or into the precursor of the matrix material thereby obtaining a mixture M comprising the at least one colorant and the at least one matrix material. The mixing is preferably carried out by dispersing or dissolving the colorant into the matrix material. Preferably, the distributing is carried out such that an even (homogenous) distribution of the colorant in the matrix material is achieved.

Preferably, the method further comprises the processing of the mixture M to a moulding M1. This is preferably carried out by

- (a) extruding and/or granulating the mixture M, and
- (b) subjecting mixture obtained in (b) to a thermal treatment.

The thermal treatment is preferably carried out at a temperature in the range of from 100 °C to 200°C, wherein the temperature may be varied during this thermal treatment or held essentially constant.

The mixture obtained in (b) is then preferably transformed into the optical waveguide using methods known to those skilled in the art.

Use of the optical detector:

Further, the present invention relates to the use of the optical detector which comprises at least one of the optical waveguides as described elsewhere in this document as a separate element or in combination with a distance sensor designed for determining a longitudinal coordinate.

Thus, generally, the devices according to the present invention, in particular the optical detector, may be applied in various fields of uses. Specifically, the detector may be applied for a purpose of use, selected from the group consisting of: a position measurement in traffic technology; an entertainment application; a human-machine interface application; a tracking application; a photography application; a cartography application; a mapping application for generating maps of at least one space; a homing or tracking beacon detector for vehicles; a mobile application; a webcam; an audio device; a Dolby surround audio system; a computer peripheral device; a gaming application; a camera or video application; a surveillance application; an automotive application; a transport application; a logistics application; a vehicle application; an airplane application; a ship application; a spacecraft application; a robotic application; a medical application; a sports' application; a building application; a construction application; a manufacturing application; a machine vision application; a use in combination with at least one sensing technology selected from time-of-flight detector, radar, Lidar, ultrasonic sensors, or interferometry. Additionally or alternatively, applications in local and/or global positioning systems may be named, especially landmark-based positioning and/or navigation, specifically for use in cars or other vehicles (such as trains, motorcycles, bicycles, trucks for cargo transportation), robots or for use by pedestrians. Further, indoor positioning systems may

be named as potential applications, such as for household applications and/or for robots used in manufacturing, logistics, surveillance, or maintenance technology.

For further possible uses, reference may be made to any one of WO 2014/097181 A1, WO 2014/198626 A1, WO 2014/198629 A1, WO 2014/198625 A1, WO 2015/024871 A1, WO 2016/120392 A1, WO 2016/169871 A1, WO 2017/012964 A1, WO 2017/025567 A1, WO 2017/046121 A1, WO 2017/089540 A1, WO 2017/089553 A1, WO 2017/093453 A1, the full content of all of which is herewith also included by reference.

The devices according to the present invention may be combined with one or more other types of measurement devices. Thus, the devices according to the present invention may be combined with one or more other types of sensors or detectors, such as a time of flight (TOF) detector, a stereo camera, a lightfield camera, a lidar, a radar, a sonar, an ultrasonic detector, or interferometry. When combining devices according to the present invention with one or more other types of sensors or detectors, the devices according to the present invention and the at least one further sensor or detector may be designed as independent devices, with the devices according to the present invention being separate from the at least one further sensor or detector. Alternatively, the devices according to the present invention and the at least one further sensor or detector may fully or partially be integrated or designed as a single device.

Thus, as a non-limiting example, the devices according to the present invention may further comprise a stereo camera. As used herein, a stereo camera is a camera which is designed for capturing images of a scene or an object from at least two different perspectives. Thus, the devices according to the present invention may be combined with at least one stereo camera.

The stereo camera's functionality is generally known in the art, since stereo cameras generally are known to the skilled person. The combination with the devices according to the present invention may provide additional distance information. Thus, the devices according to the present invention may be adapted, in addition to the stereo camera's information, to provide at least one item of information on a longitudinal position of at least one object within a scene captured by the stereo camera. Information provided by the stereo camera, such as distance information obtained by evaluating triangulation measurements performed by using the stereo camera, may be calibrated and/or validated by using the devices according to the present invention. Thus, as an example, the stereo camera may be used to provide at least one first item of information on the longitudinal position of the at least one object, such as by using triangulation measurements, and the devices according to the present invention may be used to provide at least one second item of information on the longitudinal position of the at least one object. The first item of information and the second item of information may be used to improve accuracy of the measurements. Thus, the first item of information may be used for calibrating the second item of information or vice versa. Consequently, the devices according to the present invention, as an example, may form a stereo camera system, having the stereo camera and the devices according to the present invention, wherein the stereo camera system is

adapted to calibrate the information provided by the stereo camera by using the information provided by devices according to the present invention.

Consequently, additionally or alternatively, the devices according to the present invention may be adapted to use the second item of information, provided by the devices according to the present invention, for correcting the first item of information, provided by the stereo camera. Additionally or alternatively, the devices according to the present invention may be adapted to use the second item of information, provided by the devices according to the present invention, for correcting optical distortion of the stereo camera. Further, the devices according to the present invention may adapted to calculate stereo information provided by the stereo camera, and the second item of information provided by devices according to the present invention may be used for speeding up the calculation of the stereo information.

As an example, the devices according to the present invention may be adapted to use at least one virtual or real object within a scene captured by the devices according to the present invention for calibrating the stereo camera. As an example, one or more objects and/or areas and/or spots may be used for calibration. As an example, the distance of at least one object or spot may be determined by using the devices according to the present invention, and distance information provided by the stereo camera may be calibrated by using this distance is determined by using the devices according to the present invention. For instance, at least one active light spot of the devices according to the present invention may be used as a calibration point for the stereo camera. The active light spot, as an example, may move freely in the picture.

The devices according to the present invention may be adapted to continuously or discontinuously calibrate the stereo camera by using information provided by an active distance sensor. Thus, as an example, the calibration may take place at regular intervals, continuously or occasionally.

Further, typical stereo cameras exhibit measurement errors or uncertainties which are dependent on the distance of the object. This measurement error may be reduced when combined with information provided by the devices according to the present invention.

Overall, in the context of the present invention, the following embodiments are regarded as preferred:

1. An optical detector, comprising at least one optical waveguide, the optical waveguide having at least one transparent matrix material and at least one fluorescent colorant embedded into the matrix material, wherein the fluorescent colorant, in the range of 400 nm to 900 nm, has an absorption maximum in the wavelength range of 500 nm to 850 nm, the optical waveguide being configured for waveguiding fluorescence light generated by the fluorescent colorant, the optical waveguide further having at least one light-sensitive area configured for being illuminated by at least one light beam, the optical detector

further comprising at least one photosensitive element configured for detecting fluorescence light generated by the fluorescent colorant, excited by the light beam, waveguided by the optical waveguide and coupled out from the optical waveguide.

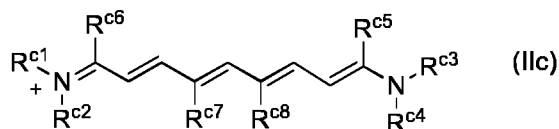
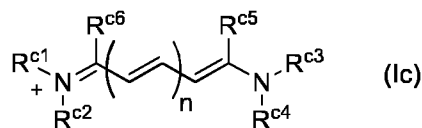
- 5 2. The optical detector according to the preceding embodiment, wherein the absorption maximum is measured with the colorant embedded into the matrix material.
3. The optical detector according to any one of the preceding embodiments, wherein the absorption maximum is an absolute maximum over the range of 400 nm to 850 nm.
- 10 4. The optical detector according to any one of the preceding embodiments, wherein the optical waveguide, at least partially, has one or more of the following shapes: a sheet, a foil, a disc, a bar or a slab.
- 15 5. The optical detector according to any one of the preceding claims, wherein the matrix material comprises polycarbonate or poly(methyl-methacrylate).
6. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant, in the range of 400 nm to 900 nm, has an absorption maximum in the wavelength range of 550 nm to 850 nm.
- 20 7. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant, in the range of 400 nm to 900 nm, has an absorption maximum in the range of 600 nm to 800 nm.
- 25 8. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is selected from the group consisting of stilbenes, benzoxazoles, squaraines, bisdiphenylethylenes, merocyanines, coumarins, benzopyrans, naphthalimides, rylene, phthalocyanines, naphthalocyanines, cyanines, xanthenes, oxazines, oxadiazols, squaraines, oxadiols, anthrachinones, acridines, arylmethanes, boron-dipyrromethenes, Aza-boron-dipyrromethenes, violanthrons, isoviolanthrons and diketopyrrolopyrrols.
- 30 9. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is selected from the group consisting rylene, phthalocyanines, naphthalocyanines, cyanines, xanthenes, oxazines, boron-dipyrromethenes, aza-boron-dipyrromethenes and diketopyrrolopyrrols.
- 35 10. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is a rylene colorant, preferably wherein the colorant is selected from the group consisting of compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, compound 15 of Table 1, compound 16 of Table 1, compound 17 of Table 1 and compound 4 of Table 1, preferably wherein the colorant is selected from the group
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consisting of compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, and compound 4 of Table 1, preferably wherein the colorant is the compound 3 of Table 1 or the compound 4 of Table 1, with compound 4 (2,13-Bis[2,6-bis(1-methylethyl)phenyl]-5,10,16,21-tetrakis[4-(1,1,3,3-tetramethylbutyl)phenoxy]-anthra[9",1",2":6,5,10;10",5",6":6',5',10']dianthra[2,1,9-def:2',1',9'-d'e'f']diisoquinoline-1,3,12,14(2H,13H)-tetrone) being particularly preferred.

11. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is a phthalocyanine colorant, which is preferably selected from the group consisting of compound 5, compound 6, compound 7, compound 8, compound 9, compound 10 and compound 14 of Table 1, more preferably the phthalocyanine colorant is the compound 14 of Table 1 or the compound 10 of Table 1, most preferably, the phthalocyanine colorant is the compound 14 of Table 1.

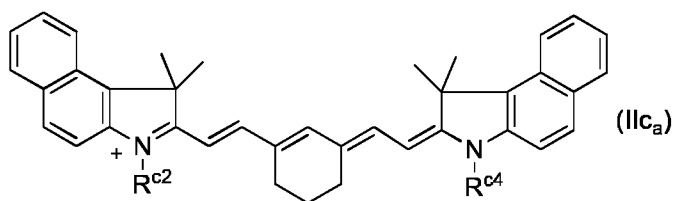
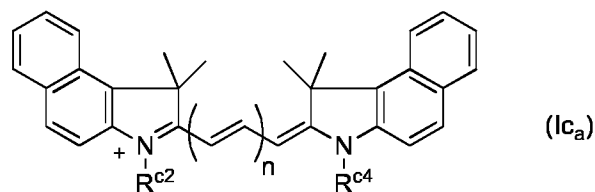
12. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is a naphthalocyanine colorant.

13. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is a cyanine having the structure (Ic) or (IIc),



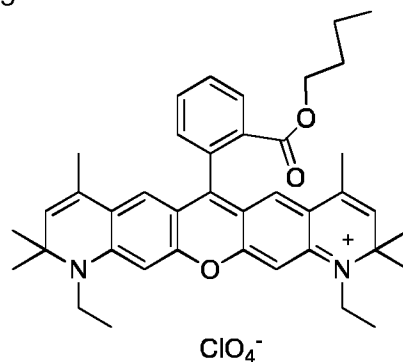
wherein $\text{R}^{\text{c}2}$ and $\text{R}^{\text{c}4}$, are independently of each other selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl, and wherein $\text{R}^{\text{c}1}$ is selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with $\text{R}^{\text{c}6}$ an, optionally substituted, cyclic ring, such as cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein $\text{R}^{\text{c}3}$ is selected from the group consisting of alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with $\text{R}^{\text{c}4}$ an, optionally substituted, cyclic ring, such as a cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein $\text{R}^{\text{c}6}$ is selected from the group consisting of H, alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with $\text{R}^{\text{c}1}$ an, optionally substituted, cyclic ring, such as a cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring, and wherein $\text{R}^{\text{c}5}$ is selected from the group consisting of H, alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl and heteroaryl or forms together with $\text{R}^{\text{c}5}$ an, optionally substituted, cyclic ring, such as an cycloalkyl, heterocycloalkyl, aryl or heteroaryl ring and wherein $\text{R}^{\text{c}2}$ and $\text{R}^{\text{c}4}$, are, independently of each other, selected from the group consisting of H, alkyl and cycloalkyl or form a cyclic

ring with one another, and wherein n is an integer in the range of from 1 to 10, preferably 1 to 10, more preferably 1 to 5, most preferably n is 2, preferably, wherein the cyanine colorant according to the invention has a structure according formula (Ic_a) or (IIc_b), more preferably according to (Ic_a).



wherein R^{c4} is methyl or butyl, and wherein R^{c2} is butyl or $-C_5H_{10}-COOH$, more preferably wherein both, R^{c2} and R^{c4} are butyl, with n being preferably of from 1 to 5, more preferably 2, and wherein the cyanine colorant is more preferably S 0315 (3-Butyl-2-[5-(3-butyl-1,3-dihydro-1,1-dimethyl-2H-benzo[e]indol-2-ylidene)-penta-1,3-dienyl]-1,1-dimethyl-1H-benzo[e]indolium perchlorate) or S 0944 (1,3,3-Trimethyl-2-[5-(1,3,3-trimethyl-1,3-dihydro-indol-2-ylidene)-penta-1,3-dienyl]-3Hindolium chloride), more preferably S 0315.

14. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is a xanthene colorant, preferably a rhodamine colorant, more preferably the colorant having the structure:



15. The optical detector according to any one of embodiments 1 to 10, wherein the fluorescent colorant is selected from the group consisting of Compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, Compound 4 of Table 1, Compound 5 of Table 1, Compound 6 of Table 1, Compound 7 of Table 1, Compound 8 of Table 1, Compound 9 of Table 1, Compound 10 of Table 1, Compound 11 of Table 1, Compound 12 of Table 1, Compound 13 of Table 1, Compound 14 of Table 1, Compound 15 of Table 1, Compound 16 of Table 1, Compound 17 of Table 1, Compound 18 of Table 1, Compound 19 of Table 1 and Compound 20 of Table 1, preferably wherein the

- fluorescent colorant is selected from the group consisting of Compound 1 of Table 1, Compound 2 of Table 1, Compound 3 of Table 1, Compound 4 of Table 1, Compound 5 of Table 1, Compound 6 of Table 1, Compound 7 of Table 1, Compound 8 of Table 1, Compound 9 of Table 1, Compound 10 of Table 1, Compound 11 of Table 1, Compound 12 of Table 1, Compound 13 of Table 1 and Compound 14 of Table 1.
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16. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is selected from the group consisting of Compound 3 of Table 1, Compound 14 of Table 1, Compound 11 of Table 1, and Compound 5 of Table 1, with Compound 4 of Table 1, being particularly preferred.
- 10
17. The optical detector according to any one of the preceding embodiments, wherein the matrix comprises at least one suitable stabilizer, preferably selected from the group consisting of antioxidants, UV absorbers, light stabilizers, hindered amine light stabilizers and antiozonants and the like, more preferably at least one hindered amine light stabilizers.
- 15
18. The optical detector according to any one of the preceding embodiments, wherein the matrix comprises at least one suitable stabilizer in an amount of 0.001 % by weight to 10 % by weight, based on the total weight of the sum of all matrix materials.
- 20
19. The optical detector according to any one of the preceding embodiments, wherein the matrix material comprises the at least one fluorescent colorant in an amount in the range of from 1 ppm to 5 % by weight, more preferably in an amount in the range of from 5 ppm to 0.5 % by weight, more preferably in an amount in the range of from 10 ppm to 0.1 % by weight, based on the total weight of the waveguide.
- 25
20. The optical detector according to any one of the preceding embodiments, wherein waveguide comprises the at least one fluorescent colorant in an amount in the range of from 1 ppm to 5 % by weight, more preferably in an amount in the range of from 5 ppm to 0.5 % by weight, more preferably in an amount in the range of from 10 ppm to 0.1 % by weight, more preferably in an amount in the range of from 100 ppm to 0.05 % by weight.
- 30
21. The optical detector according to any one of the preceding embodiments, wherein the fluorescent colorant is not texas red, DRAQ5, DRAQ7, CyTRAK orange, nile red, nile blue, cresyl violet, oxazine 170, acridine orange, auramine, crystal violet or malachite green, more preferably not eosin, texas red, SeTa, SeTau, DRAQ5, DRAQ7, CyTRAK orange, nile red, nile blue, cresyl violet, oxazine 170, acridine orange, auramine, crystal violet or malachite green.
- 35
22. The optical detector according to any one of the preceding embodiments, wherein the photosensitive element is optically coupled to the optical waveguide by at least one optical coupling element configured for at least partially coupling the fluorescence light out of the waveguide.
- 40

23. The optical detector according to the preceding embodiment, wherein the photosensitive element is optically coupled to the optical waveguide by at least one optical coupling element configured for at least partially coupling the fluorescence light guided by the optical waveguide out of the optical waveguide.
24. The optical detector according to the preceding embodiment, wherein the optical coupling element is selected from the group consisting of: a portion of transparent adhesive attaching the photosensitive element to the optical waveguide; an etched portion within the optical waveguide; a scratch in the optical waveguide; a prism.
25. The optical detector according to any one of the preceding embodiments referring to an optical detector, wherein the optical detector comprises at least two of the photosensitive elements located at different positions, the optical detector further comprising at least one evaluation device, the evaluation device being configured for determining at least one transversal coordinate of a light spot generated by the light beam on the light-sensitive area.
26. The optical detector according to the preceding embodiment, wherein the evaluation device comprises at least one subtracting device configured to form at least one difference signal D between signals generated by at least two of the photosensitive elements.
27. The optical detector according to the preceding embodiment, wherein the signals comprise at least one first signal s_1 and at least one second signal s_2 , wherein the at least one difference signal D is proportional to $a \cdot s_1 - b \cdot s_2$, with a, b being real number coefficients, preferably with $a=1$ and $b=1$, in particular, wherein the at least one difference signal D is derived according to the equation $D = (a \cdot s_1 - b \cdot s_2) / (a \cdot s_1 + b \cdot s_2)$.
28. The optical detector according to any one of the preceding embodiments referring to an optical detector, wherein the photosensitive elements comprise at least two photosensitive elements located at opposing partitions, e.g. at opposing rim portions and/or corners, of the optical waveguide.
29. The optical detector according to the preceding embodiment, wherein the photosensitive elements comprise at least one first pair of photosensitive elements located at opposing partitions, e.g. at opposing rim portions and/or corners, of the optical waveguide in a first dimension of a coordinate system, wherein the photosensitive elements further comprise at least one second pair of photosensitive elements located at opposing partitions, e.g. at opposing rim portions and/or corners, of the optical waveguide in a second dimension of the coordinate system.

30. The optical detector according to any one of the preceding embodiments referring to an optical detector, wherein the optical detector further comprises at least one transfer device, the transfer device being adapted to guide the light beam onto the optical waveguide.
- 5
31. The optical detector according to the preceding embodiment, wherein the transfer device comprises one or more of: at least one lens, preferably at least one focus-tunable lens; at least one beam deflection element, preferably at least one mirror; at least one beam splitting element, preferably at least one of a beam splitting cube or a beam splitting mirror; at least one multi-lens system.
- 10
32. The optical detector according to any one of the preceding embodiments referring to an optical detector, wherein the optical detector is furthermore designed in a manner that the signal is dependent on a modulation frequency of a modulation of the illumination, wherein the optical detector is configured to detect at least two signals at respectively different modulation frequencies.
- 15
33. A detector system for determining a position of at least one object, the detector system comprising at least one detector according to any one of the preceding embodiments referring to an optical detector, the detector system further comprising at least one beacon device adapted to direct at least one light beam towards the detector, wherein the beacon device is at least one of attachable to the object, holdable by the object and integratable into the object.
- 20
34. A human-machine interface for exchanging at least one item of information between a user and a machine, wherein the human-machine interface comprises at least one detector system according to the preceding embodiment, wherein the at least one beacon device is adapted to be at least one of directly or indirectly attached to the user and held by the user, wherein the human-machine interface is designed to determine at least one position of the user by means of the detector system, wherein the human-machine interface is designed to assign to the position at least one item of information.
- 25
35. An entertainment device for carrying out at least one entertainment function, wherein the entertainment device comprises at least one human-machine interface according to the preceding embodiment, wherein the entertainment device is designed to enable at least one item of information to be input by a player by means of the human-machine interface, wherein the entertainment device is designed to vary the entertainment function in accordance with the information.
- 30
36. A tracking system for tracking a position of at least one movable object, the tracking system comprising at least one detector system according to any one of the preceding embodiments referring to a detector system, the tracking system further comprising at
- 35
- 40

least one track controller, wherein the track controller is adapted to track a series of positions of the object at specific points in time.

37. A camera for imaging at least one object, the camera comprising at least one detector according to any one of the preceding embodiments referring to a detector.

38. A use of the optical detector according to any one of the preceding embodiments referring to an optical detector, for the purpose of use, selected from the group consisting of: a scanning application; an application for detecting a position of at least one object; a position measurement in traffic technology; an entertainment application; a surveillance application; a safety application; a human-machine interface application; a tracking application; a photography application; a use in combination with at least one time-of-flight detector; a use in combination with a structured light source; a use in combination with a stereo camera; a machine vision application; a robotics application; a quality control application; a manufacturing application; a use in combination with a structured illumination source; a use in combination with a stereo camera.

Brief description of the figures

Further optional details and features of the invention are evident from the description of preferred exemplary embodiments which follows in conjunction with the dependent claims. In this context, the particular features may be implemented in an isolated fashion or in combination with other features. The invention is not restricted to the exemplary embodiments. The exemplary embodiments are shown schematically in the figures. Identical reference numerals in the individual figures refer to identical elements or elements with identical function, or elements which correspond to one another with regard to their functions.

Specifically, in the figures:

Figures:

Fig. 1: Overview over absorption spectra of waveguides Nos. 1.1, 2.1-2.4, i.e. with Compounds 1, 2, 3 and 4 (see examples I.1 and I.2)

Fig. 2: Absorption spectrum of waveguide No 1.1. (see example I.1, Compound 4)

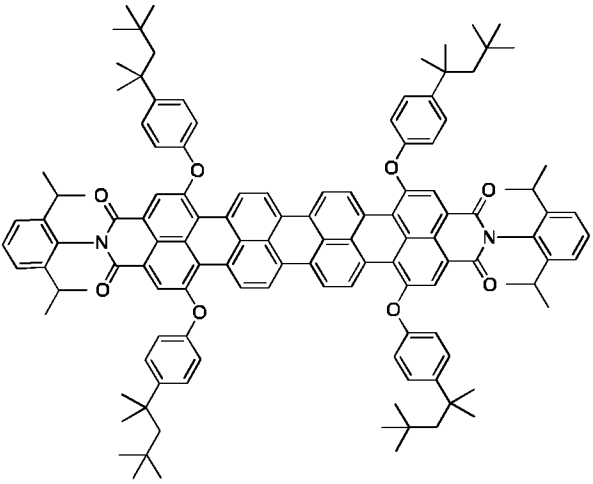
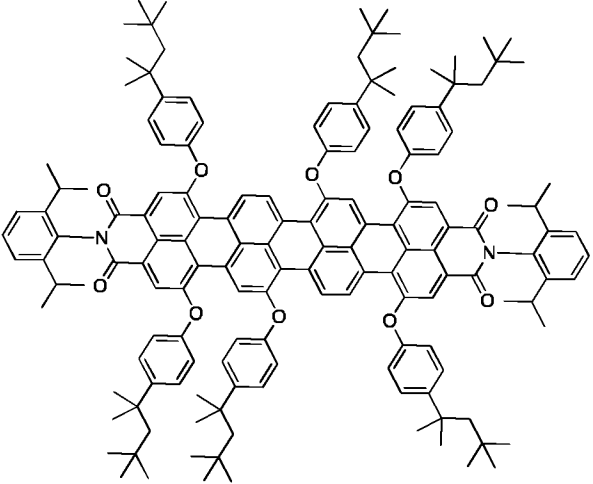
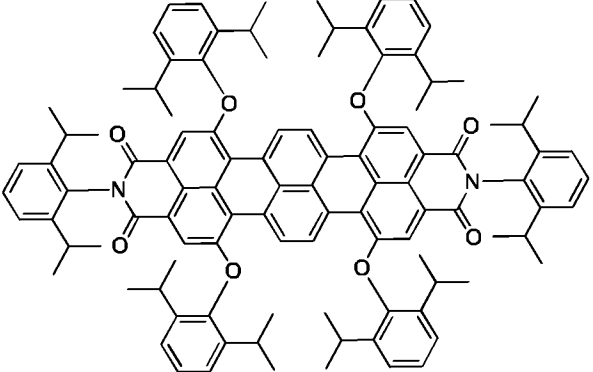
Fig. 3: Absorption spectrum of waveguide No 2.3. (see example I.2, Compound 3)

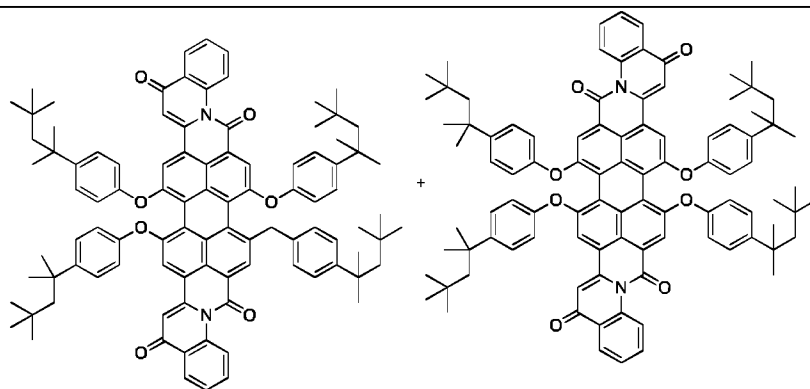
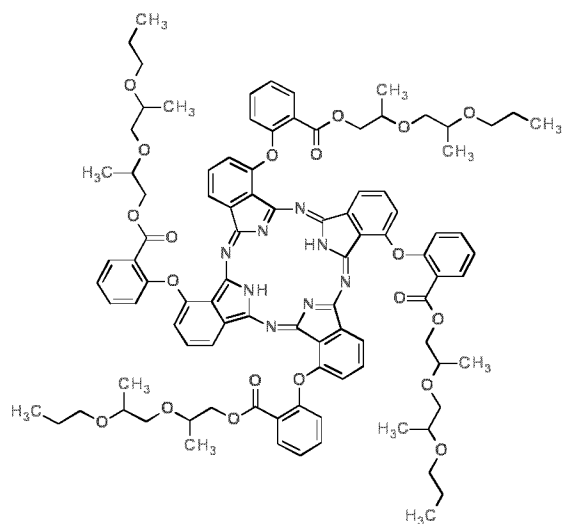
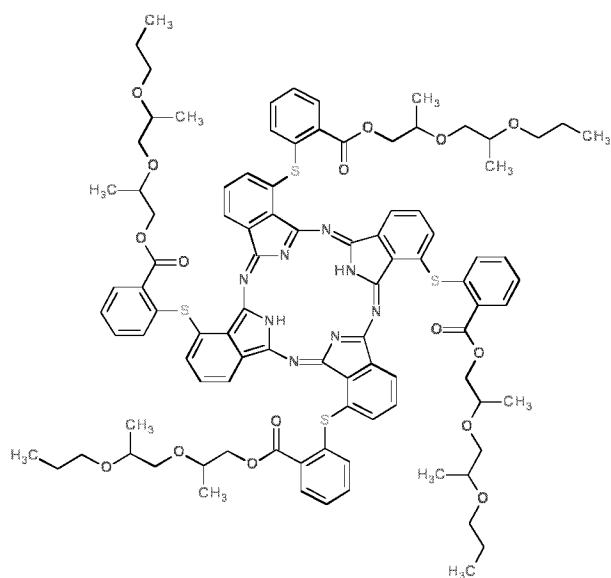
Fig. 4: Absorption spectrum of waveguide No 2.1. (see example I.2, Compound 1)

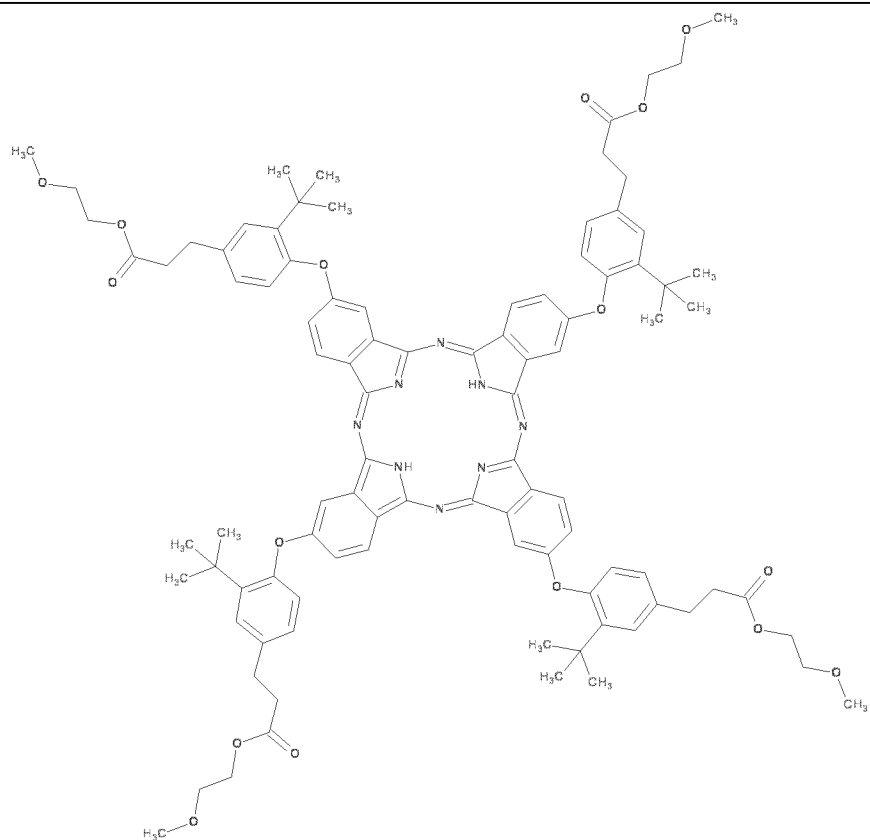
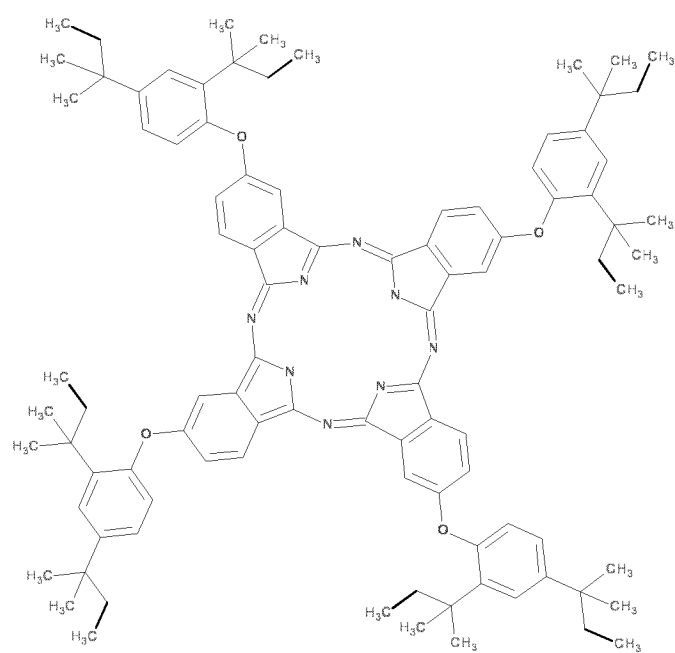
Fig. 5: Absorption spectrum of waveguide No 2.2 (see example I.2, Compound 2)

- Fig. 6:** Absorption and emission spectra measured on plastic films with compound 1 and compound 2 of Table 1 (waveguides Nos 2.1-2.2).
- 5 **Fig. 7:** Absorption and emission spectra measured on plastic films with compound 1 and compound 2 of Table 1 (waveguides Nos 2.1-2.2).
- Fig. 8:** Absorption spectrum of waveguide No 1.2. (see example I.1, Compound 11)
- Fig. 9:** Overview over absorption spectra of waveguides Nos. 1.3-1.10 (see example I.1)
- 10 **Fig.10:** Absorption spectrum of waveguide No 1.5 (see example I.1).
- Fig.11:** Absorption spectrum of waveguide No 1.3 (see example I.1).
- 15 **Fig.12:** Absorption spectrum of waveguide No 1.9. (see example I.1)
- Fig.13:** Absorption spectrum of waveguide No 1.4 (see example I.1)
- Fig.14:** Absorption spectrum of waveguide No 1.10 (see example I.1)
- 20 **Fig.15:** Absorption spectrum of waveguide No 1.6 (see example I.1)
- Fig.16:** Absorption spectrum of waveguide No 1.8 (see example I.1)
- Fig.17:** Absorption spectrum of waveguide No 1.7 (see example I.1)
- 25 **Fig.18:** Reference example: Determination of the absorption of a plastic sheet with 0.02% Lumogen F (see example III)
- Fig.19 – Fig. 26:** Evaluation of the waveguiding properties of plastic sheets incorporating 0.02% of various fluorescent colorants according to example IV.
- 30
- Fig. 27 and 28:** Different views of an exemplary embodiment of an optical detector in a top view onto a light-sensitive area (Fig. 27) and in a cross-sectional view (Fig. 28).
- 35 **Fig. 29:** Top view onto the light-sensitive area of Fig. 27 with a light spot generated by a light beam.
- Fig. 30:** An exemplary schematic setup of the evaluation device.
- 40 **Fig. 31:** Exemplary embodiment of an optical detector, a detector system, a human-machine interface, an entertainment device and a tracking system.
- Fig. 32A and 32B:** An alternative embodiment of the detector.

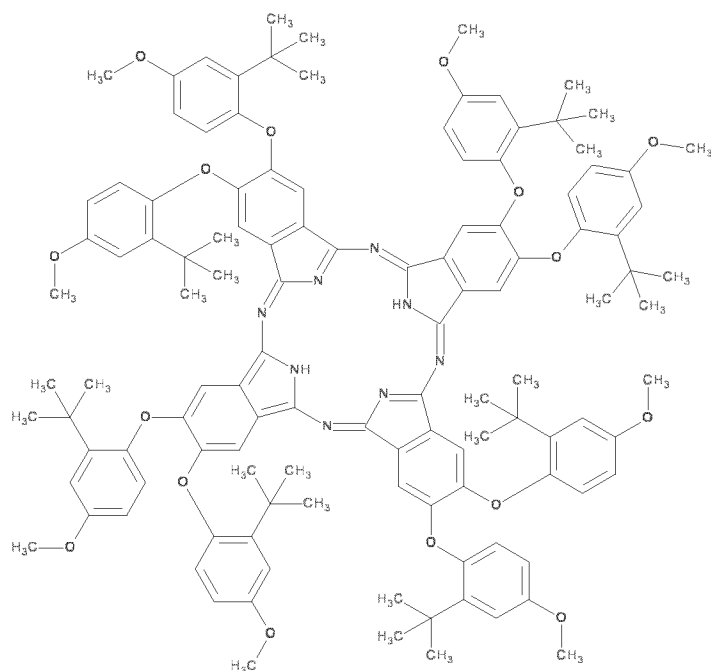
Table 1: Preferred Fluorescent Colorants

Compound	Chemical Structure
<u>1</u>	
<u>2</u>	
<u>3</u>	

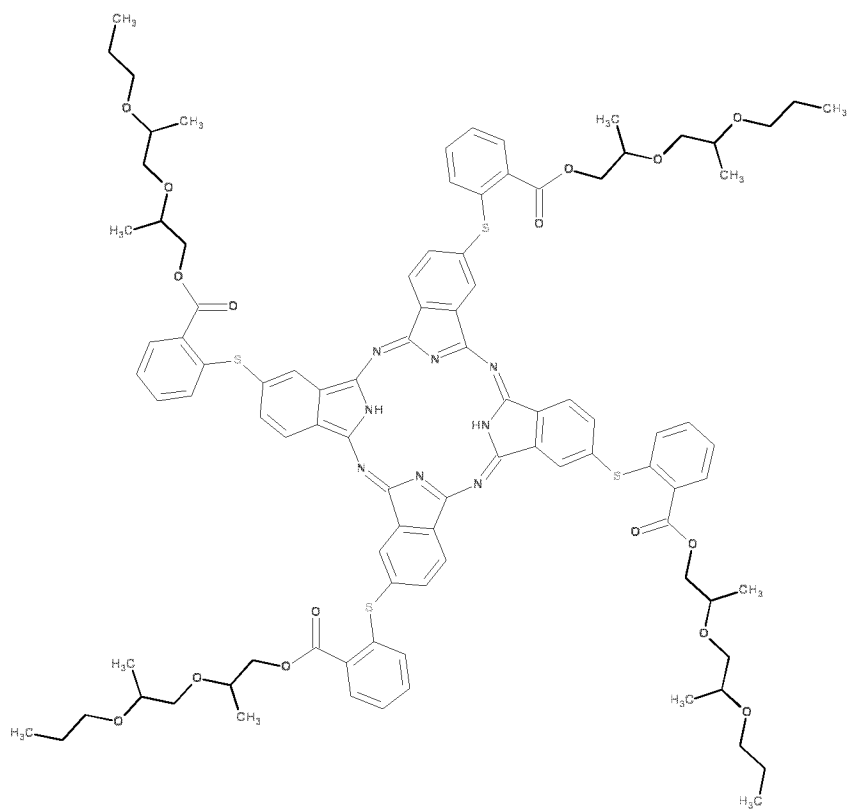
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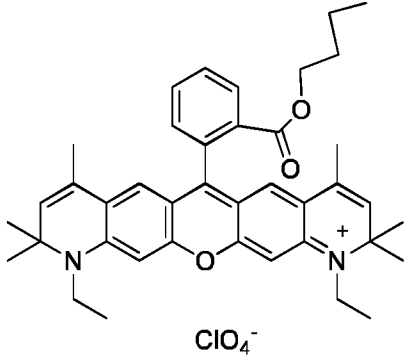
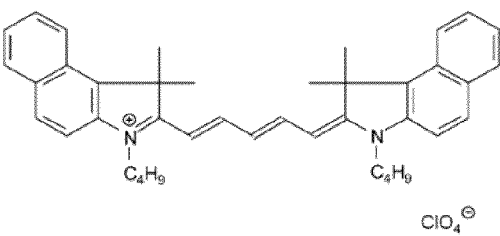
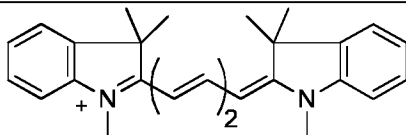
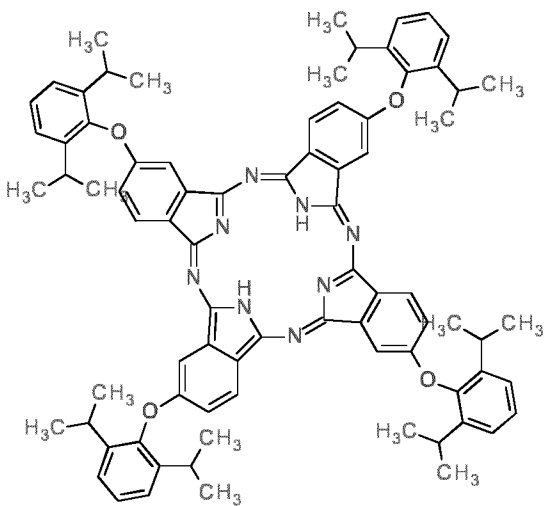
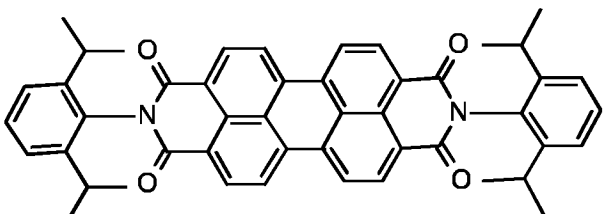
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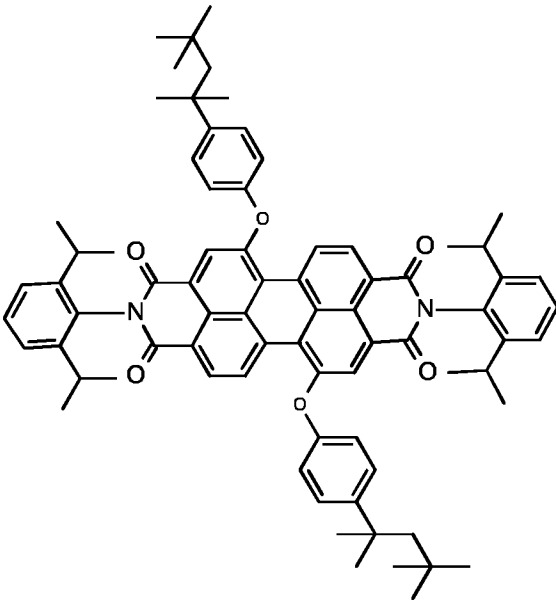
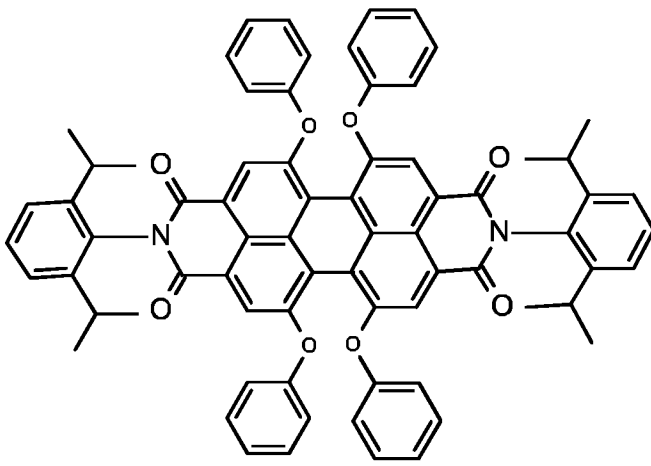
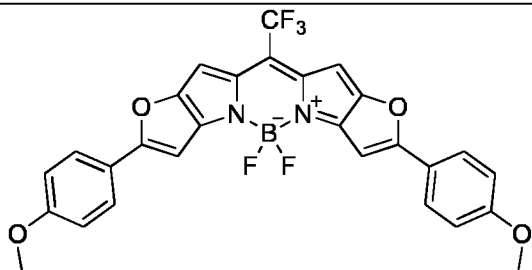
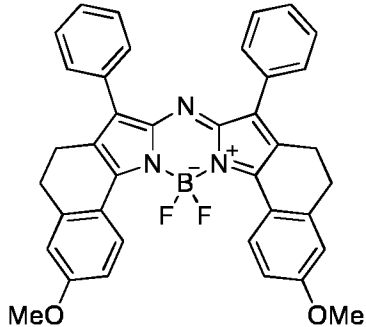
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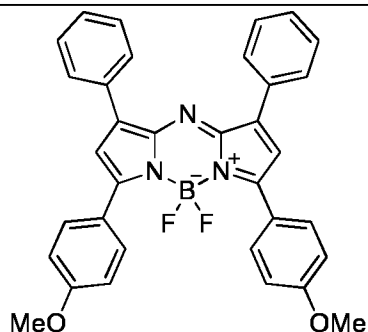
10



<u>11</u>	 ClO_4^-
<u>12</u>	 ClO_4^- (S 0315)
<u>13</u>	 Cl^- (S 0944)
<u>14</u>	
<u>15</u>	

<u>16</u>	
<u>17</u>	
<u>18</u>	
<u>19</u>	

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Working examples:

I. Production of the colored samples

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I.1 PMMA as matrix

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1000.00 g of polymethyl methacrylate (PMMA 6N clear, available from Röhm GmbH, Germany) were predried at a maximum temperature of 90°C for 4 hours and then mixed with 0.02 weight % of a Fluorescent colorant X (see Table 2) in a Turbula Fuchs mixer for 20 min. The homogenous mixture was extruded on a Twin Screw 25 mm extruder from Collin, Germany, six heating zones (cold, 150°C, 195°C, 200°C, 200°C, 200°C, 200°C) at a maximum temperature of 200°C. The extrudate was granulated in a granulator (Scheer, Stuttgart). The granulate was dried at a maximum temperature of 90°C for 4 hours and then processed to colored samples (30 mm x 55 mm x approx. 1.2 mm) using a Boy Injection Molding Machine (Boy 30A from Dr. Boy GmbH, Neustadt, Germany) or a Klöckner Ferromatik FM 40 (from Klöckner, Germany). The mouldings obtained were packed up in an oxygen free plastic bag with a vacuum pack machine after drying.

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Table 2:

Waveguide No	Fluorescent colorant X	Geometry
1.1	Compound <u>4</u> of Table 1	Foil**
1.2	Compound <u>11</u> of Table 1	Slab*
1.3	Compound <u>7</u> of Table 1	Slab*
1.4	Compound <u>6</u> of Table 1	Slab*
1.5	Compound <u>5</u> of Table 1	Slab*
1.6	Compound <u>8</u> of Table 1	Slab*
1.7	Compound <u>12</u> of Table 1	Slab*
1.8	Compound <u>14</u> of Table 1	Slab*
1.9	Compound <u>10</u> of Table 1	Slab*
1.10	Compound <u>9</u> of Table 1	Slab*

* (30 mm x 55 mm x approx. 1.2 mm)

** 200 µm thick

I.2 Macrolon (Polycarbonat) as matrix

1000.00 g of Polycarbonate (MACROLON 2805, Bayer) were predried at a maximum temperature of 120°C for 4 hours and then mixed with 0.2 g of a Fluorescent colorant X (see Table 3) in a Turbula Fuchs mixer for 20 min. The homogenous mixture was extruded on a Twin Screw 25 mm extruder from Collin, Germany, six heating zones (cold, 150°, 265°, 275°, 280°, 280°, 280°C) at a maximum temperature of 280°C. The extrudate was granulated in a granulator (Scheer, Stuttgart). The granulate was dried at a maximum temperature of 120°C for 4 hours and then processed to colored samples using a Boy Injection Molding Machine (Boy 30A from Dr. Boy GmbH, Neustadt, Germany) or a Klöckner Ferromatik FM 40 (from Klöckner, Germany). The mouldings obtained were packed up in an oxygen free plastic bag with a vacuum pack machine after drying.

Table 3:

Waveguide No	Fluorescent colorant X	Geometry
2.1	Compound <u>1</u> of Table 1	Foil**
2.2	Compound <u>2</u> of Table 1	Foil**
2.3	Compound <u>3</u> of Table 1	Foil**

** 200 µm thick

II. Determination of the absorption of plastic sheets with 0.02% fluorescent colorants

The absorption properties of plastic sheets prepared according to working example I.1 and I.2 were measured. The results are shown in figures 1 to figure 17.

III. Reference example: Determination of the absorption of plastic sheets with 0.02% Lumogen F violet 570

The absorption properties of a plastic sheet (2 mm thick, PMMA 7N) with 0.02 % Lumogen F Violet 570 (BASF) as colorant were measured. The result is given in Figure 18.

IV. Evaluation of the waveguiding properties of plastic sheets incorporating 0.02% of various fluorescent colorant

The waveguiding properties of plastic sheets incorporating 0.02% of various fluorescent colorant samples were evaluated. The films were produced using various methods and matrix polymers and in accordance with examples I.1 and I.2.

A photodiode was glued onto the foil and the photoresponse was recorded at various distances to an incident light spot (70 mW light power at 405 nm).

The absolute response at short distances is large, when the colorant is strongly absorbing, the fluorescence quantum yield is large, and the reabsorption of fluorescence light is small.

Weighting the photoresponse by the absorption is hence considered a meaningful way to evaluate. This is achieved by dividing the photoresponse by the optical density of the foil at 405 nm. As generally known, the optical density may be determined by measuring a fraction of light passing through a sample at a given wavelength. The wavelength of 405 nm was chosen here because all the studied colorants show an absorption band around this wavelength.

The decay of the photoresponse with the distance over which the fluorescence light has to travel inside the plastic sheet is a measure of the waveguiding properties of the sample. A less preferred film and surface quality will cause a fast decline with distance, hence yielding a large slope in the graphs below.

The results are given in Figures 19 to 26.

The highest weighted photoresponse values at 5 mm distance between light spot and photodiode (> 2000) were achieved with the rylene colorants Compound 3 and Compound 4, as well as the phthalocyanine colorant Compound 14 and the rhodamine colorant Compound 11. These values are comparable or even exceed results achieved with Lumogen F according to example III. In particular, the supreme performance of compound 4, displaying a high absolute photoresponse as well as a low absorption at 405 nm as well as 660 nm, is surprising.

Optical detector

Figures 27 to 32 each provide, in a highly schematic illustration, exemplary embodiments of an optical detector 110 according to the present invention.

Figure 27 shows a top view and Figure 28 a cross-sectional view of a first exemplary embodiment of the optical detector 110. Herein, the optical detector 110 comprises an optical waveguide 112. In this exemplary embodiment, the optical waveguide 112 may be designed as a flat fluorescent waveguiding sheet 114, wherein the fluorescent waveguiding sheet 114 forms a light-sensitive area 116. As symbolically depicted by the arrow 118, in the fluorescent waveguiding sheet 114 a waveguiding by internal reflection may take place, specifically by internal total reflection, specifically a waveguiding of fluorescence light generated within the fluorescent waveguiding sheet 114. The fluorescent waveguiding sheet 114, as an example, may have a lateral extension of at least 25 mm^2 , such as at least 100 mm^2 , more preferably of at least 400 mm^2 . As an example, a $10 \text{ mm} \times 10 \text{ mm}$ square sheet, a $20 \text{ mm} \times 20 \text{ mm}$ square sheet, a $50 \text{ mm} \times 50 \text{ mm}$ square sheet or another dimension may be used. It shall be noted,

however, that the non-square geometries or even non-rectangular geometries may be used, such as circular or oval geometries.

The fluorescent waveguiding sheet 114 comprises at least one transparent matrix material 120 and at least one fluorescent colorant 122 embedded into the matrix material 120, wherein the fluorescent colorant 122, in the range of 400 nm to 900 nm, has an absorption maximum in the wavelength range of 500 nm to 850 nm, being configured for waveguiding fluorescence light generated by the fluorescent colorant 122. Particularly preferred examples which may be used as the fluorescent colorant 122 may be found elsewhere in this document, in particular in any one of Figures 1-26 and the corresponding description.

In general, the optical detector 110 has a single photosensitive element or, as schematically depicted in Figure 27, a plurality of photosensitive elements 124, 126, 128, 130. Depending on the application of the optical detector 110 the number of photosensitive elements may be selected. In a case in which the optical detector 110 may be, in particular, be designed to detect a single beam of fluorescence light, providing a single photosensitive element may be sufficient (not depicted here). In this case the optical detector may be used for measuring property of the fluorescence light, such as an intensity, a wavelength, or a polarization.

However, under other circumstances providing a plurality of photosensitive elements 124, 126, 128, 130, such as illustrated in Figure 27, may be advantageous, such as in an alternative case in which the optical detector 110 may be, particularly, be designed in order to detect various beams of fluorescence light under predefined directions. A preferred example for the latter case may be a position sensitive device, also abbreviated to a "PSD", in which a location of a generation of fluorescence light by the fluorescent colorant 122 may be detectable, such as in a fashion as described below in more detail. However, other applications of the optical detector 110 may also be feasible.

According to the application of the optical detector 110 as position sensitive device, the plurality of the photosensitive elements 124, 126, 128, 130, which are referred to as PD1-PD4 in Figures 27 and 28, are located at respective partitions 132, 134, 136, 138 of the fluorescent waveguiding sheet 114. In this exemplary embodiment, the fluorescent waveguiding sheet 114 may have a rectangular shape, such that pairs of the photosensitive elements are opposing each other, such as a first pair of the photosensitive elements 124, 126 and a second pair of the photosensitive elements 128, 130. The sides of the rectangular shape of the waveguiding sheet 114 may define a Cartesian coordinate system, with an x-dimension defined by an interconnection between the first pair of the photosensitive elements 124, 126, and a y-dimension defined by an interconnection between the second pair of the photosensitive elements 128, 130. It shall be noted, however, that other coordinate systems are feasible, in particular, in a case in which the optical waveguide 112 may assume a different shape apart from a square configuration as shown in Figures 27 to 29 and 32.

The photosensitive elements 124, 126, 128, 130, as an example, may comprise photodiodes. In general, however, other photosensitive elements may be used. The photosensitive elements 124, 126, 128, 130, as an example, may be or may comprise strip-shaped photodiodes covering, preferably, the full length of the respective partitions 132, 134, 136, 138, or, preferably, covering at least 50% or more preferably at least 70% of the length of these respective partitions 132, 134, 136, 138. Other embodiments, however, are feasible, such as embodiments in which more than one photosensitive element is located at a respective partition of the optical waveguide 112.

The photosensitive elements 124, 126, 128, 130 each produce at least one signal, in response to the light, specifically the fluorescence light, detected by these photosensitive elements 124, 126, 128, 130. The photosensitive elements 124, 126, 128, 130 may, preferably, be connected to an evaluation device 140 of the optical detector 110, the function of which will be explained in further detail below. Thus, the signals of the photosensitive elements 124, 126, 128, 130 may be provided to the evaluation device 140. The evaluation device 140 may be configured to determine at least one transversal coordinate x , y , as will be outlined in further detail below with reference to Figures 29 and 30.

The optical waveguide 112 further may comprise at least one reference photosensitive element 142, in Figure 28 also referred to as PD5, which may be located on a reverse side 144 of the optical waveguide 112, facing away from the object and facing away from the light-sensitive area 116. Again, the reference photosensitive element 142 may be or may comprise at least one photodiode, such as at least one large area photodiode. As an example, the reference photosensitive element 142 may comprise a large area photodiode covering at least 50% of the reverse side 144, which may also be referred to as the back side, of the fluorescent waveguiding sheet 114. It shall be noted, however, that other embodiments are feasible, such as embodiments comprising a plurality of reference photosensitive elements 142. As an example, a plurality of reference photosensitive elements 142 may be located on the reverse side 144, the plurality, in total, covering the full reverse side 144. As a further example, a matrix of photosensitive elements 142 may be located on the reverse side 144, such as an image sensor or image chip, such as a one-dimensional or two-dimensional CCD or CMOS chip.

The optical waveguide 112 further may comprise at least one optical filter element 146. As an example, as illustrated in the cross-sectional view in Figure 28, at least one optical filter element 146 may be placed in front of the reference photosensitive element 142, such as in a beam path in between the fluorescent waveguiding sheet 114 and the reference photosensitive element 142. As an example, a layer setup may be used. Thus, the optical waveguide 112 generally, in this embodiment or in other embodiments of the present invention, may comprise a stack and/or a layer setup having the at least one fluorescent waveguiding sheet 114, the at least one optical filter element 146 and the at least one reference photosensitive element 142, preferably in the given order. As an example, the at least one optical filter element 146 may be designed to prevent fluorescence light from entering the reference photosensitive element 142 or, at least, may attenuate fluorescence light by at least 70% or preferably by at least 80%. Accreditation

light, however, such as light from the light beam, may preferably pass the optical filter element 146, such as with an attenuation of preferably no more than 40%, more preferably of no more than 20%. Thus, as an example, in this exemplary embodiment or in other exemplary embodiments of the present invention, the at least one optical filter element 146 specifically may
5 comprise a short-pass filter, such as a short pass filter having a threshold wavelength in the range of 400 nm to 900 nm, such as in the range of 500 to 850 nm. The short pass filter may ensure that the at least one reference photosensitive element 142 generally provides a measure for the total power of the light beam and/or the excitation light rather than measuring the fluorescence light. Alternatively or in addition, a band-pass filter which may, in particular, be
10 designed for providing a high transmission for fluorescent light the wavelength in the range of 400 nm to 900 nm, such as in the range of 500 to 850 nm, can also be used.

In Figure 29, an illumination of the light-sensitive area 116 of the fluorescent waveguiding sheet 114 by a light beam is shown. Therein, two different situations are depicted, representing
15 different distances between the object, from which the light beam propagates towards the optical detector 110, and the optical detector 110 itself, resulting in two different spot sizes of light spots generated by the light beam in the fluorescent waveguiding sheet 114, firstly, a small light spot 148 and, secondly, a large light spot 150. The illumination by the light beam induces fluorescence which, as depicted in Figure 28 above, is fully or partially transported by
20 waveguiding towards the photosensitive elements 124, 126, 128, 130. As indicated above, corresponding signals are generated by the photosensitive elements 124, 126, 128, 130 and provided to the evaluation device 140, in conjunction with at least one reference signal generated by the at least one reference photosensitive element 142.

The evaluation device 140, as schematically and symbolically depicted in Figure 30, is designed to evaluate the signals which, therein, are represented by the symbols PD1-PD4 for the signals of the photosensitive elements 124, 126, 128, 130 and PD5 for the reference signal. As outlined above, at least one transversal coordinate x , y may be derived by using the signals. This is mainly due to the fact that the distances between a center of the light spot 148, 150 and the
30 photosensitive elements 124, 126, 128 and 130 are non-equal. Thus, the center of the light spot 148, 150 has a distance from the photosensitive element 124 of l_1 , a distance from the photosensitive element 126 of l_2 , a distance from the photosensitive element 128 of l_3 , and a distance from the photosensitive element 130 of l_4 . Due to these differences in the distances between the location of the generation of the fluorescence light and the photosensitive elements
35 124, 126, 128, 130 detecting the fluorescence light, the signals will differ. This is due to various effects. Firstly, again, internal losses will occur during waveguiding, since each internal total reflection implies a certain loss, such that the fluorescence light will be attenuated on its way, depending on the length of the path. The longer the distance of travel, the higher the attenuation and the higher the losses. Further, absorption effects will occur. Thirdly, a spreading of the light
40 will have to be considered. The longer the distance between the light spot 148, 150 to the respective photosensitive element 124, 126, 128, 130, the higher the probability that a photon will be directed into a direction other than the photosensitive element 124, 126, 128, 130.

Consequently, by comparing the signals of the photosensitive element 124, 126, 128, 130, the transversal location information is generated.

The comparison of the signals may take place in various ways. Thus, generally, the evaluation device 140 may be designed to compare the signals in order to derive the at least one transversal coordinate of the object or of the light spot. As an example, the evaluation device 140 may comprise at least one subtracting device 154 and/or any other device which provides a function which is dependent on at least one transversal coordinate, such as on the coordinates x, y. For exemplary embodiments, the subtracting device 154 may be designed to generate at least one difference signal D, such as a signal according to Equation (1) above. As an example, a simple difference between PD1 and PD2, such as $(PD1-PD2)/(PD1+PD2)$, may be used as a measure for the x-coordinate, and a difference between PD3 and PD4, such as $(PD3-PD4)/(PD3+PD4)$, may be used as a measure for the y-coordinate. A transformation of the transversal coordinates of the light spot 148, 150 in the plane of the light-sensitive area 116, as an example, into transversal coordinates of the object from which the light beam propagates towards the optical detector 110 may simply be made by using the well-known lens equation. For further details, as an example, reference may be made to one or more of the above-mentioned prior art documents, such as to WO 2014/097181 A1.

It shall be noted, however, that other transformations or other algorithms for processing the signals by the evaluation device 140 are feasible. Thus, besides subtractions or the near combinations with positive or negative coefficients, nonlinear transformations are generally feasible. As an example, for transforming the signals into x- and/or y-coordinates, one or more known or determinable relationships may be used, which, as an example, may be derived empirically, such as by calibrating experiments with the object placed at various transversal positions and by recording the respective signals.

Figure 31 shows, in a highly schematic illustration, an exemplary embodiment of an optical detector 110, having a plurality of optical waveguides 112. The optical detector 110 specifically may be embodied as a camera 156 or may be part of a camera 156. The camera 156 may be made for imaging, specifically for 3D imaging, and may be made for acquiring standstill images and/or image sequences such as digital video clips. Other embodiments are feasible.

Figure 31 further shows an embodiment of a detector system 158, which, besides the at least one optical detector 110, comprises one or more beacon devices 160, which, in this exemplary embodiment, are attached and/or integrated into an object 162, the position of which shall be detected by using the optical detector 110. Figure 31 further shows an exemplary embodiment of a human-machine interface 164, which comprises the at least one detector system 158, and, further, an entertainment device 166, which comprises the human-machine interface 164.

Figure 31 further shows an embodiment of a tracking system 168 for tracking a position of the object 162, which comprises the detector system 158. The components of the devices and systems shall be explained in further detail in the following.

As outlined above, an exemplary embodiment of an optical detector 110 which may be used in the setup of Figure 31 is shown in any one of Figures 27 to 30 or 32 or a combination thereof. Thus, the optical detector 110, besides the one or more optical waveguides 112, comprises at least one evaluation device 140, optionally having the at least one subtracting device 154, as symbolically depicted in Figure 31. The components of the evaluation device 140 may fully or partially be integrated into one or all of or even each of the optical waveguides 112 or may fully or partially be embodied as separate components independent from the optical waveguides 112.

Figure 31 further shows an exemplary embodiment of at least one illumination source 172 adapted to emit at least one light beam 174 configured for an illumination of the object 162.

Besides the above-mentioned possibility of fully or partially combining two or more components, one or more of one or more optical waveguides 112 and one or more of the components of the evaluation device 140 may be interconnected by one or more connectors 176 and/or one or more interfaces, as symbolically depicted in Figure 31. Further, the optional at least one connector 176 may comprise one or more drivers and/or one or more devices for modifying or pre-processing signals. Further, instead of using the at least one optional connector 176, the evaluation device 140 may fully or partially be integrated into the optical waveguides 112 and/or into a housing 178 of the optical detector 110. Additionally or alternatively, the evaluation device 140 may fully or partially be designed as a separate device.

In this exemplary embodiment, the object 162, the position of which may be detected, may be designed as an article of sports equipment and/or may form a control element or a control device 180, the position of which may be manipulated by a user 182. As an example, the object 162 may be or may comprise a bat, a racket, a club or any other article of sports equipment and/or fake sports equipment. Other types of objects 162 are possible. Further, the user 182 may be considered as the object 182, the position of which shall be detected.

As outlined above, the optical detector 110 comprises one or more optical waveguides 112. The optical waveguides 112 may be located inside the housing 178 of the optical detector 110. Further, at least one transfer device 184 may be comprised, such as one or more optical systems, preferably comprising one or more lenses 186.

An opening 188 inside the housing 178, which, preferably, is located concentrically with regard to an optical axis 190 of the optical detector 110, preferably defines a direction of view 192 of the optical detector 110. A coordinate system 194 may be defined, in which a direction parallel or antiparallel to the optical axis 190 is defined as a longitudinal direction, whereas directions perpendicular to the optical axis 190 may be defined as transversal directions. In the coordinate system 194, symbolically depicted in Fig. 31, transversal directions are denoted by x and y, respectively, while a longitudinal direction is denoted by z. However, other types of coordinate systems 194 are feasible.

The optical detector 110 may comprise one or more of the optical waveguides 112. Preferably, as depicted in Fig. 31, a plurality of optical waveguides 112 is comprised, which, as an example, may be located in different partial beam paths 196, as depicted in Figure 31, which may be split by one or more beam splitting devices 198. It shall be noted, however, that other options are feasible, such as stacked configurations of two or more optical waveguides 112. Further, embodiments having a different number of optical waveguides 112 are feasible.

One or more light beams 174 may be propagating from the object 162 and/or from and/or one or more of the beacon devices 160 towards the optical detector 110. The optical detector 110 may be adapted for determining a position of the at least one object 162. For this purpose, as explained above in the context of Figures 27 to 30 and 32, the evaluation device 140 may be configured to evaluate signals provided by the one or more optical waveguides 112. The optical detector 110 may be adapted to determine a position of the object 162, and the optical waveguides 112 may, thus, be adapted to detect the light beam 174 propagating from the object 162 towards the optical detector 110, specifically from one or more of the beacon devices 160. The light beam 174, directly and/or after being modified by the transfer device 184, such as being focused by the lens 186, creates the light spot 148, 150 on the light-sensitive area 116 of the optical waveguide 112 or of each of the optical waveguides 112.

As outlined above, the determination of a position of the object 162 and/or a part thereof by using the optical detector 110 may be used for providing a human-machine interface 164, in order to provide at least one item of information to a machine 200. In the embodiment schematically depicted in Fig. 31, the machine 200 may be a computer and/or may comprise a computer. Other embodiments are feasible. The evaluation device 140 even may fully or partially be integrated into the machine 200, such as into the computer.

As outlined above, Figure 31 also depicts an example of a tracking system 168, configured for tracking the position of the at least one object 162. The tracking system 168 comprises the optical detector 110 and at least one track controller 202. The track controller 202 may be adapted to track a series of positions of the object 162 at specific points in time. The track controller 202 may be an independent device and/or may fully or partially form part of the computer of the machine 200.

Similarly, as outlined above, the human-machine interface 164 may form part of an entertainment device 166. The machine 200, specifically the computer, may also form part of the entertainment device 166. Thus, by means of the user 182 functioning as the object 162 and/or by means of the user 182 handling a control device 180 functioning as the object 162, the user 182 may input at least one item of information, such as at least one control command, into the computer, thereby varying the entertainment function, such as controlling the course of a computer game.

In Figures 32A and 32B, an alternative embodiment of the optical waveguide 112 is shown, in a top view (Fig. 32A) and in a cross-sectional view (Fig. 32B). For most of the details of the optical

waveguide 112, reference may be made to Fig. 32A and 32B above. The embodiment, however, shows various variations from the embodiment of Fig. 32A and 32B, which may be realized in an isolated fashion or in combination therewith.

5 Thus, firstly, the embodiment shows variations of the placement of the photosensitive elements. Besides the photosensitive elements 124, 126, 128, 130 located at opposing partitions 132, 134, 136, 138, which, in this embodiment, are arranged as straight edges, additional photosensitive elements 204 may be located at corners 206 of the fluorescent waveguiding sheet 114. The partitions 132, 134, 136, 138 in combination may form a rim of the fluorescent
10 waveguiding sheet 114, such as a rectangular rim. The rim itself may be roughened or even blackened in order to avoid back reflections from the rim. The corners 206 also are part of the partitions of the fluorescent waveguiding sheet 114. The photosensitive elements 204 located at the corners 206 may provide additional signals which may be evaluated in a similar fashion as shown e.g. in Fig. 30. They may provide an increased accuracy of the determination of the x, y-
15 coordinates. Thus, as an example, the additional signals may be implemented into the formation of difference signals, such as according to Equation (1) above. As an example, difference signals between two photosensitive elements 204 located at opposing corners 206 may be formed and/or difference signals between one photosensitive element 204 located at a corner 206 and one photosensitive element located at a straight edge may be formed. The difference
20 signal D, in each case, may denote a location of the light spot on an axis interconnecting the two photosensitive elements.

Further, the embodiment of Figures 32A and 32B shows a variation of the placement of the photosensitive elements 124, 126, 128, 130, 204 with respect to the fluorescent waveguiding
25 sheet 114. Thus, in the embodiment of Figures 27 and 28, the photosensitive elements 124, 126, 128, 130 may be located within the plane of the fluorescent waveguiding sheet 114. Additionally or alternatively, as shown in the embodiment of Fig. 32A and 32B, one, some or even all of the photosensitive elements 124, 126, 128, 130, 204 may be located outside the plane of the fluorescent wave-guiding sheet 114. Specifically, as shown in the cross-sectional
30 view of Figure 32B, as an example, the photosensitive elements 124, 126, 128, 130, 204 may be optically coupled to the fluorescent waveguiding sheet 114 by optical coupling elements 208. As an example, the photosensitive elements 124, 126, 128, 130, 204 simply may be glued to the fluorescent waveguiding sheet 114 by using one or more transparent adhesives, such as an
35 epoxy adhesive.

In a further embodiment in which the optical detector 110 only has a single photosensitive element (not depicted here), the single photosensitive element may be located outside the plane of the fluorescent waveguiding sheet 114 and, therefore, being optically coupled to the fluorescent waveguiding sheet 114 by a single optical coupling element 208 or, as an
40 alternative, by two or more optical coupling elements 208.

Further, the embodiment of Figures 32A and 32B shows a variation of the size and shape of the photosensitive elements 124, 126, 128, 130, 204. Thus, the photosensitive elements 124, 126,

128, 130, 204 do not necessarily have to be strip-shaped photosensitive elements. As an example, very small photodiodes may be used, such as rectangular photodiodes or even point-like or spot-like photodiodes. As outlined above, a small size of the photodiodes generally may lead to a lower electrical capacitance and, thus, may lead to a faster response of the optical detector 110.

Further, the embodiment of Figures 32A and 32B shows that no reference photosensitive element 142 may be necessary. Thus, the optical waveguide 112 as shown in the embodiment of Figures 32A and 32B provides a fully functional and, optionally, transparent position sensitive detector (PSD).

List of reference numbers

110	Optical detector
112	Optical waveguide
114	Fluorescent waveguiding sheet
116	Light-sensitive area
118	Waveguiding
120	Matrix material
122	Fluorescent colorant
124	Photosensitive element
126	Photosensitive element
128	Photosensitive element
130	Photosensitive element
132	Partition
134	Partition
136	Partition
138	Partition
140	Evaluation device
142	Reference photosensitive element
144	Reverse side
146	Optical filter element
148	(small) light spot
150	(large) light spot
154	Subtracting device
156	Camera
158	Detector system
160	Beacon device
162	Object
164	Human-machine interface
166	Entertainment device
168	Tracking system
172	Illumination source

174	Light beam
176	Connector
178	Housing
180	Control device
182	User
184	Transfer device
186	Lens
188	Opening
190	Optical axis
192	Direction of view
194	Coordinate system
196	Partial beam path
198	Beam-splitting device
200	Machine
202	Track controller
204	Photosensitive element
206	Corner
208	Optical coupling element

Patent claims

1. An optical detector (110) comprising at least one optical waveguide (112), the optical waveguide (112) having at least one transparent matrix material (120) and at least one fluorescent colorant (122) embedded into the matrix material (120), wherein the fluorescent colorant (122), in a wavelength range of 400 nm to 900 nm, has an absorption maximum which occurs in the wavelength range of 500 nm to 850 nm, the optical waveguide (112) being configured for waveguiding fluorescence light generated by the fluorescent colorant (122), the optical waveguide (112) further having at least one light-sensitive area (116) configured for being illuminated by at least one light beam (174), the optical detector (110) further comprising at least one photosensitive element (124, 126, 128, 130) configured for detecting fluorescence light generated by the fluorescent colorant (122), excited by the light beam (174), waveguided by the optical waveguide (112) and coupled out from the optical waveguide (112).
2. The optical detector (110) according to the preceding claim, wherein the absorption maximum is measured with the fluorescent colorant (122) embedded into the matrix material (120).
3. The optical detector (110) according to any one of the preceding claims, wherein the absorption maximum is an absolute maximum over the range of 400 nm to 850 nm.
4. The optical detector (110) according to any one of the preceding claims, wherein the optical waveguide (112), at least partially, exhibits a shape selected from the following shapes: a sheet, a foil, a disc, a bar, a slab.
5. The optical detector (110) according to any one of the preceding claims, wherein the fluorescent colorant (122) is selected from the group consisting of stilbenes, benzoxazoles, squaraines, bisdiphenylethylenes, merocyanines, coumarins, benzopyrans, naphthalimides, rylene, phthalocyanines, naphthalocyanines, cyanines, xanthenes, oxazines, oxadiazols, squaraines, oxadiols, anthrachinones, acridines, arylmethanes, boron-dipyrromethenes, Aza-boron-dipyrromethenes, violanthrons, isoviolanthrons and diketopyrrolopyrrols.
6. The optical detector (110) according to any one of the preceding claims, wherein the fluorescent colorant (122) is selected from the group consisting of rylene, phthalocyanines, naphthalocyanines, cyanines, rhodamines, oxazines, boron-dipyrromethenes, aza-boron-dipyrromethenes and diketopyrrolopyrrols.
7. The optical detector (110) according to any one of the preceding claims, wherein the matrix material (120) comprises polycarbonate or poly(methyl-methacrylate).

8. The optical detector (110) according to any one of the preceding claims, wherein the fluorescent colorant (122) is 2,13-Bis[2,6-bis(1-methylethyl)phenyl]-5,10,16,21-tetrakis[4-(1,1,3,3-tetramethylbutyl)phenoxy]anthra[9",1",2":6,5,10;10", 5",6":6',5',10']dianthra[2,1,9-def:2',1',9'-d'e'f']diisoquinoline-1,3,12,14(2H,13H)-tetrone.
- 5
9. The optical detector (110) according to any one of the preceding claims, wherein the at least one photosensitive element (124, 126, 128, 130) is optically coupled to the optical waveguide (112) by at least one optical coupling element (208) configured for at least partially coupling the fluorescence light out of the waveguide (112).
- 10
10. The optical detector (110) according to any one of the preceding claims, wherein the optical coupling element (208) is selected from the group consisting of: a portion of transparent adhesive attaching the photosensitive element (124, 126, 128, 130) to the optical waveguide (112); an etched portion within the optical waveguide; a scratch in the optical waveguide; a prism.
- 15
11. The optical detector (110) according to any one of the preceding claims, wherein the optical detector (110) comprises at least two of the photosensitive elements (124, 126, 128, 130) located at different partitions (132, 134, 136, 138), the optical detector (110) further comprising at least one evaluation device (140), the evaluation device (140) being configured for determining at least one transversal coordinate of a light spot (148, 150) generated by the light beam (174) on the light-sensitive area (116).
- 20
12. The optical detector (110) according to any one of the preceding claims, wherein the photosensitive elements (124, 126, 128, 130) comprise at least one first pair of photosensitive elements (124,126) located at opposing partitions of the optical waveguide (112) in a first dimension of the coordinate system, and at least one second pair of photosensitive elements (128, 130) located at opposing partitions of the optical waveguide (112) in a second dimension of the coordinate system.
- 25
13. The optical detector (110) according to any one of the preceding claims, wherein the photosensitive element (124, 126, 128, 130) is or comprises at least one element selected from the group consisting of a photodiode, a photocell, a photoconductor, a phototransistor or any combination thereof.
- 30
14. The optical detector (110) according to any one of the preceding claims, wherein the optical detector (110) further comprises at least one transfer device (184), the transfer device (184) being adapted to guide the light beam (174) onto the optical waveguide (112).
- 35
15. A use of the optical detector (110) according to any one of the preceding claims, for the purpose of use, selected from the group consisting of: a scanning application; an application for detecting a position of at least one object; a position measurement in traffic
- 40

5 technology; an entertainment application; a surveillance application; a safety application; a human-machine interface application; a tracking application; a photography application; a use in combination with at least one time-of-flight detector; a use in combination with a structured light source; a use in combination with a stereo camera; a machine vision application; a robotics application; a quality control application; a manufacturing application; a use in combination with a structured illumination source; a use in combination with a stereo camera.

FIG.1

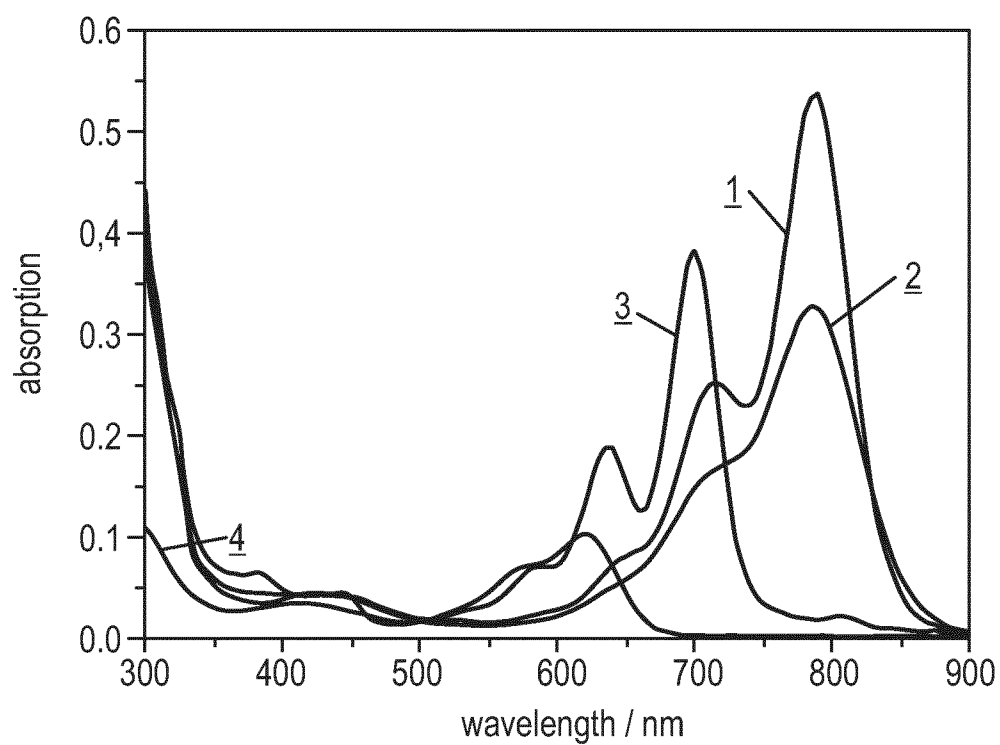
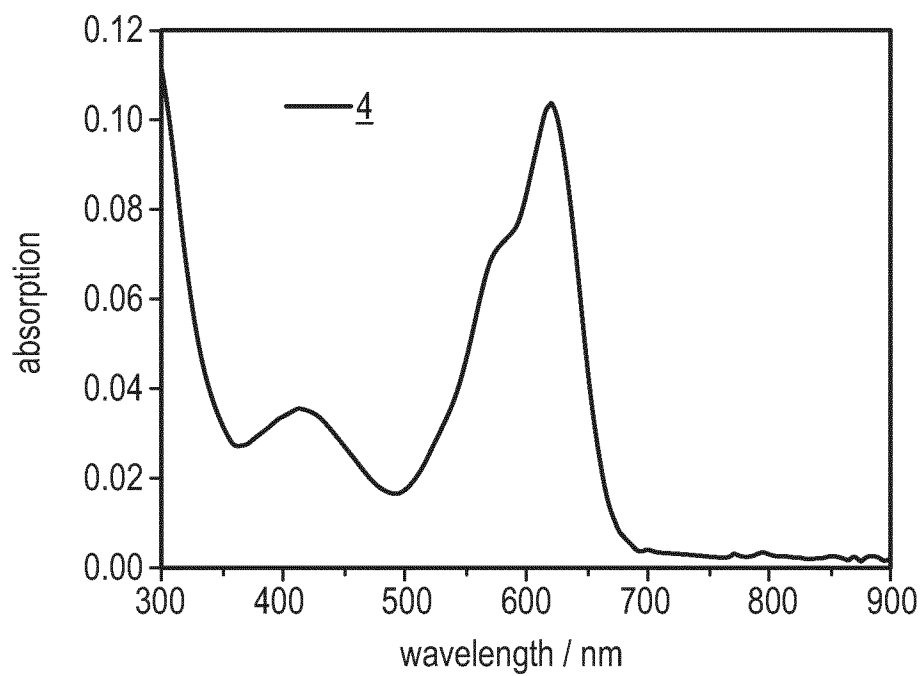


FIG.2



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FIG.3

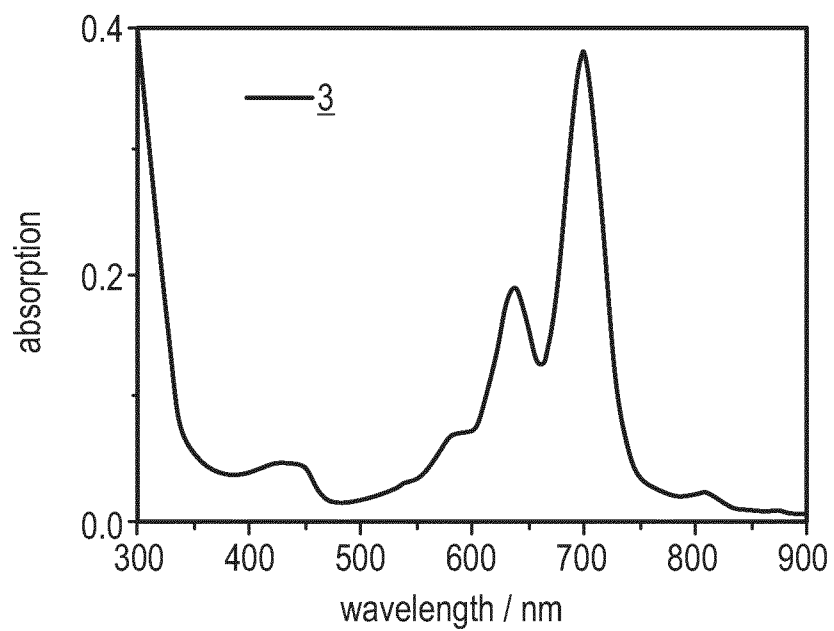
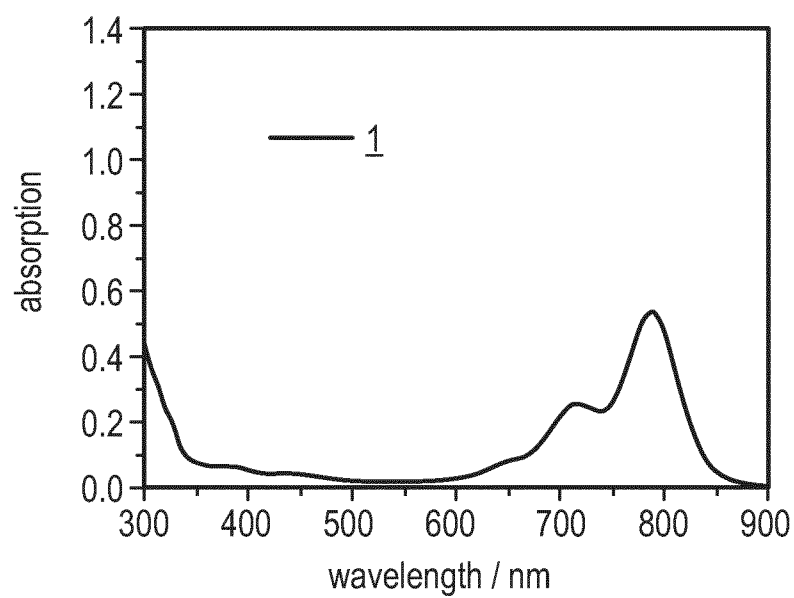


FIG.4



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FIG.5

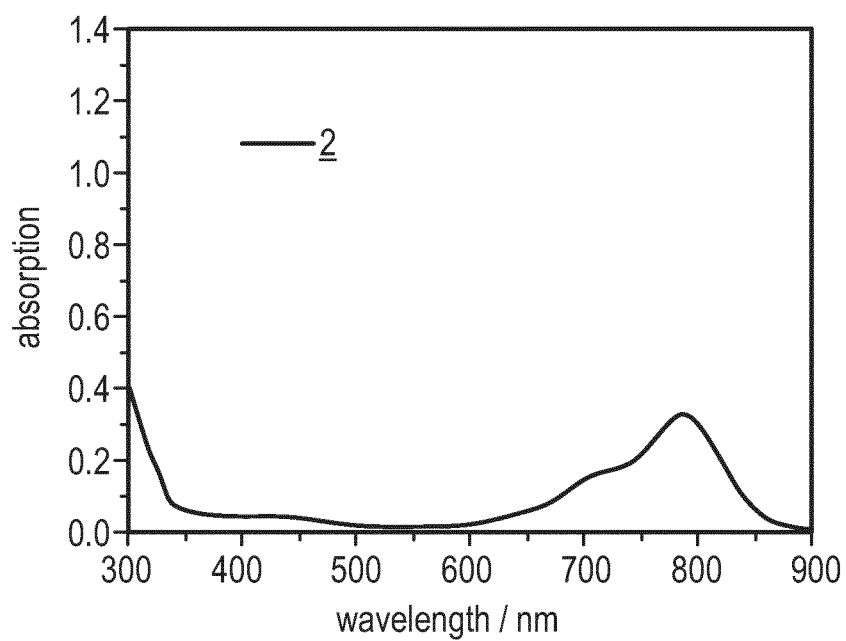


FIG.6

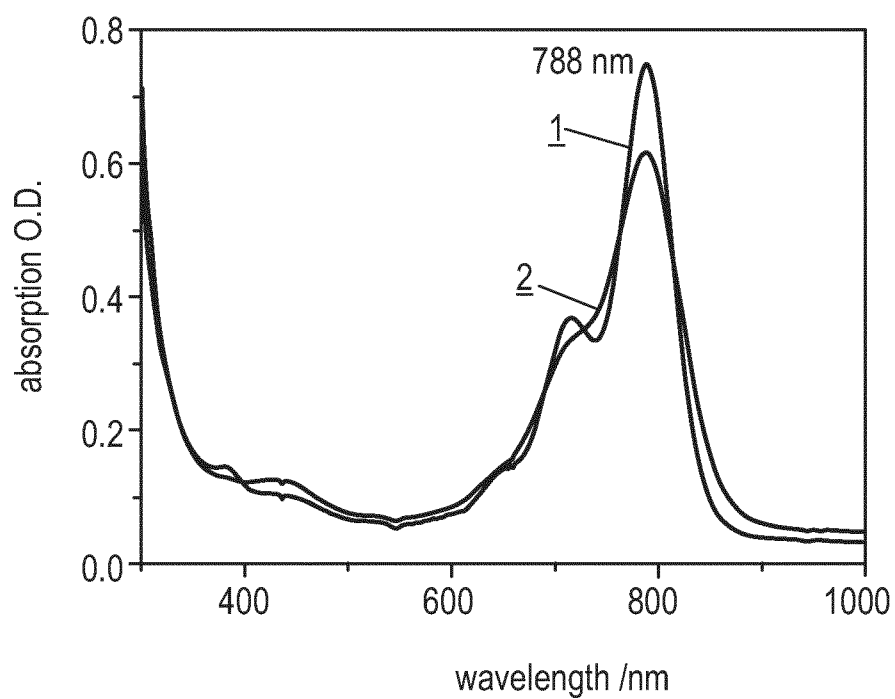
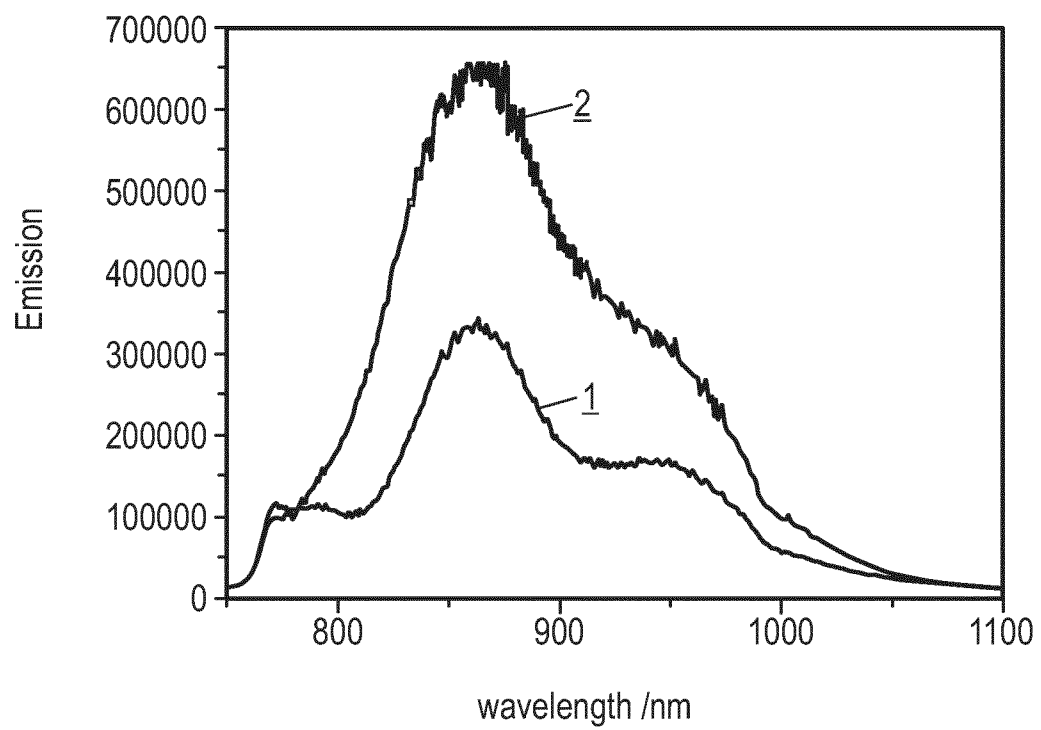


FIG.7



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FIG.8

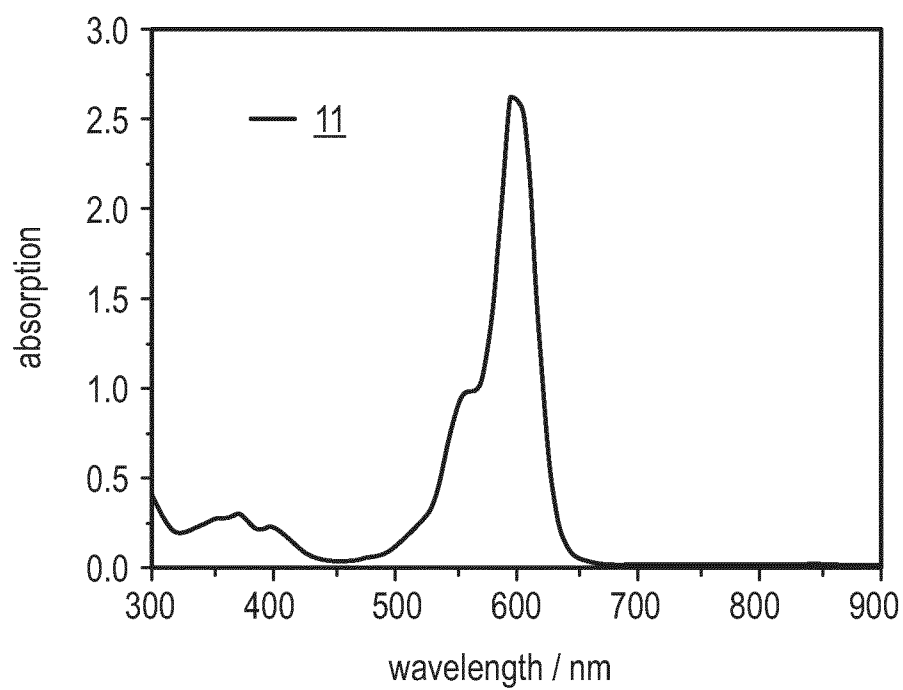
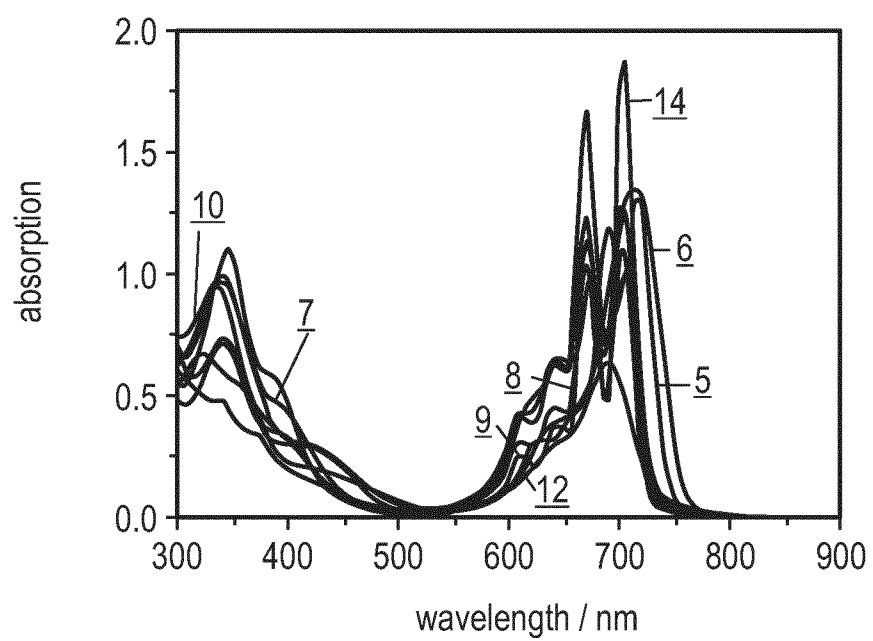


FIG.9



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FIG.10

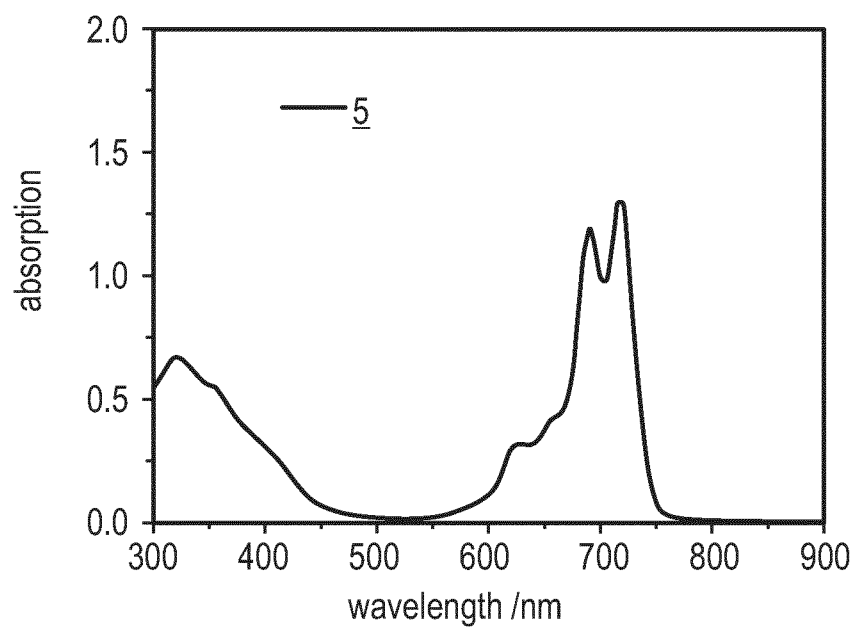
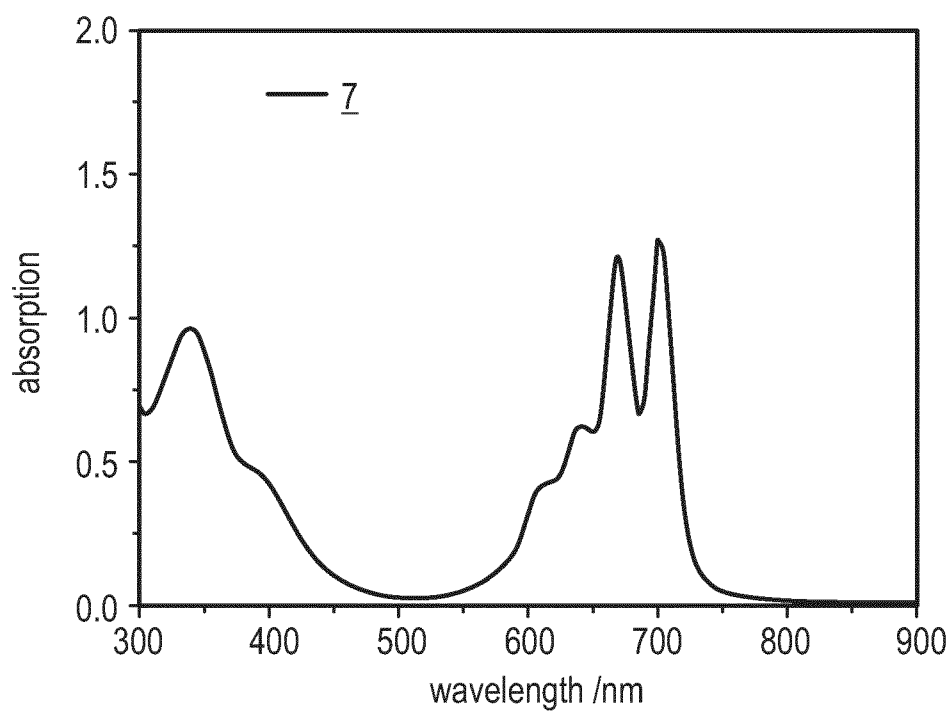


FIG.11



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FIG.12

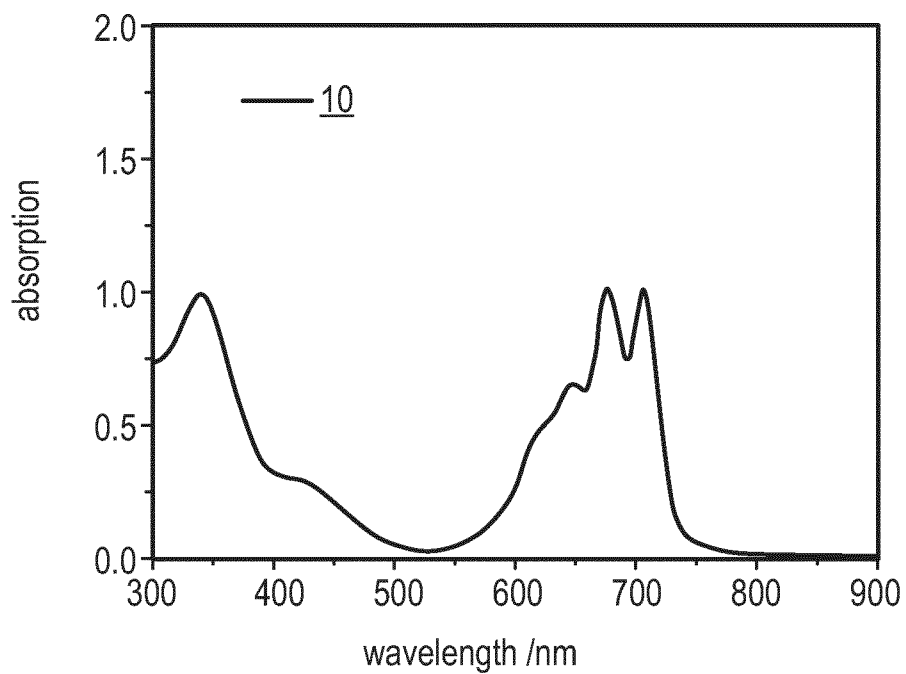
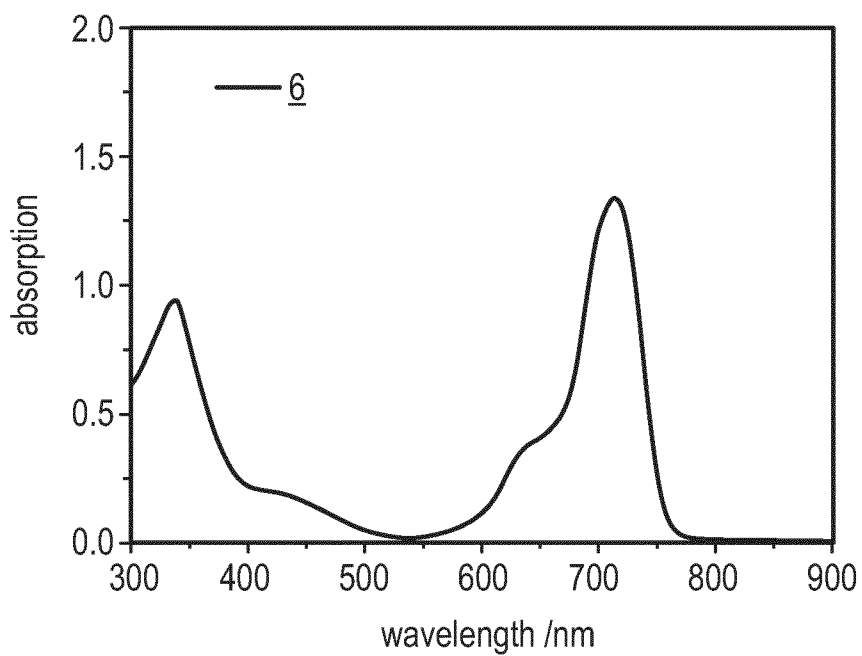


FIG.13



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FIG.14

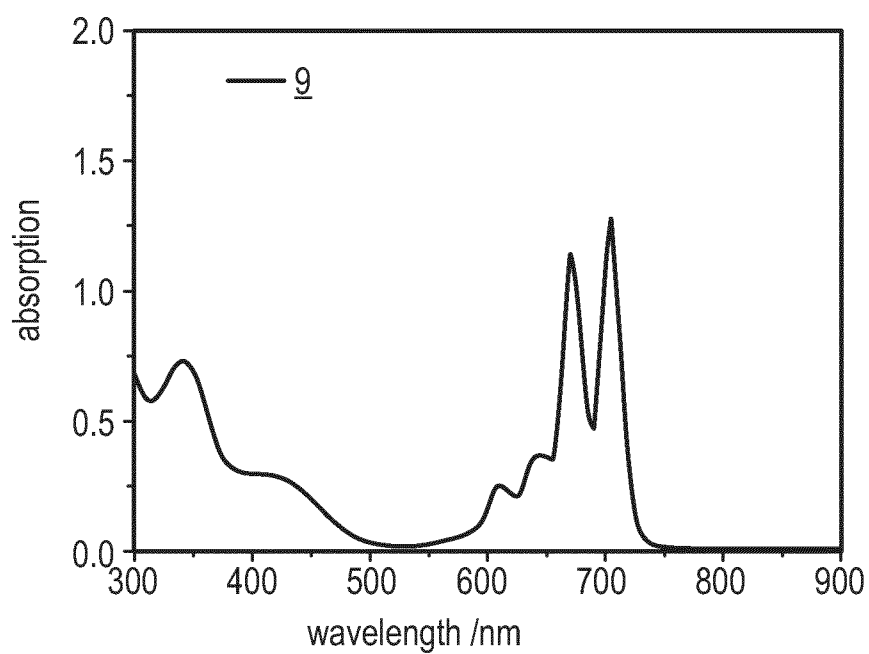
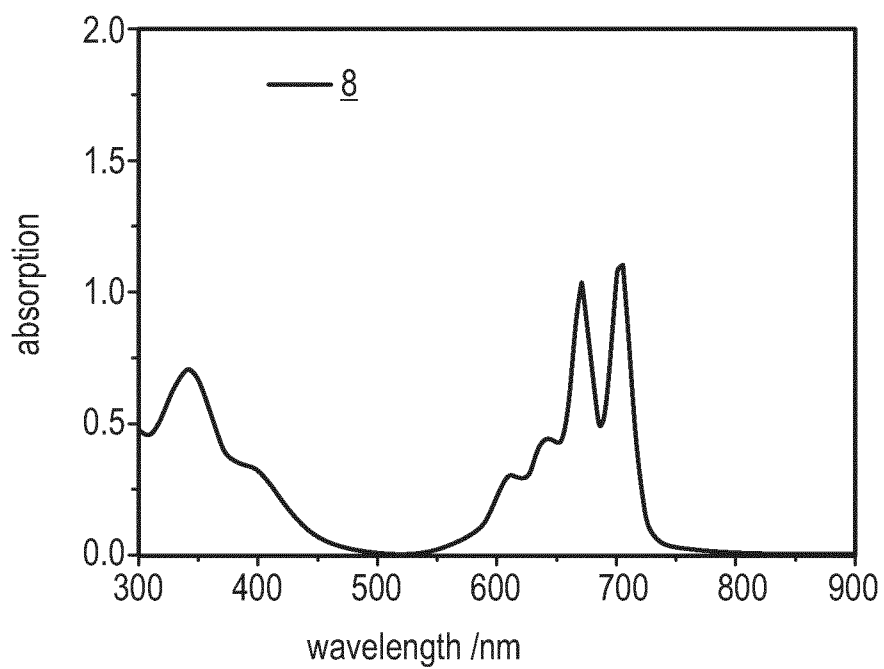


FIG.15



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FIG.16

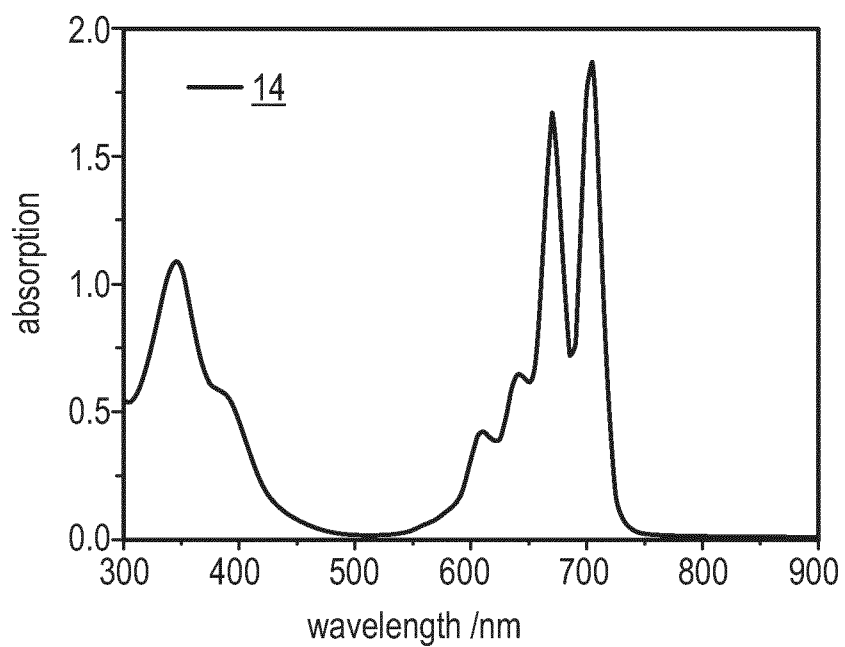
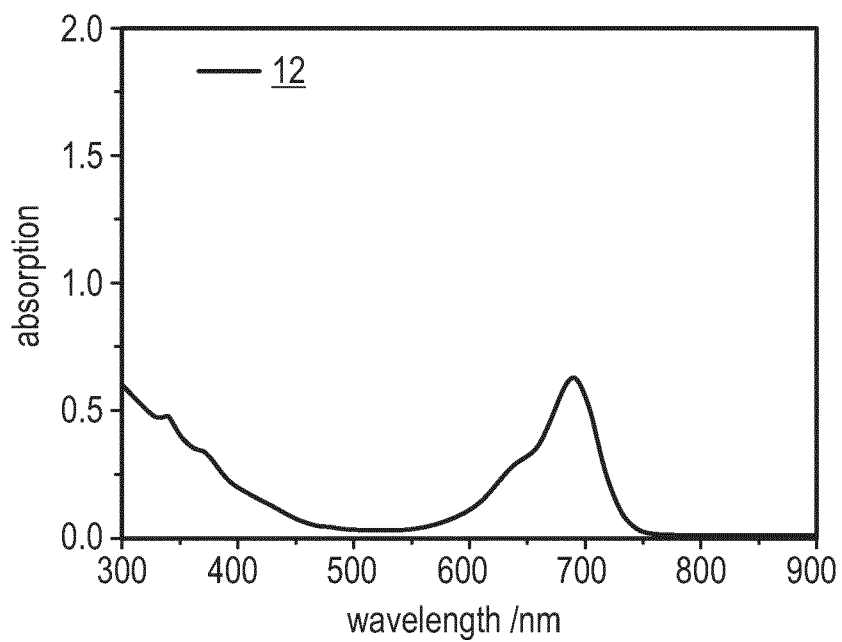
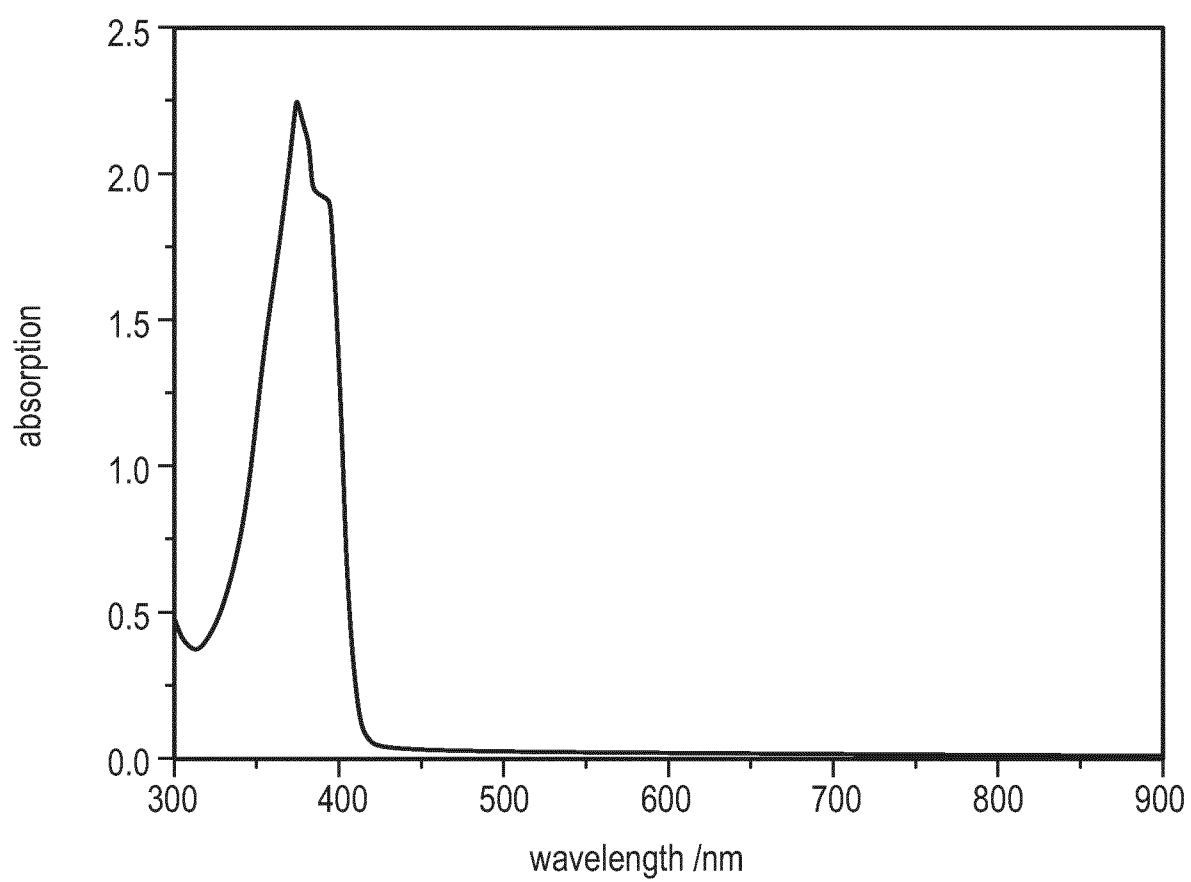


FIG.17



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FIG.18



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FIG.19

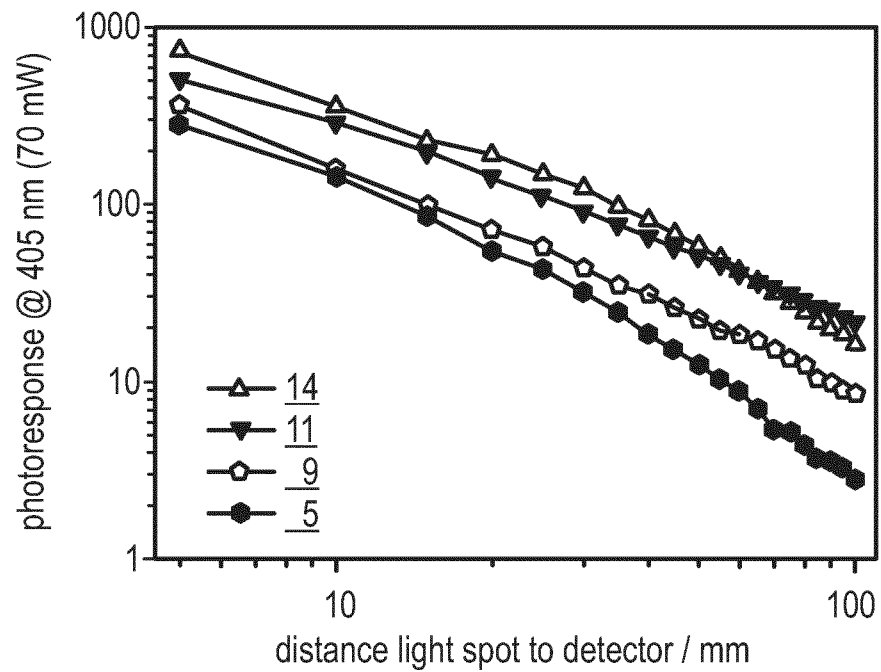
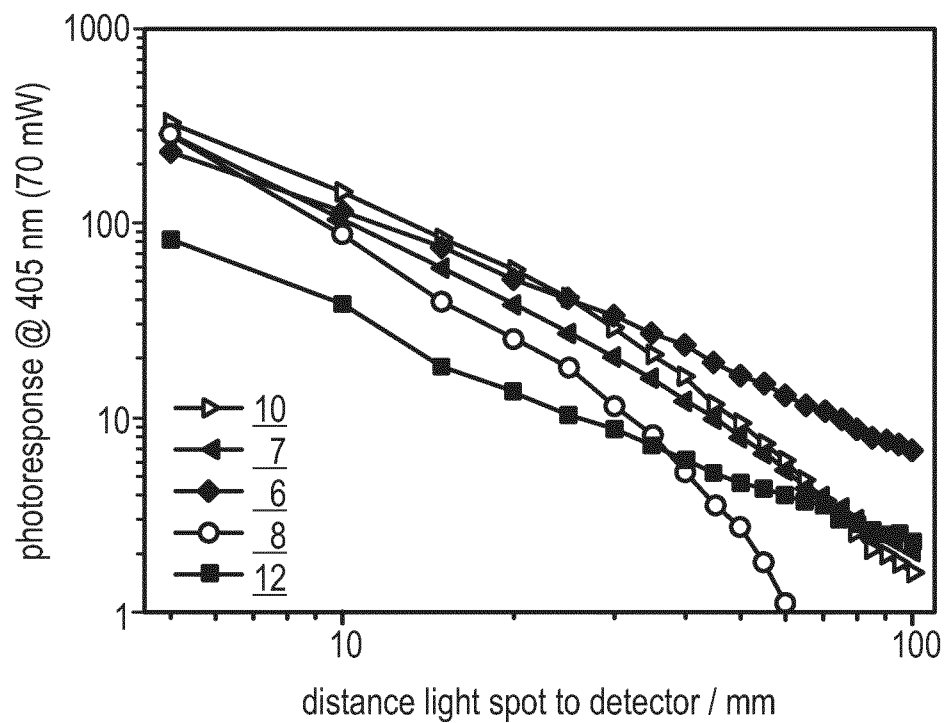


FIG.20



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FIG.21

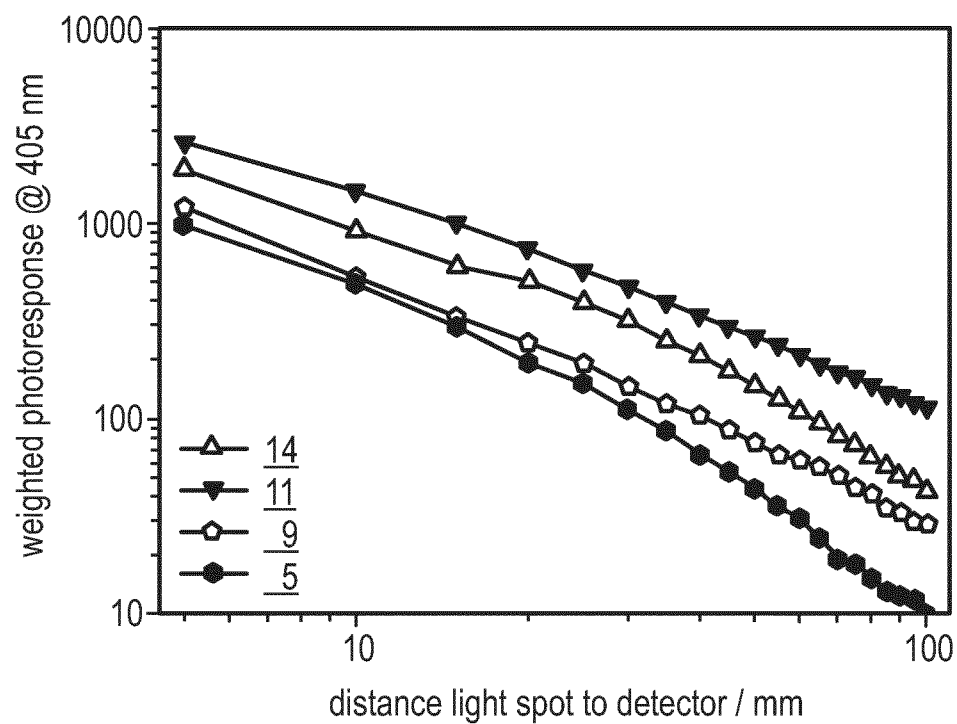
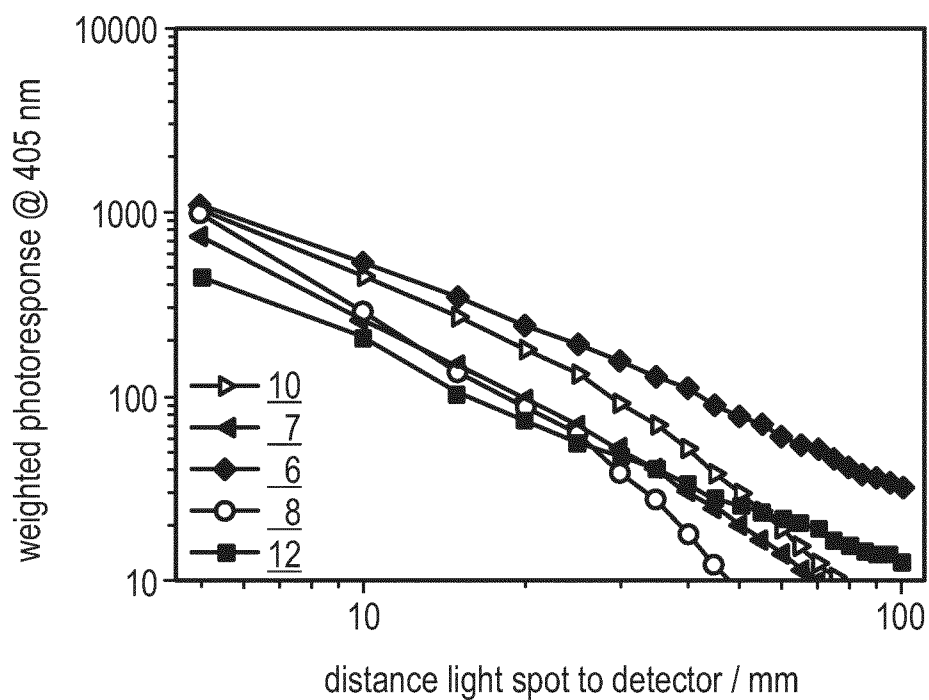


FIG.22



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FIG.23

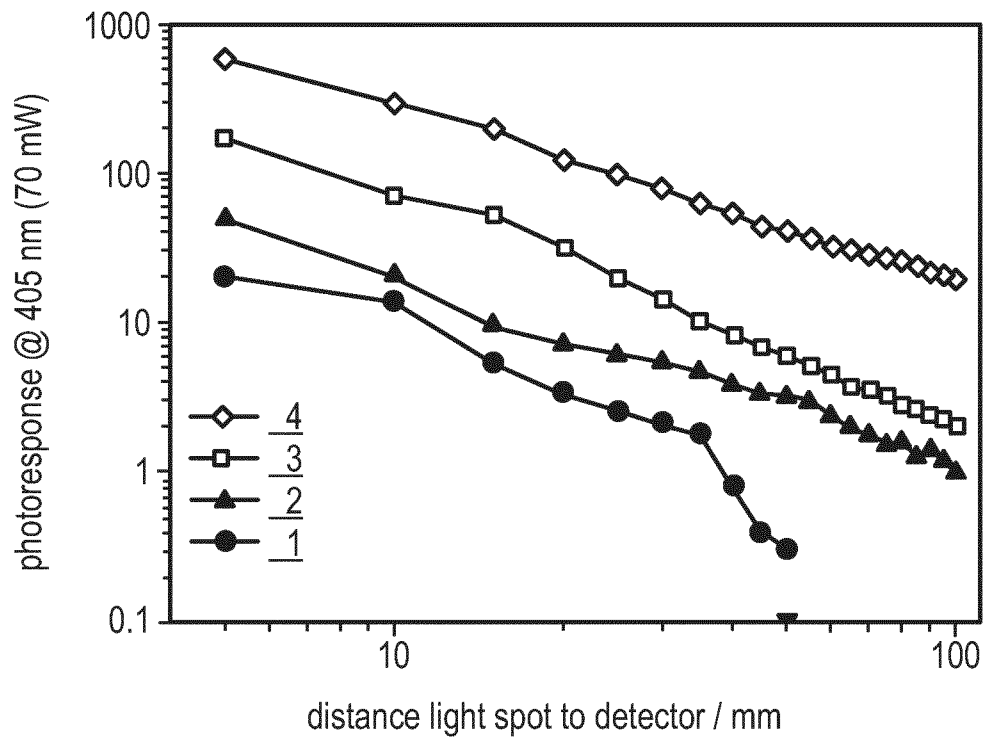
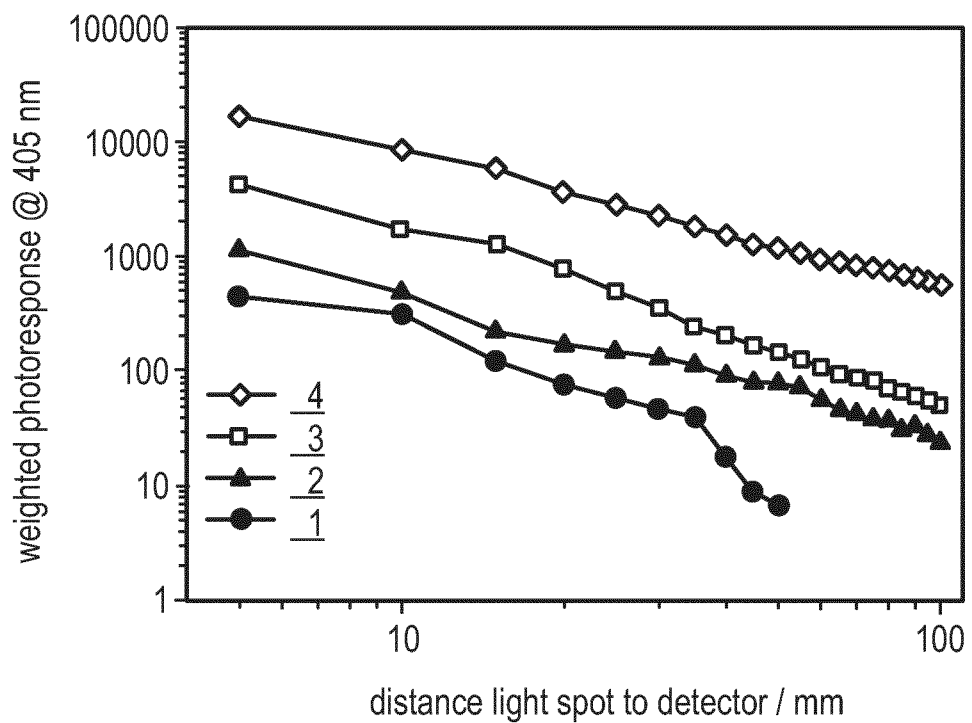


FIG.24



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FIG.25

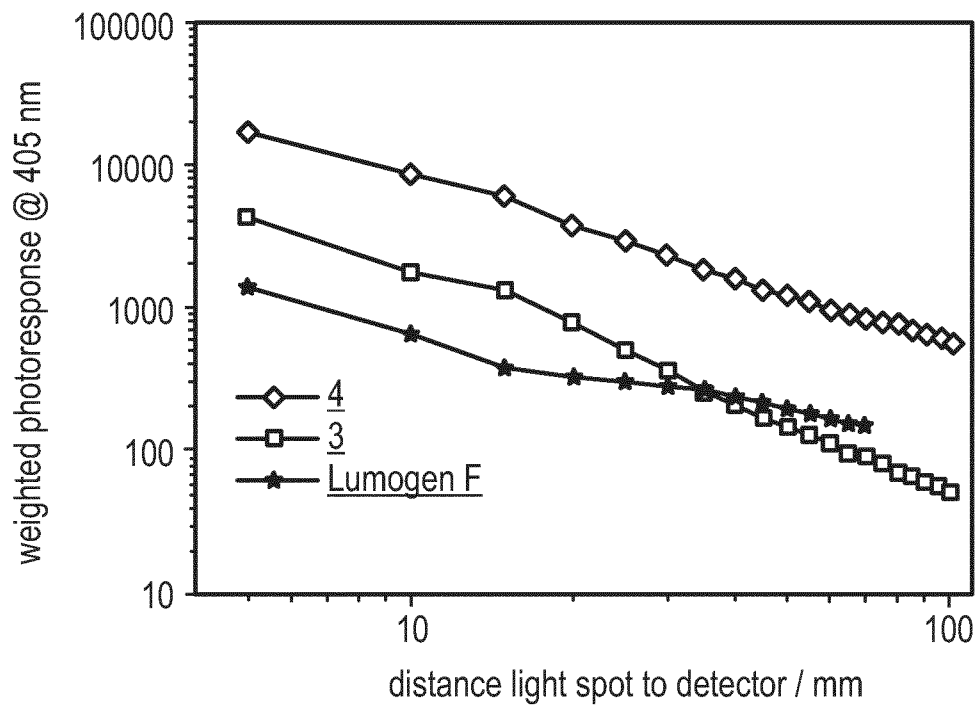


FIG.26

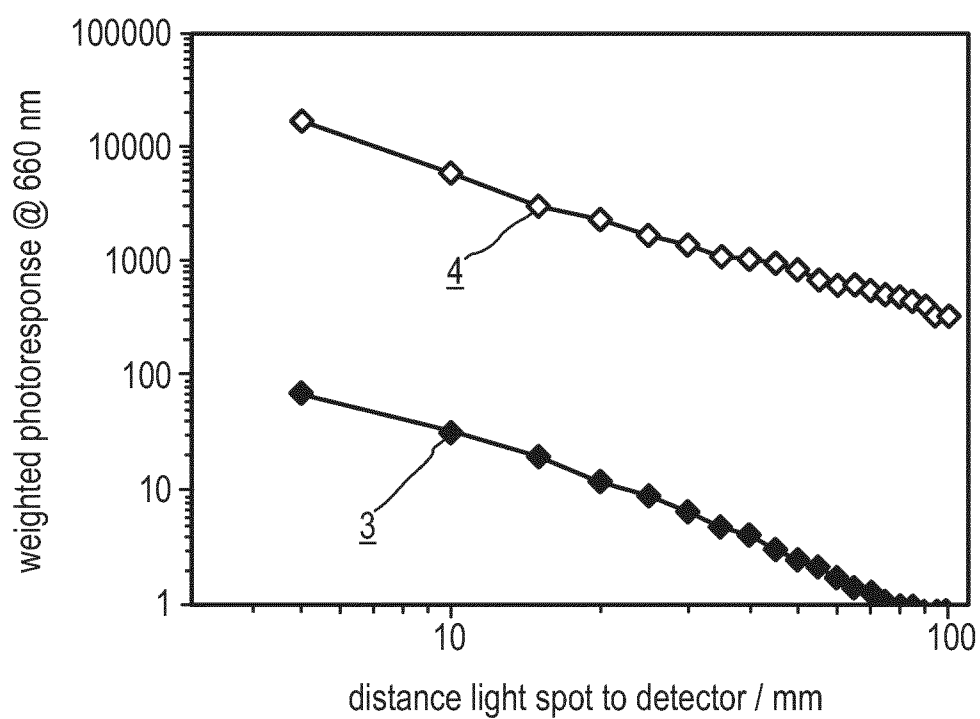


FIG.27

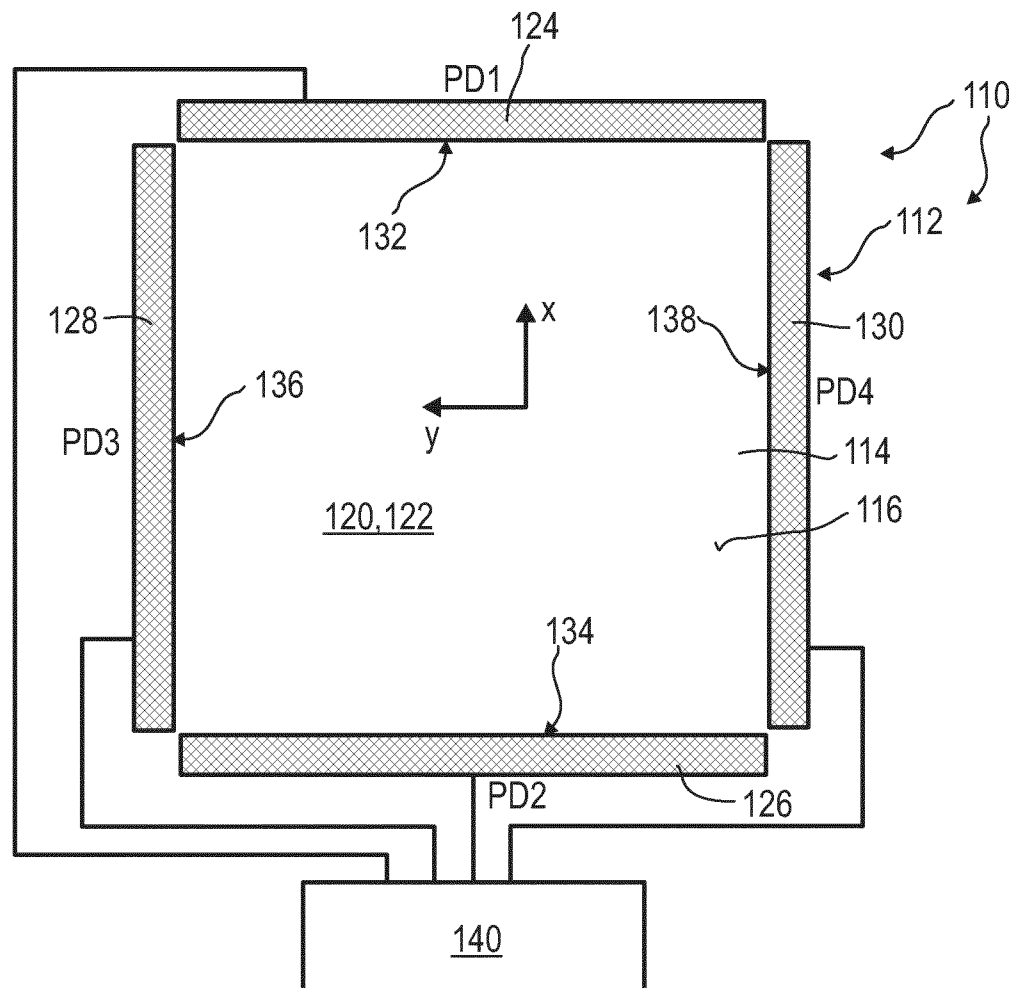
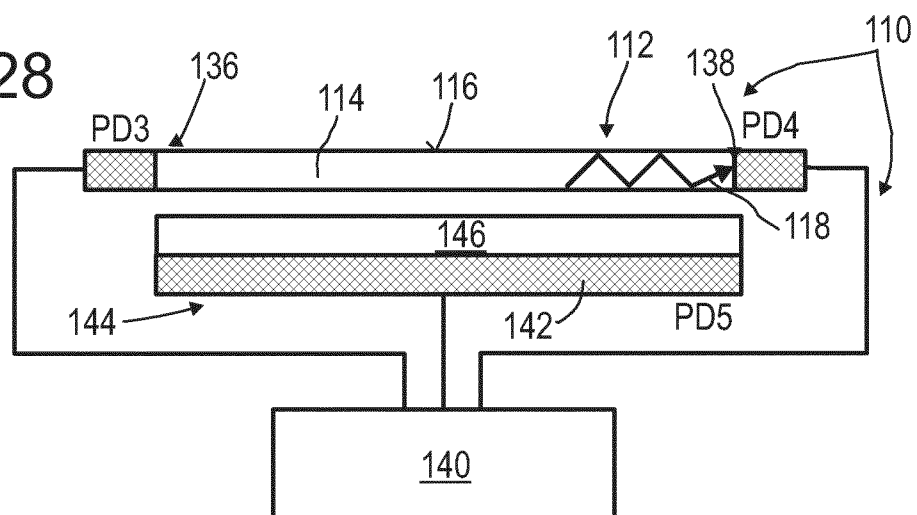


FIG.28



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FIG.30

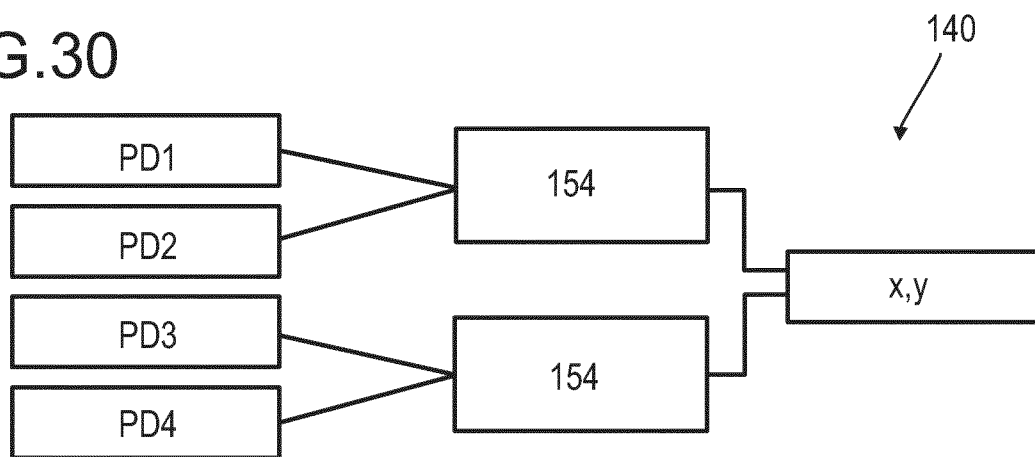
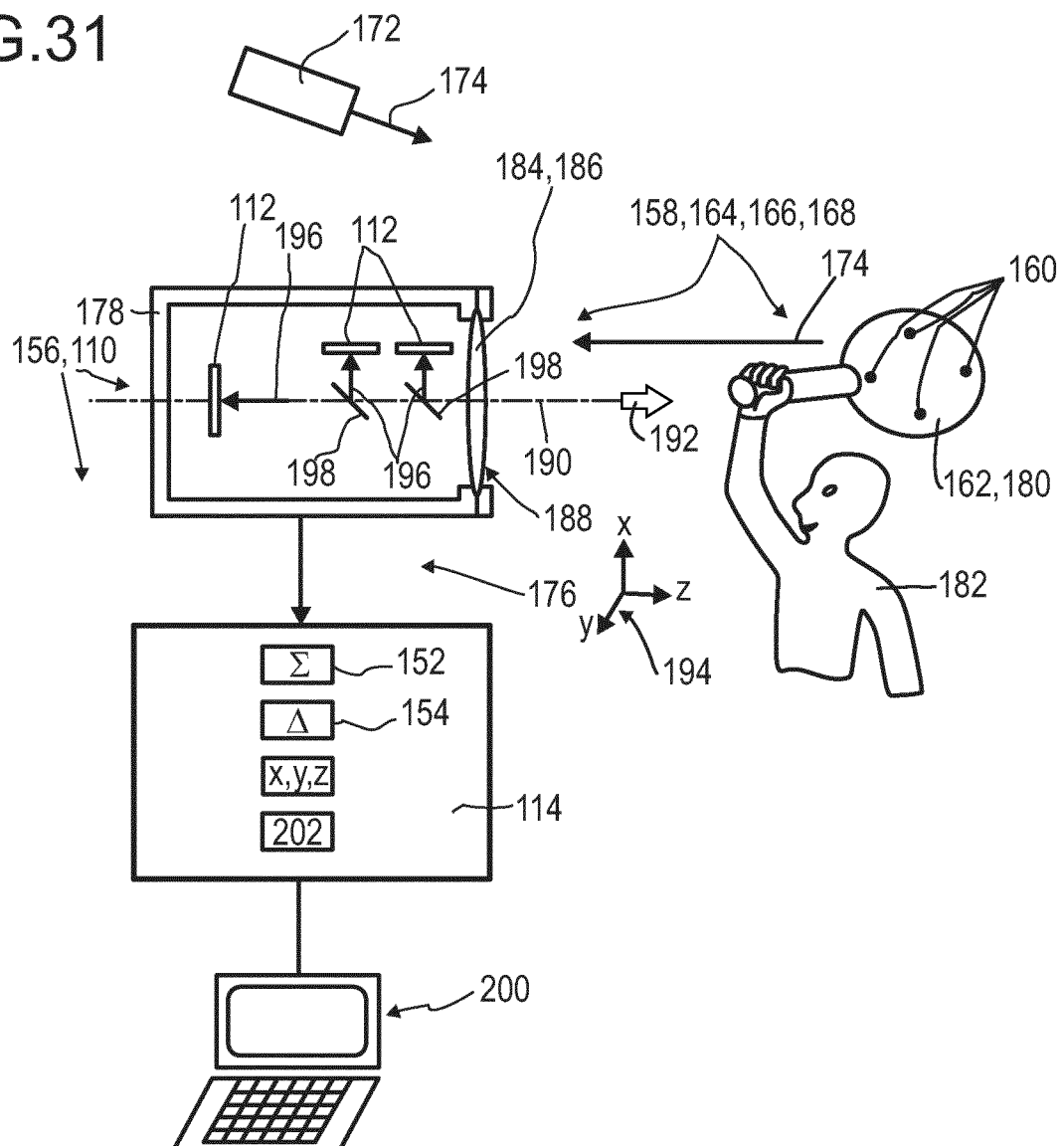


FIG.31



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FIG.32A

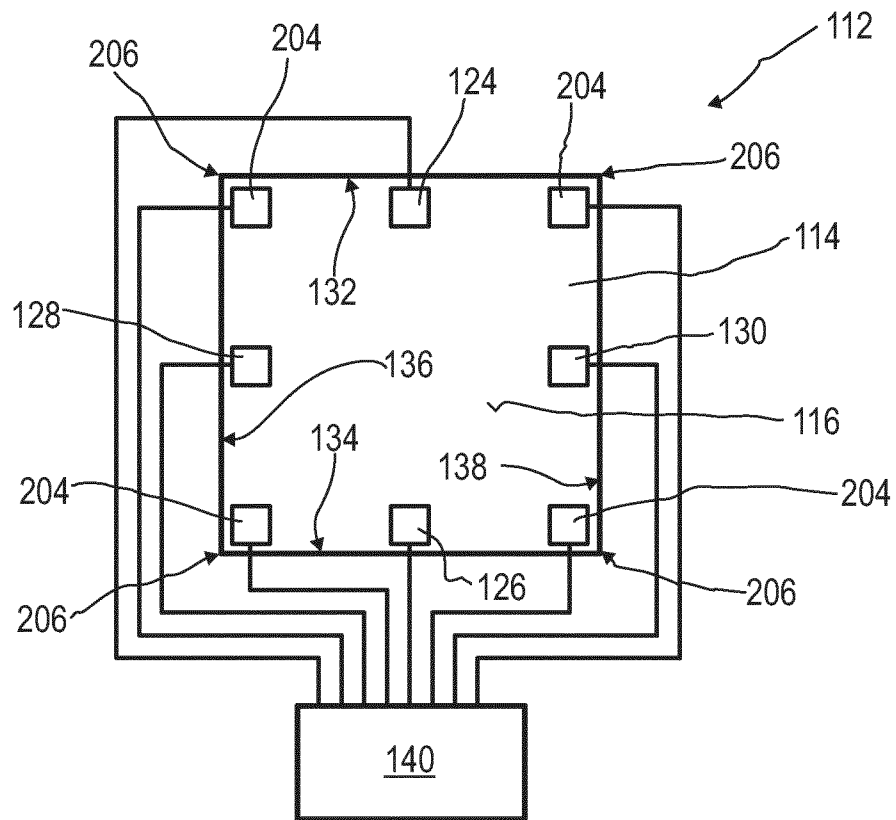
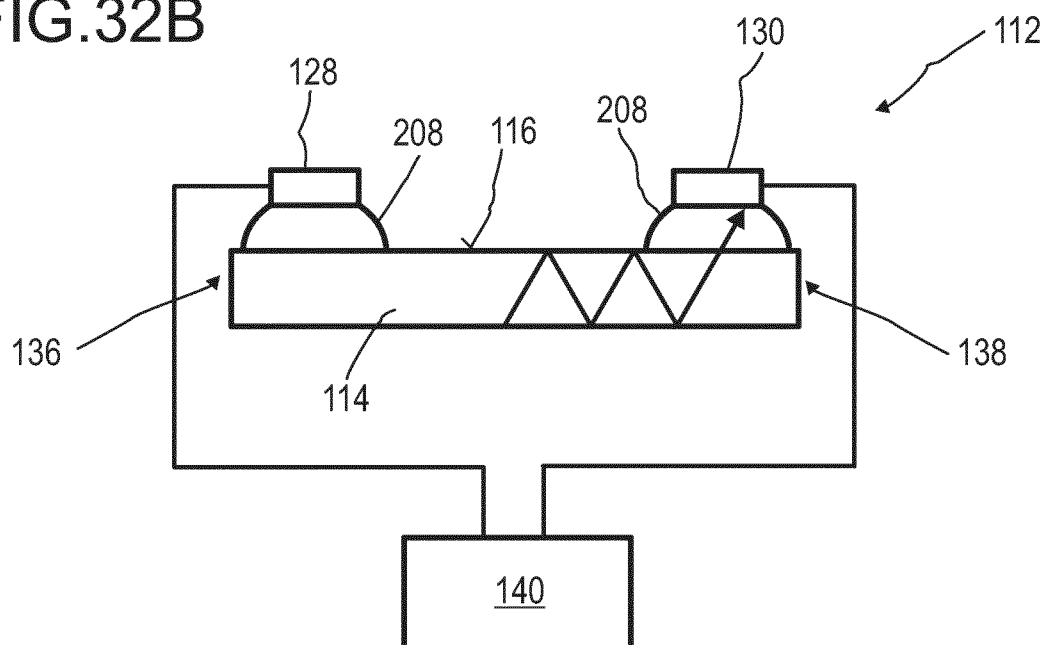


FIG.32B



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/080308

A. CLASSIFICATION OF SUBJECT MATTER

INV. F21V8/00 H01L31/054
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)

G02B 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GOETZBERGER A ET AL: "SOLAR ENERGY CONVERSION WITH FLUORESCENT COLLECTORS", APPLIED PHYSICS, SPRINGER VERLAG, HEIDELBERG; DE, BERLIN/HEIDELBERG, vol. 14, 1 October 1977 (1977-10-01), pages 123-139, XP009082077, ISSN: 0340-3793, DOI: 10.1007/BF00883080 the whole document -----	1-15
X	WILHELM STAHL ET AL: "Fluoreszenzkollektoren", PHYSIK IN UNSERER ZEIT, VCH, WEINHEIM, DE, vol. 16, no. 6, 1 January 1985 (1985-01-01), pages 167-179, XP007907359, ISSN: 0031-9252, DOI: 10.1002/PIUZ.19850160602 the whole document ----- -/-	1-15



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

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/050059 A1 (SHARP KK [JP]; UCHIDA HIDEKI; MAEDA TSUYOSHI; YOSHIDA HIDEFUMI) 19 April 2012 (2012-04-19) abstract figure 3 -----	1-15
X	US 2015/138823 A1 (CORRIGAN THOMAS R [US] ET AL) 21 May 2015 (2015-05-21) abstract paragraphs [0013], [0017], [0018], [0030] - [0035], [0043], [0052], [0053] figure 1 claims 1,8,9,15,17 -----	1-15
X	US 4 884 860 A (BROWN DAVID C [US]) 5 December 1989 (1989-12-05) abstract column 10, paragraph 4 - column 11, paragraph 2 figures 4,5 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/080308

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012050059	A1	19-04-2012	NONE

US 2015138823	A1	21-05-2015	TW 201348765 A 01-12-2013
			US 2015138823 A1 21-05-2015
			WO 2013154917 A1 17-10-2013

US 4884860	A	05-12-1989	AU 3214289 A 22-09-1989
			CA 1315377 C 30-03-1993
			US 4884860 A 05-12-1989
			WO 8908224 A1 08-09-1989
