(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 February 2013 (07.02.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/017738 A1

(51) International Patent Classification:
D21H 21/40 (2006.01) *B42D 15/00* (2006.01) *D21H 21/48* (2006.01) *B44F 1/12* (2006.01) *B41M 3/14* (2006.01)

(21) International Application Number: PCT/FI2012/050765

(22) International Filing Date: 3 August 2012 (03.08.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20115781 3 August 2011 (03.08.2011) FI

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

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

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR MARKING A PRODUCT

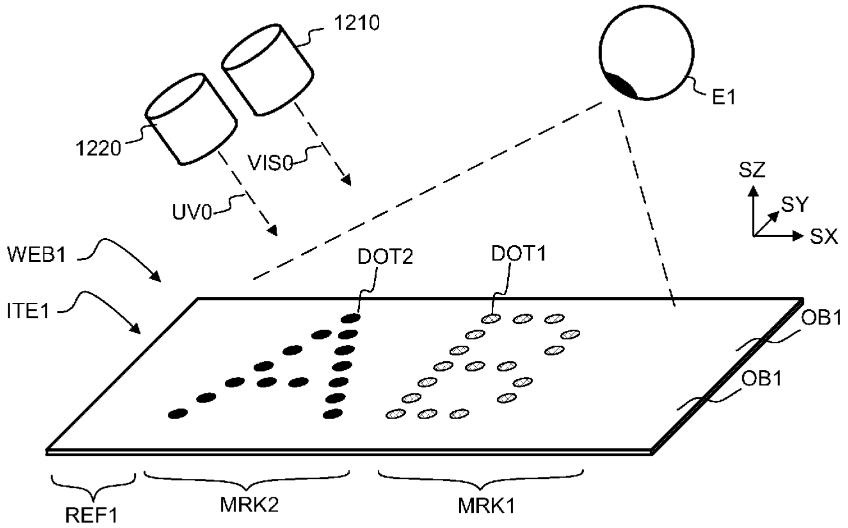


Fig. 2a

(57) Abstract: A method for producing markings (MRK1, MRK2) on a web (WEB1) comprises forming a first altered portion (DOT1) of the web (WEB1) by directing a laser beam (LB2) to the web (WEB1) so as to locally reduce the fluorescence yield of the web (WEB1) at the location of the first altered portion (DOT1), wherein the web (WEB1) comprises cellulose fibers and a fluorescent substance, and wherein the visual contrast between the first altered portion (DOT1) and a reference portion (REF1) is smaller than or equal to 5% when the web (WEB1) is illuminated by substantially white visible light (VIS0), which does not contain ultraviolet light (UV0).

WO 2013/017738 A1

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

METHOD AND APPARATUS FOR MARKING A PRODUCT

FIELD OF THE INVENTION

The invention relates to a method for marking a product. The invention also relates to a product made by a method according to the invention. The invention also relates to an apparatus for marking a product.

BACKGROUND

In industry, there may be a need to make markings in products as such and/or in packages for the products. The markings may include, among other things, various printings, cuts and embossings. The markings may be used to make forging and/or counterfeiting of a product more difficult.

Markings which hinder forging and counterfeiting can be used for authenticating various products at a later stage. Markings which hinder forging and counterfeiting can also be used, for example, in documents relating to valuable brands, wherein it may be possible to hinder manufacturing and marketing of pirate products, which try to exploit product brands without authorization.

An example of a marking which makes forging and counterfeiting more difficult is the so-called copy-protected paper that may be arranged to produce a suitable text, e.g. "illegally copied" when it is e.g. copied, scanned or faxed, so that the copy of the document cannot be presented as the original document. Known approaches to prevention of copying and to protection are typically based on mechanical perforation or embossing of the paper, for example at the calendering stage of paper manufacturing.

It is known that a paper document may comprise a watermark in order to improve visual appearance of the document or in order to make counterfeiting of the document more difficult.

SUMMARY

An object of the invention is to provide a method for producing markings on a paper or cardboard web. An object of the invention is to provide paper or cardboard web, which comprises a marking. An object of the invention is to provide an apparatus for producing markings on a paper or cardboard web.

According to a first aspect of the invention, there is provided a method for producing paper or cardboard web according to claim 1.

According to a second aspect of the invention, there is provided a web according to claim 18.

According to a third aspect of the invention, there is provided an apparatus according to claim 22.

Markings related to forging and counterfeiting do not necessarily need to be visible to the naked eye; in fact, it may even be advantageous that they are not clearly visible to the naked eye when viewed in indoor lighting conditions. However, the markings may be visible in a certain way so that the product can be authenticated on the basis of the marking.

A paper or cardboard web may comprise a covert security marking e.g. to indicate authenticity. The covert security marking may be visually detectable only in special illumination. In particular, the covert marking may be detectable by the naked eye only when the web is illuminated by ultraviolet light. The web may comprise a marking, which is formed of one or more altered portions, which are optically different from a surrounding area. The covert portion may be formed by exposing the web to a laser beam. The intensity of the laser beam, the wavelength of the laser beam, and a fluorescent substance contained in the web may be selected such the fluorescence yield of the web may be locally reduced without altering the visual color and/or thickness of the web at the location of the covert portion. The covert portion may also be called e.g. as a concealed portion.

In particular, the fluorescent substance may be selected such that it loses its fluorescent properties when exposed to a beam of an ultraviolet laser, wherein the photons of the laser beam may cause alteration of the chemical structure of the fluorescent substance.

The energy of a laser beam may also be converted into heat by absorption. The fluorescent substance may be arranged to decompose or lose its fluorescent properties due to heating caused by absorption of a laser beam.

In an embodiment, the web may further comprise an overt marking, which can be easily detected by the naked eye when the web is illuminated by visible white light. The overt marking may comprise e.g. an altered portion, wherein the color of the altered portion may be different from the color of a reference portion. The color of the web may be locally changed e.g. by setting the intensity of a laser beam so high that the cellulose fibers of the web are locally charred (i.e. carbonized).

The overt marking may comprise e.g. an altered portion, which has a different thickness than a reference portion. The overt marking may comprise e.g. a hole or a depression, which has been formed by laser ablation.

In an embodiment, the covert marking may be formed by using a first laser beam, and the overt marking may be formed by using a second laser beam, wherein the first laser beam and the second laser beam have the same wavelength but different intensities. In an embodiment, the first laser beam and the second laser beam may be obtained from the same laser, by changing the intensity of laser light obtained from said laser. In an embodiment, the covert marking and the overt marking may be formed substantially simultaneously, by dividing light of a primary laser beam into a first laser beam and a second laser beam, which have the same wavelength but different intensities.

A written document or a package for a product may comprise a portion of the web. The web may be cut into sheets e.g. to form a ticket or a label for a medicament. A marking produced on the web by the first laser beam may indicate e.g. a trade name, a name of a person, a date stamp, or a page number.

The security-marked web may be easily mass-produced at low costs e.g. by using a modified paper machine, which has been equipped with a laser marking device. In an embodiment, it is not necessary to use an additional security printer or a security converter after producing the web by the modified paper machine. The markings may be produced when the web is moving at a typical speed of a paper machine.

In particular, the fluorescent substance may be an optical brightener added to a paper or cardboard web during the manufacture of the web.

If a counterfeiting person wants to produce a further marking, which is optically identical to an original marking, he should typically have knowledge about the laser parameters, which were used when producing the original marking. The laser parameters may be e.g. intensity, pulse duration, and wavelength. The laser parameters may be kept secret so that a person intending to counterfeit a document would need to make experimental tests to find the suitable laser parameters. If the counterfeiting person has access to only one piece of the paper, i.e. to the document, which he desires to falsify, he cannot use said document for making the experimental tests.

Marking with a laser beam may allow higher spatial resolution, i.e. producing a narrower base portion than conductive heating. Bringing a hot stamp into contact with the web is likely to produce a marking, which has slightly blurred boundaries.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described in more detail with reference to the appended drawings, in which:

Fig. 1 shows, in a top view, a web comprising a covert marking,

Fig. 2a shows, in a three dimensional view, inspecting the web by the naked eye,

Fig. 2b shows, in a three dimensional view, inspecting the web by an image detector,

Fig. 3a shows, in a top view, visual appearance of the web when illuminated with visible light,

Fig. 3b shows, in a top view, visual appearance of the web when illuminated with ultraviolet light,

Fig. 4a shows, by way of example, intensity ranges for producing different types of alterations,

Fig. 4b shows, by way of example, the spectrum of light emitted from the altered portion in ultraviolet illumination,

Fig. 4c shows, by way of example, the spectrum of light reflected from altered portions in visible illumination,

Fig. 5 shows, by way of example, a visual contrast between an altered portion and a reference portion

Fig. 6a shows, in a side view, an optical set-up for producing a non-uniform intensity distribution,

Fig. 6b shows, by way of example, a non-uniform intensity distribution,

Fig. 6c shows, in a top view, a first altered portion surrounding a second altered portion,

Fig. 7a shows, in a top view, a web comprising an overt marking and covert markings,

Fig. 7b shows, in a top view, the visual appearance of the web of Fig. 7a in visible illumination,

Fig. 7c shows, in a top view, the visual appearance of the web of Fig. 7a in ultraviolet illumination,

Fig. 8a shows, in a side view, an optical set-up for producing a first laser spot and a second laser spot,

Fig. 8b shows, in a top view, a first altered portion and a second altered portion,

Fig. 8c shows, in a side view, providing a modified intensity distribution by using a diffractive element,

Fig. 9a shows, in a top view, a web comprising overt portions and covert portions,

Fig. 9b shows, in a top view, appearance of the web of Fig. 9a when illuminated with visible light,

Fig. 9c shows, in a top view, appearance of the web of Fig. 9a when illuminated with ultraviolet light,

Fig. 10 shows, in a side view, steps for producing a paper or cardboard web,

Fig. 11 shows, in a side view, a combination of a web producing apparatus and a laser marking device,

Fig. 12a shows, in a three dimensional view, a device for producing markings,

Fig. 12b shows, in a three dimensional view, a device for producing markings,

Fig. 12c shows producing several independently controllable laser beams,

Fig. 12d shows, in a three dimensional view, a device for producing markings,

Figs. 13a and 13b
show, in a simplified schematic view, systems for marking products according to some embodiments,

Figs. 14 to 16
show products marked by using a UV laser,

Fig. 17 shows, in simplified view, a UV laser apparatus for marking a product according to an example, and

Fig. 18 shows a basic figure of an optical brightener, the figure comprising a marked location where a change of the chemical structure takes place in said optical brightener.

DETAILED DESCRIPTION

Referring to Fig. 1, a web WEB1 may comprise a first marking MRK1, which comprises one or more altered portions DOT1. The altered portions DOT1 may be produced by altering the structure and/or composition of the web WEB1 by a laser beam. The altered portions DOT1 may be produced by altering the composition of the web WEB1 by a laser beam. In particular, the altered portions DOT1 may be produced by deactivating a fluorescent substance OB1 with a laser beam. The wavelength of the marking laser beam may be e.g. in the range of 180 nm to 400 nm. In particular, the wavelength of the marking laser beam may be in the range of 180 nm to 380 nm, e.g. in the range of 350 nm to 360 nm.

The WEB1 may optionally comprise a second marking MRK2, which comprises one or more altered portions DOT2. The altered portions DOT2 may also be produced by altering the structure and/or composition of the web WEB1 by a laser beam.

The mechanical structure and/or chemical composition of the web WEB1 may be locally altered by a laser beam. The laser beam may e.g. locally change the color of web WEB1, the laser beam may deactivate fluorescence from the web WEB1, and/or the laser beam may change a light-scattering property of the WEB1. The laser beam may be used to ablate material away from the WEB1.

The web WEB1 may comprise cellulose fibers. In particular, the web WEB1 may be a paper web or a cardboard web. The cellulose fibers may easily absorb various additives.

The cellulose fibers may be charred (carbonized) by heating with a laser beam such that black, grey or brown color is formed. The material of the cellulose fibers may be easily ablated by a laser beam.

The cellulose fibers of the web WEB1 may be natural cellulose fibers. The web WEB1 may comprise natural cellulose fibers. The cellulose fibers of the web WEB1 may be natural vegetable fibers. The natural vegetable fibers may be selected e.g. from a group consisting of wood fibers, cotton fibers, linen fibers, flax fibers (i.e. linen fibers), hemp fibers, sisal fibers, jute fibers, kenaf fibers, bamboo fibers and coconut fibers. In particular, the cellulose fibers may be selected e.g. from a group consisting of wood fibers, cotton fibers and linen fibers. These fibers are traditionally utilized in when making paper and/or cardboard. The wood fibers may be e.g. pine fibers, spruce fibers, and/or eucalyptus fibers.

The web WEB1 may comprise a fluorescent substance OB1. The fluorescent substance may have been applied substantially to the whole upper and/or lower surface of the web WEB1. The fluorescent substance may be applied e.g. by spraying, curtain-coating, dip-coating or brushing. The chemical composition of the fluorescent substance may be selected such that a trans-isomer of the fluorescent substance is converted into a cis-isomer when exposed to laser radiation, wherein the fluorescence yield of the cis-isomer is smaller than the fluorescence yield of the trans-isomer. The trans-isomer of the fluorescent substance OB1 may be converted into a cis-isomer of the fluorescent substance OB1 when exposed to laser radiation whose wavelength λ_0 is in the ultraviolet regime. The fluorescent substance OB1 may be e.g. stilbene, coumarin or pyrazoline.

The marking laser beam may be obtained from a laser. The laser may be e.g. an excimer laser, a CO2-laser or a fiber laser. The peak wavelength λ_0 of the laser beam may be e.g. in the ultraviolet range, in the visible range, or in the infrared range.

The method may comprise forming a first altered portion DOT1 by directing a laser beam LB2 to the web WEB1 so as to suppress fluorescence of a fluorescence substance OB1 from the first altered portion DOT1, wherein the web WEB1 comprises cellulose fibers and the fluorescent substance OB1, and wherein the visual contrast $((L_{REF,1}-L_{1,1})/L_{REF,1})$ between the first altered portion DOT1 and a reference portion REF1 is smaller than or equal to 5% when the web WEB1 is illuminated by substantially white visible light VIS0, which does not contain ultraviolet light UV0.

The altered portions DOT1, DOT2 may be optically detected by comparing the optical properties of the altered portion DOT1, DOT2 with the optical properties of a reference portion REF1. The reference portion REF1 may surround an altered portion DOT1 and/or DOT2. The reference portion REF1 may surround the first marking MRK1 and/or the second marking MRK2. The distance between the altered portion DOT1 and the reference portion REF1 may be smaller than the dimension of the altered portion DOT1 in the direction SX or SY. In particular, the distance between the altered portion DOT1 and the reference portion REF1 may be substantially equal to zero.

An item ITE1 obtained by cutting a piece of the web WEB1 may comprise the first marking MRK1 and/or the second marking MRK2. The item ITE1 may e.g. a paper sheet or a cardboard sheet. The size of the sheet may be e.g. A5, A4, A3, A2, A1, A0, ANSI A, ANSI B, ANSI C, ANSI D, and ANSI E, as determined in the standards ISO 216 and ANSI/ASME Y14.1. The web WEB1 and the item ITE1 may optionally comprise text and/or graphics INF1, which has been printed on the item ITE1 (the text may be e.g. a marking "TXT1"). The graphics and/or text may be printed on the web WEB1 by using conventional printing means (e.g. flexography, offset printing, inkjet printing). The item ITE1 may be e.g. a receipt, a label, a certificate of warranty, a diploma, a written agreement, or a product package. The item ITE1 may be optionally lined with an adhesive. The item ITE1 may be e.g. a label. In particular, the item ITE1 may be a label for a medicament. An individual altered portion DOT1, DOT2 may have e.g. a substantially circular or linear shape, or it may have e.g. the shape of a letter or a number.

The reference portion REF1 may mean the intact area of the web WEB1 which does not comprise any altered portions and which does not comprise any printed portions. The markings MRK1, MRK2, TXT1 may cover e.g. less than 50% of the total (one-sided) surface area of the web WEB1. The surface area of the reference portion REF1 may be e.g. greater than 50% of the total (one-sided) surface area of the web WEB1. In an embodiment, the markings MRK1, MRK2, TXT1 may cover less than 20% of the total (one-sided) surface area of the web WEB1. The surface area of the reference portion REF1 may be e.g. greater than 80% of the total (one-sided) surface area of the web WEB1, respectively.

SX, SY and SZ denote orthogonal directions. The direction SZ is shown e.g. in Fig. 2a.

Referring to Fig. 2a, an optical difference between an altered portion DOT1, DOT2 and a reference portion REF1 may be detected by illuminating the web WEB1. The illuminating light may be e.g. visible light VIS0 and/or ultraviolet light UV0. The optical properties of the portions DOT1, DOT2 may be monitored by a human eye E1 when the web WEB1 is illuminated with visible light VIS0 and/or with ultraviolet light UV0. The portion DOT1 and/or DOT2 may be detectable by an unaided eye E1, i.e. by a naked eye E1. Alternatively, an optical device may be used to facilitate detection of the portions DOT1 and/or DOT2, when viewed by a human eye E1. The optical device may be e.g. a microscope or an optical narrowband filter positioned between the web WEB1 and the eye E1. The illuminating light VIS0 and/or UV0 may be obtained from a light source 1210 and/or 1220. The light source

1210, 1220 may be e.g. a light-emitting diode, gas discharge lamp (in particular a fluorescent tube), or a tungsten halogen lamp. The same light source may provide visible light VIS0 and ultraviolet light UV0.

A first altered portion DOT1 may be optically detectable by the naked eye E1 when the web WEB1 is illuminated by ultraviolet light UV0. The first altered portion DOT1 may be substantially invisible to the naked eye when the web WEB1 is illuminated by visible light UV0, which does not contain ultraviolet light. The first altered portion DOT1 may be called e.g. as a covert portion. The covert portion DOT1 may be produced e.g. by locally deactivating fluorescent properties of the web WEB1. The covert portion DOT1 may appear e.g. as a darker region when the web WEB1 is illuminated by ultraviolet light UV0. The thickness of the web WEB1 at the location of the covert portion DOT1 may be substantially equal to the thickness of the web WEB1 within the area of the reference portion REF1.

A second altered portion DOT2 may be optically detectable when the web WEB1 is illuminated by visible light VIS0, which does not contain ultraviolet light. The second altered portion DOT2 may be called e.g. as an overt portion. The overt portion DOT2 may have e.g. a color, which is darker or brighter than the color of the reference portion REF1 when the web WEB1 is illuminated by white visible light VIS0, and when viewed by the naked eye. In particular, the overt portion DOT2 may have a black, grey or brown color formed due to charring of the web WEB1. The overt portion DOT2 may also be a hole or a depression formed by ablating material away from the web WEB1 by a laser beam.

The expression "detectable by the naked eye" may mean that a visual contrast between an altered portion DOT1, DOT2 and a reference portion REF1 is high enough so as to allow reliable detection by an unaided eye. The minimum visual contrast for reliable detection may be e.g. 2%. The expression "substantially invisible to the naked eye" may mean that a visual contrast between the altered portion DOT1 and a reference portion REF1 is smaller than the limit for reliable detection. The portion DOT1 may be substantially invisible when the visual contrast is lower than 2%.

The portion DOT1, DOT2 may be "easily detectable" when the visual contrast is higher than or equal to 5%. The portion DOT1, DOT2 is not "easily detectable" when the visual contrast is lower than 5%.

A covert portion DOT1 and the overt portion DOT2 may be produced in successive order or substantially simultaneously. A first laser beam for producing the covert portion DOT1 and a second laser beam for producing the overt portion DOT2 may be obtained from the same laser 400. The first laser beam and the second laser beam may have the same wavelength λ_0.

The altered portion DOT2 may be detectable by the naked eye E1 when the web WEB1 is illuminated by white visible light VIS0, which does not contain ultraviolet light UV0. For example, the color of the altered portion DOT2 may be different from the color of the reference portion REF1. The different color may be produced e.g. by setting the intensity of the marking laser beam such that the cellulose fibers of the web WEB are locally charred. In particular, the color of the altered portion DOT2 may be darker than the color of the reference portion REF1.

The portion DOT2 may also be a hole or a depressed portion formed by laser ablation. The reference portion REF1 may have a first thickness of the web, and the altered portion DOT2 may have a second thickness of the web, wherein the second thickness may be substantially smaller than the first thickness.

The gloss value of the altered portion DOT2 may be substantially different from the gloss value of the reference portion REF1. The gloss values may be measured e.g. by a method defined in the standard "TAPPI T480". The portion DOT2 may have a glossy visual appearance, and the reference portion REF1 may have a matte visual appearance. The portion DOT2 may have a matte visual appearance, and the reference portion REF1 may have a glossy visual appearance.

Referring to Fig. 2b, the optical properties of the portions DOT1, DOT2 may be monitored by an optical sensor CAM1 when the web WEB1 is illuminated with visible light VIS0 and/or with ultraviolet light UV0. The optical sensor

CAM1 may be e.g. an image sensor. For example, the digital camera of a mobile phone may be used as the image sensor. For example, the sensor CAM1 may be a digital microscope.

The optical sensor CAM1 may be spectrally selective so as to measure e.g. reflectance spectrum and/or a fluorescence spectrum. The optical sensor CAM1 may be arranged to detect visible light, ultraviolet light, and/or infrared light.

In an embodiment, the first marking MRK1 and/or the second MRK2 may be a forensic marking. The first marking MRK1 and/or the second MRK2 may be implemented on the web WEB1 such that is not immediately evident that the web WEB1 even comprises the marking MRK1 and/or MRK2 when the web WEB1 is inspected by the naked eye E1 in visible illumination VIS0. In an embodiment, also the second marking MRK2 may be a covert marking. The second marking MRK2 may be implemented e.g. such that the marking can be detected only by using special apparatus, e.g. by a microscope.

The first marking MRK1 and/or the second MRK2 may be implemented such that they can be inspected only by using special apparatus. The marking MRK1, MRK2 may comprise e.g. very small altered portions DOT1, DOT2, which need to be inspected by a microscope. The first marking MRK1 and/or the second MRK2 may be implemented e.g. such that the information content of the marking may be extracted only by using special apparatus. For example, the marking MRK1 and/or MRK2 may be scrambled. For example, the marking MRK1 and/or MRK2 may be scrambled such that it appears as a chaotic group of dots, wherein a data processor may be arranged to provide e.g. an alphanumeric code by analyzing and processing a digital image of said group of dots, said alphanumeric code depending on the information content of said marking MRK1 and/or MRK2. The information contained in the marking MRK1 and/or MRK2 may be scrambled such that the information can be decoded only by using a password.

Fig. 3a shows visual appearance of the web WEB of Fig. 1 when the web WEB1 is illuminated with visible (white) light VIS0, which does not contain ultraviolet light UV0. The overt portions DOT2 may be easy to detect in this visible illumination VIS0, and the marking MRK2 can be easily seen by the naked eye E1. The visual contrast of the covert portions DOT1 may be so low that it is difficult or impossible to detect the covert portions DOT1 by the naked eye E1, and the first marking MRK1 may be substantially invisible in this visible illumination VIS0.

Fig. 3b shows visual appearance of the web WEB of Fig. 1 when the web WEB1 is illuminated with ultraviolet light VIS0. Both the covert portions DOT1 and the covert portions DOT1 may be visible in this ultraviolet illumination UV0. The first marking MRK1 and the second marking MRK2 can be easily detected by the naked eye E1. The visual contrast of the covert portions DOT1 in this ultraviolet illumination UV0 may be so high that it allows reliable detection by the naked eye E1.

Fig. 4a shows, by way of example, an intensity limit $I_{MIN,1}$ for suppressing fluorescence, an intensity limit $I_{MIN,2}$ for changing color, and an intensity limit $I_{MIN,0}$ for causing ablation. The limits $I_{MIN,0}$, $I_{MIN,1}$, $I_{MIN,2}$ may also be called as threshold values. The capability of the web WEB1 to fluoresce may be deactivated by directing a laser beam to the web WEB1 such that the intensity of the laser beam is higher than or equal to the limit $I_{MIN,1}$. The color of the web WEB1 may be changed by directing a laser beam to the web WEB1 such that the intensity of the laser beam is higher than or equal to the limit $I_{MIN,2}$. Material may be ablated away from the by directing a laser beam to the web WEB1 such that the intensity of the laser beam is higher than or equal to the limit $I_{MIN,0}$. The limit $I_{MIN,2}$ may be substantially higher than the limit $I_{MIN,1}$. The limit $I_{MIN,0}$ may be substantially higher than the limit $I_{MIN,2}$.

A covert portion DOT1 may be produced by directing a laser beam to the web WEB1 such that the intensity of the laser beam is greater than or equal to $I_{MIN,1}$, and lower than the limit $I_{MIN,2}$.

An overt portion DOT2 may be produced by directing a laser beam to the web WEB1 such that the intensity of the laser beam is greater than or equal to $I_{MIN,2}$.

The parameter shown in the vertical axis of Fig. 4a may also be the duration of a laser pulse instead of the intensity. The expression "deactivation of fluorescence" means that the fluorescence yield is decreased. The expression "suppressing fluorescence" means that the fluorescence yield is decreased.

The "fluorescence yield" is defined as the ratio of the number of photons emitted to the number of photons absorbed, wherein the wavelengths of the emitted photons are longer than the wavelength of the absorbed photons. The fluorescence yield may also be called as the fluorescence efficiency.

Fig. 4b shows, by way of example, spectrum of light emitted from the reference portion REF1 and spectrum of light emitted from a covert portion DOT1 when the web WEB1 is illuminated by ultraviolet light UV0, which does not contain visible light VIS0. The fluorescence yield of the covert portion DOT1 may be substantially lower than the fluorescence yield of the reference portion REF1. Thus, the covert portion DOT1 may appear darker than the reference portion REF1, when viewed by the naked eye E1, allowing detection of the marking MRK1 of Fig. 1 by the naked eye E1.

Fig. 4c shows, by way of example, spectrum of light reflected from the covert portion DOT1, the spectrum of light reflected from the overt portion DOT2, and the spectrum of light reflected from the reference portion REF1 when the web WEB1 is illuminated by visible (white) light UV0, which does not contain ultraviolet light UV0.

Referring to Fig. 5, an altered portion DOT1, DOT2 may appear darker or brighter than the reference portion REF1 depending on the spectral properties of illuminating light, depending on the spectral properties of the altered portion, and depending on the spectral properties of the image sensor CAM1 or eye E1.

An altered portion may be detected by measuring the radiance of the altered portion, and by comparing the radiance value of the altered portion with the radiance value of the reference portion REF1 and/or with a reference value stored in a memory.

The web WEB1 may have covert altered portion DOT1 having an altered fluorescence property and an overt altered portion DOT2 having an altered color. The altered portions may be distinguished from the background REF1 based on spatial variations of the brightness. An altered portion DOT1, DOT2 may appear darker or brighter than the background REF1.

The brightness of a portion may be substantially proportional to the radiance of said portion in a predetermined wavelength range. The radiance in a predetermined wavelength range is equal to the integral of spectral radiance over said predetermined wavelength range. When inspecting the web WEB1 by an eye E1, the predetermined wavelength range may be the visible range of wavelengths from 400 nm to 760 nm. The predetermined wavelength range may also be limited by viewing the web WEB1 through an optical filter. The predetermined wavelength range may be limited by viewing the web WEB1 through a color filter. The predetermined wavelength range may be limited by viewing the web WEB1 through a narrowband optical filter. The bandwidth of the narrowband optical filter may be e.g. narrower than or equal to 50 nm, 20 nm, or 10 nm.

When inspecting the web WEB1 by an optical sensor CAM1, the predetermined wavelength range may e.g. be in the visible range (e.g. from 400 nm to 760 nm), and/or in the ultraviolet range (e.g. from 200 nm to 400 nm). The predetermined wavelength range of an optical sensor CAM1 may be defined by one or more optical filters.

The fluorescent substance OB1 contained in the web WEB1 may be selected such that it can be deactivated by heating, i.e. the fluorescent substance may be thermally deactivated. The fluorescent substance may have a minimum deactivation temperature T_{DEACT}, wherein keeping the fluorescent substance at the minimum deactivation temperature T_{DEACT} in complete darkness during a time period of 1 ms may cause a local reduction of the fluorescence yield of the web WEB1, said reduction of the fluorescence yield being greater than or equal to 5% of the initial value of the fluorescence yield.

The heating may cause decomposition of the fluorescent substance and/or the heating may cause conversion of the fluorescent substance to one or more substantially non-fluorescent substances. Keeping the fluorescent substance at the minimum deactivation temperature T_{DEACT} in complete darkness during a time period of 1 ms may cause a reduction of the amount of the fluorescent substance, said reduction being greater than or equal to 5% of the initial amount of the fluorescent substance.

Exposure to a marking laser beam may temporarily increase the temperature of the fluorescent substance OB1 contained in the web WEB1 to a temperature, which is higher than or equal to the minimum deactivation temperature T_{DEACT}. For example, an infrared laser beam may be used for local heating of the web WEB1 in order to deactivate fluorescence.

By using the marking laser beam, the fluorescent properties may also be deactivated substantially without heating the fluorescent substance OB1. In particular, an ultraviolet laser beam may be utilized when forming the covert portions DOT1. The ultraviolet laser beam may be a pulsed beam having a pulse duration.

When forming a covert portion DOT1, the wavelength of the marking laser beam may be in the ultraviolet regime, e.g. in the range of 180 nm to 400 nm (in particular in the range of 180 to 380 nm), and the intensity and/or the pulse duration of the marking laser beam may be selected such that exposing the web WEB1 to said marking laser beam causes a local reduction of the fluorescence yield of the web WEB1, the reduction being greater than 5% of the initial fluorescence yield of the web WEB1, wherein the temperature of the fluorescent substance OB1 remains lower than the minimum deactivation temperature T_{DEACT} during exposure to said marking laser beam.

The web WEB1 may be produced in a paper machine, which comprises a drying section and/or a calandering section. The chemical composition of the fluorescent substance OB1 contained in a paper or cardboard web WEB1 may be selected such that the fluorescent substance can withstand the high temperature of a drying section and/or the high temperature of a calandering section substantially without losing its fluorescent properties. The surface temperature of the web WEB1 in the drying section may be e.g. in the range of 70 to 150°C. The surface temperature of the web WEB1 in the calendering section may temporarily be e.g. in the range of 150 to 250°C. The chemical composition of the fluorescent substance may be selected such that the minimum deactivation temperature T_{DEACT} is higher than or equal to 150°C, advantageously higher than or equal to 200°C, or even higher than or equal to 250°C

When forming a covert portion DOT1, the wavelength of the marking laser beam may be in the ultraviolet regime, e.g. in the range of 180 nm to 400 nm, and the intensity and/or the pulse duration of the marking laser beam may be selected such that temperature of the fluorescent substance OB1 remains substantially below the melting point of the fluorescent substance during exposure to the marking laser beam.

When forming a covert portion DOT1, the wavelength of the marking laser beam may be in the ultraviolet regime, and the intensity and/or the pulse duration of the marking laser beam may be selected such that exposing the web WEB1 to said marking laser beam increases the temperature of the fluorescent substance OB1 less than 10°C, and the temperature the fluorescent substance may be kept under the minimum deactivation temperature T_{DEACT}.

The fluorescent substance OB1 has a certain spectral absorbance in the UV regime. The spectral absorbance may be represented graphically by a curve, which may have one or more spectral peaks. The wavelength of the marking laser beam and/or the composition of the fluorescent substance may be selected such that the wavelength of the marking laser beam substantially matches with the spectral position of a peak of the spectral absorbance. Thus, the marking may be produced faster and/or by using a less powerful laser.

The uppermost curve CR1 of Fig. 5 shows, by way of example, luminance $L_{VIS,1}$ at different locations of the web WEB1 when the web WEB1 is illuminated by visible white light VIS0, which does not contain ultraviolet light UV0. The illuminating light may have spatially uniform intensity distribution.

The luminance L is the luminous intensity reflected (or emitted) from a unit area. The luminance indicates how much luminous power will be detected by an eye looking at the surface from a particular angle of view. The luminance L takes into account the spectral sensitivity of the eye. The unit of the luminance may be cd/m^2 (candela per unit area). The "visible white light" means the visible portion of blackbody emission spectrum when the blackbody temperature is in the range of 3000 K to 6500K. When the illuminating light does not contain ultraviolet light, this means that the illuminating light does not contain any spectral components whose wavelength is shorter than 400 nm.

The curve CR1 may also be interpreted to represent a weighted average of spectral reflectance of the web WEB1 at different locations, wherein the spectral reflectance is weighted by the spectral sensitivity of the eye and averaged over the range of visible wavelengths from 400 nm to 760 nm. The reference portion REF1 may have a luminance value $L_{REF,1}$.

The overt altered portion DOT2 may be e.g. carbonized such that it appears to be black when illuminated by the visible light VIS0, and when it is viewed by the eye E1. The overt altered portion DOT2 may have a luminance value $L_{2,1}$.

For reliable detection by the naked eye, there should be a minimum depth of spatial modulation of luminance. The depth of spatial modulation of the luminance may be called as the "visual contrast".

A contrast relevant for inspection by the naked eye may be called as the "visual contrast". A portion may be considered to be "visible to the naked eye" when the visual contrast is higher than or equal to 2%. A portion may be considered to be "substantially invisible to the naked eye" when the visual contrast is smaller than 2%.

The visual contrast of the overt portion DOT2 is equal to $(L_{REF,1}-L_{2,1})/L_{REF,1}$, with respect to the reference portion REF1. The visual contrast of the overt portion DOT2 may be e.g. higher than 5%, in order to facilitate easy detection by the naked eye E1.

$L_{1,1}$ denotes the luminance of the covert portion DOT1. The visual contrast of the covert portion DOT1, is equal to $(L_{REF,1}-L_{1,1})/L_{REF,1}$, with respect to the reference portion REF1.

The visual contrast $(L_{REF,1}-L_{1,1})/L_{REF,1}$ of the covert portion DOT1 may be e.g. smaller or equal to 5% such that the covert portion DOT1 may remain substantially less visible than e.g. a further marking, when the web WEB1 is illuminated by visible white light VIS0, which does not contain ultraviolet light UV0. The further marking (e.g. the marking TXT1 in Fig. 1) may be be printed on the web WEB1 at a later stage e.g. by using conventional ink.

The visual contrast $(L_{REF,1}-L_{1,1})/L_{REF,1}$ of the covert portion DOT1 may be e.g. smaller or equal to 2% such that it is difficult or impossible to detect the presence of the covert portion DOT1 when the web WEB1 is illuminated by visible white light VIS0, which does not contain ultraviolet light UV0.

The visual contrast $(L_{REF,1}-L_{1,1})/L_{REF,1}$ of the covert portion DOT1 may be e.g. smaller or equal to 0.5% such that it is nearly impossible to detect the presence of the covert portion DOT1 by the naked eye when the web WEB1 is illuminated by visible white light VIS0, which does not contain ultraviolet light UV0.

In case of a very low visual contrast, the covert portion DOT1 may still be detectable e.g. by using an image sensor CAM1.

The second curve CR2 shows, by way of example, luminance $L_{VIS,2}$ at different locations of the web WEB1 when the web WEB1 is illuminated by ultraviolet light UV0, which does not contain visible light. Also in this case the luminance LVIS,2 indicates how much luminous power will be detected by an eye looking at the surface from a particular angle of view.

The web WEB1 may be initially fluorescing, wherein the fluorescence from the covert portion DOT1 and from the overt portion DOT2 may be suppressed, as a consequence of exposure to the laser beam. Thus, the covert portion DOT1 and the overt portion DOT2 may appear darker than the reference portion REF1, when illuminated by ultraviolet light UV0 and inspected by the naked eye E1.

$L_{REF,2}$ denotes the luminance of the reference portion REF1. $L_{1,2}$ denotes the luminance of the covert portion DOT2. $L_{2,2}$ denotes the luminance of the overt portion DOT1. In this case, the visual contrast of the covert portion DOT1 is equal to $(L_{REF,2}-L_{1,2})/L_{REF,2}$. The visual contrast of the overt portion DOT2 is equal to $(L_{REF,2}-L_{2,2})/L_{REF,2}$. When illuminating with the ultraviolet light UV0, the visual contrast of the covert portion DOT1 may be substantially greater than 2% even if the visual contrast of the covert portion DOT1 would be less than 2% when illuminated with visible light VIS0.

Fluorescence from underlying layers of the web WEB1 may cause residual radiance L_{RESI}. Fluorescence light emitted from the surrounding portions and scattered from the portions DOT1, DOT2 may also cause residual radiance L_{RESI}.

The third curve CR3 shows, by way of example, ultraviolet radiance R_{UV} at different locations of the web WEB1 when the web WEB1 is illuminated by ultraviolet light UV0, which does not contain visible light. The ultraviolet radiance R_{UV} is equal to the integral of spectral radiance over a range of ultraviolet wavelengths. Spatial variations of the radiance R_{UV} may be detected by an optical sensor CAM1, which is sensitive to ultraviolet wavelengths. Spatial variations of the radiance R_{UV} cannot be detected by the naked eye E1. The curve CR3 may also represent spatial variations of ultraviolet reflectance of the web WEB1.

$R_{1,3}$ denotes the ultraviolet radiance of the covert portion DOT1. $R_{2,3}$ denotes the ultraviolet radiance of the overt portion DOT2. $R_{REF,3}$ denotes the ultraviolet radiance of the reference portion REF1. In this case, the ultraviolet contrast of the covert portion DOT1, is equal to $(R_{REF,3}-R_{1,3})/R_{REF,3}$. The ultraviolet contrast of the overt portion DOT2, is equal to $(R_{REF,3}-R_{2,3})/R_{REF,3}$.

The ultraviolet contrast cannot be detected by the naked eye. The web WEB1 may be monitored by an optical sensor CAM1, which detects ultraviolet light. The (carbonized) covert portion DOT1 may have a low reflectance for ultraviolet light such that the covert portion DOT1 appears to be darker than the reference portion REF1 when viewed by a UV-sensitive optical sensor CAM1.

Fluorescence from the covert portion DOT1 has been suppressed by altering the web WEB1 with a laser beam. Exposure to the laser beam may change the chemical structure of the fluorescent substance OB1 so that the substance may still absorb ultraviolet radiation, even if the fluorescent property would be deactivated. The ultraviolet radiance $R_{1,3}$ of the covert portion DOT1 may be lower than the ultraviolet radiance $R_{REF,3}$ of the reference portion REF1.

In an embodiment, the laser beam may convert the first fluorescent substance to a second substance, which has a different fluorescence spectrum than the first substance.

In an embodiment, the laser beam may convert a first fluorescent substance to a second substantially non-fluorescent substance.

In an embodiment, the visual contrast may be increased or maximized by selecting the wavelength range of the illuminating light VIS0.

In an embodiment, a covert portion DOT1 may be substantially invisible when illuminated by white visible light, but said covert portion DOT1 may be visible when illuminated by visible light having narrow spectral band. The contrast may be e.g. less than 2% when illuminated by white light (e.g. sunlight, tungsten halogen lamp), wherein the contrast may be higher than 2% when illuminated by light having narrow spectral band (e.g. by using visible laser light, or light from a blue, red, green or yellow light-emitting diode).

In an embodiment, the covert portion DOT1 may be implemented such that it is difficult or impossible to detect by monitoring only visible light, wherein the presence of the covert portion DOT1 may be detected by using an optical sensor CAM1, which is arranged to detect ultraviolet light reflected and/or fluoresced from the web WEB1.

A fluorescent material may absorb optical energy at a shorter wavelength, and emit a part of the optical energy at a longer wavelength. In an embodiment, the reference portion REF1 may be fluorescing such that it absorbs visible light, and emits infrared light. In this case, the presence of the portion DOT2 may be detected by using an optical sensor CAM1, which is sensitive to infrared light.

Referring to Figs. 6a- 6c, 8a-8c, a covert portion DOT1 and an overt portion DOT2 may be produced substantially simultaneously by providing a non-uniform intensity distribution on the surface of the web WEB1.

Fig. 6b shows, by way of example, a non-uniform intensity distribution for producing the altered portions shown in Fig. 6c. A portion of the web WEB1 exposed to an intensity higher than the limit $I_{MIN,1}$ but lower than the limit I_{MIN2} may be converted into a covert portion DOT1' (see Fig. 4a). A portion of the web WEB1 exposed to intensity higher than the limit I_{MIN2} may be converted into an overt portion DOT2. x denotes a position coordinate in the direction SX.

For example, a laser marking device may provide an intensity distribution, which has a region of high intensity near the center of a laser spot SP2, and an annular region DOT1' of lower intensity near the periphery of said laser spot SP2. In particular, optical aberrations of the focusing optics 350 may provide such an intensity distribution.

Referring to Fig. 6c, the laser beam LB2 provided by a laser marking device may be arranged to substantially simultaneously produce a combination of a covert portion DOT1' and an overt portion DOT2.

The covert portion DOT1' may have a dimension d1 in the direction SX, and the overt portion DOT2 may have a dimension d2 in the direction SX. The dimension d2 may be e.g. greater than or equal to two times the dimension d1. The dimension d2 may be e.g. greater than or equal to four times the dimension d1. The dimension d2 may be e.g. in the range of 2 to 5 times the dimension d1. The covert portion DOT1' may surround the overt portion DOT2. In particular, the covert portion DOT1' may be an annular ring.

A desired intensity distribution may also be implemented e.g. by using diffractive optics (See Fig. 8c).

Fig. 7a shows a web WEB1, which comprises a marking MRK3, which in turn comprises a plurality of narrow overt portions DOT2 surrounded by broader covert portions DOT1'. The covert portions may be annular. A covert portion DOT1' may surround an overt portion DOT2. The covert portions DOT1' may be difficult or impossible to detect by the naked eye E1 when the web WEB1 is illuminated only with the visible light VIS0.

Fig. 7b shows shows visual appearance of the web WEB of Fig. 7a when the web WEB1 is illuminated with visible light VIS0, which does not contain ultraviolet light UV0. The narrow overt portions DOT2 may be easy to detect in this visible illumination VIS0. The contrast of the covert portions DOT1' may be so low that it is difficult or impossible to detect the covert portions DOT1' by the naked eye E1 in this illumination.

Fig. 7c shows visual appearance of the web WEB of Fig. 7a when the web WEB1 is illuminated with ultraviolet light UV0. Both the overt portions DOT2 and the covert portions DOT1' may be visible in this ultraviolet illumination UV0. Thus, the dots of the marking MRK3 may appear to be larger in the ultraviolet illumination UV0 than in the visible illumination VIS0.

Fig. 8a shows, by way of example, an optical set-up for simultaneously providing two separate laser spots SP2 and SP2' such that the maximum intensity of the first spot SP2 is different from the maximum intensity of the second spot SP2'. In particular, the maximum intensity of the first spot SP2 may be substantially higher than the maximum intensity of the second spot SP2'.

A primary laser beam LB0 provided by a laser 400 may be split to form two or more intermediate beams LB1, LB1', which propagate in different directions.

The intermediate beams LB1, LB1' may be subsequently reflected to provide two marking beams LB2, LB2', which also propagate in slightly different directions. The primary beam LB0 may be provided by a laser 400. The intermediate beams LB1, LB1' may be provided e.g. by a beam splitter 431 and a reflector 432. The direction of the beams may be changed by a reflector 433. The beams may be optionally focused by focusing optics 350. The marking beams LB2, LB2' may be generated substantially simultaneously. The beams LB2, LB2' may be called e.g. as "sub-beams". The beams LB2, LB2' may have the same wavelength λ_0.

Fig. 8b shows, by way of example, a covert portion DOT1 and an overt portion DOT2 formed on the web WEB1. The portions DOT1, DOT2 may be formed substantially simultaneously e.g. by using the set-up of Fig. 8a or Fig. 8c. The portions DOT1, DOT2 may be overlapping or separate (i.e. non-overlapping). The portions DOT1, DOT2 may be separated by a distance g12. The portions DOT1, DOT2 may be separated by a distance g12 e.g. in the direction SX, in the direction SY, or in some other direction.

Referring to Fig. 8c, a part of light of a laser beam LB2 may be deflected to form a secondary marking beam LB2'. The secondary marking beam LB2' may be provided e.g. by a beam-deflecting element 351. The beam-deflecting element 351 may be positioned such that it at least partly intercepts a laser beam provided by a laser. The beam-deflecting element 351 may be positioned e.g. between focusing optics 350 and the web WEB1. The beam-deflecting element 351 may be e.g. a transmissive or reflective diffraction grating. The beam-deflecting element 351 may be e.g. a transmissive or reflective diffraction grating, which may diffract light e.g. in the zeroth diffraction order and in the first diffraction order. The diffractive features of the beam-deflecting element 351 may be selected such that the power diffracted in the first diffraction order is e.g. 10% of the power diffracted in the zeroth diffraction order. Light diffracted in the zeroth order may provide the first spot SP2 and light diffracted in the first diffraction order may provide the second spot SP2'.

The beam-deflecting element 351 may be e.g. a holographic element. The diffractive features of the beam-deflecting element 351 may be selected to provide a laser spot SP2, SP2', which has a desired (predetermined) shape. The shape may be e.g. circular, elliptical, rectangular, star-shaped, or the shape may resemble e.g. the letter or a number.

Referring to Fig. 9a, a first marking MRK1 may comprise covert portions DOT1, and a second marking MRK2 may comprise overt portions DOT2. The covert portions DOT1 may be displaced with respect to the overt portions DOT2. The portions DOT1, DOT2 may be formed substantially simultaneously e.g. by using the set-up of Fig. 8a or 8c.

Fig. 9b shows shows visual appearance of the web WEB of Fig. 9a when the web WEB1 is illuminated with visible light VIS0, which does not contain ultraviolet light UV0. The overt portions DOT2 may be easy to detect in this visible illumination VIS0, and the marking MRK2 can be easily seen by the naked eye E1. The visual contrast of the covert portions DOT1 may be so low that it is difficult or impossible to detect the covert portions DOT1 by the naked eye E1. The marking MRK1 may be difficult or impossible to detect in this visible illumination VIS0.

Fig. 9c shows visual appearance of the web WEB of Fig. 9a when the web WEB1 is illuminated with ultraviolet light UV0. Both the covert portions DOT1 and the overt portions DOT2 may be visible to the naked eye E1 in this ultraviolet illumination UV0.

Referring to Fig. 10, production of a paper or cardboard web may typically comprise one or more of the following steps:
- compressing, where wet cellulose fiber web is compressed between rolls in order to remove water,
- drying, where water is removed from the web by heating,
- calandering, where the surface of the web is smoothed by compressing between rolls,
- sizing, where one or more sizing agents are added to the web e.g. in order to improve the mechanical strength of the web,
- coating, where the web is coated with one or more fillers e.g. in order to produce a smooth surface, to modify optical reflectance of the web, and/or to facilitate subsequent printing on the web.

One or more covert portions DOT1 may be formed after applying the fluorescent substance OB1. POS1, POS2, POS3, POS4 denotes different positions where marking may be performed.

Altered portions DOT1, DOT2 may be formed e.g. between drying and calandering.

Altered portions DOT1, DOT2 may be formed e.g. between calandering and adding a sizing.

Altered portions DOT1, DOT2 may be formed e.g. between adding a sizing and adding a filler.

Altered portions DOT1, DOT2. The sizing agent may comprise e.g. starch, resin, and/or glue. The filler may comprise e.g. calcium carbonate or china clay. The filler may be suspended in a binder of cooked starch and styrene-butadiene latex.

The composition of a fluorescent substance OB1 may be selected such that the fluorescence yield of the web WEB1 is substantially reduced when the fluorescent substance is heated to a temperature which is higher than or equal to a first threshold temperature. The composition of the WEB1 may be selected such that the color of the WEB1 may be altered when the WEB1 is heated to a temperature which is higher than or equal to a second threshold temperature. The composition of the web WEB1 and/or the composition of the fluorescent substance contained in the web WEB1 may be selected such that the first threshold temperature is lower than the second threshold temperature. The composition of a fluorescent substance may be selected such that the fluorescence from the web WEB1 is substantially reduced when the fluorescent substance contained in the web is exposed to laser radiation. The composition of a fluorescent substance may be selected such that the fluorescence yield of the WEB1 is substantially reduced when the fluorescent substance is exposed to ultraviolet laser radiation. The composition of a fluorescent substance may be selected such that the fluorescence yield of the web WEB1 is substantially reduced when the fluorescent substance is exposed to ultraviolet laser radiation, wherein the composition of the web WEB1 may be selected such that exposure to said ultraviolet laser radiation does not cause a detectable change of color of the web WEB1. The composition of a fluorescent substance contained in the web WEB1 may be selected such that the fluorescent substance is at least partially decomposed and/or at least partially converted into a non-fluorescing substance when the fluorescent substance is exposed to ultraviolet laser radiation, wherein the composition of the web WEB1 may be selected such that exposure to said ultraviolet laser radiation does not cause a detectable change of color of the web WEB1.

Referring to Fig. 11, an apparatus 1000 for processing a paper web or a cardboard web may comprise a laser marking unit 500. The laser marking unit 500 may be arranged to provide one or more marking laser beams LB2, which may form one or more laser spots SP2 on the web WEB1. The web WEB1 may be stationary or it may move at a velocity v_1 during producing the markings MRK1, MRK2. In particular, the markings MRK1, MRK2 may be produced when the web WEB1 is moving at a typical web velocity of a paper making machine. The velocity v_1 may be e.g. in the range of 5 to 50 m/s.

The apparatus 1000 may optionally comprise an additive feeding unit 600 arranged to add a fluorescent substance OB1 to the web WEB1. The web WEB1 may be coated with an additive, which contains a fluorescent substance OB1 and/or a fluorescent substance OB1 may be mixed with the cellulose fibers before the web WEB1 is formed.

The apparatus 1000 may optionally comprise e.g. rolls 1010, 1020 e.g. for moving the web and/or for compressing the web WEB1. The apparatus 1000 may be a paper machine. The apparatus 1000 may optionally comprise a coating unit e.g. to apply a sizing agent. The apparatus may optionally comprise a cutting unit arranged to cut the web WEB1 into a plurality of pieces.

Referring to Fig. 12a, a laser marking unit 500 may be arranged to provide one or more marking laser beams LB2 for locally altering the structure and/or chemical composition of the web WEB1. The laser marking unit 500 may comprise e.g. one or more beam deflecting optics 100, 200 arranged to direct a laser beam LB2 to a laser spot SP2. The laser spot SP2 may be moved with respect to the web WEB0 so as to form two-dimensional markings MRK1, MRK2. The intensity of laser light impinging on the web WEB1 may be controlled according to the position of the spot SP2 in order to produce the altered portions DOT1, DOT2 on the desired locations.

The web WEB1 may be moved in the longitudinal direction SX at a velocity v_1. The laser marking unit 500 may provide a scanning laser beam. A first beam deflector 100 may be arranged to move the laser spot SP2 in a transverse direction SY in order to provide a two-dimensional marking MRK1 and/or MRK2, which has a desired size and shape. In particular, the laser spot SP2 may be moved such that it crosses a longitudinal line YREF several times during writing a marking MRK1 and/or MRK2.

An optional second beam deflector 200 may be arranged to periodically move the laser spot SP2 in the longitudinal direction SX. The use of the second beam deflector 200 may allow producing the marking MRK1 and/or MRK2 also when the web WEB1 is moved at a high velocity. The velocity v_1 of the web may be e.g. in the range of 5 to 50 m/s. The use of the second beam deflector 200 may allow producing the marking MRK1 and/or MRK2 also on a stationary (non-moving) web.

The laser marking unit 500 may comprise e.g. a first rotatable mirror 100 which can be rotated about an axis AX1 by an actuator 120 at an angular speed ω_1. The laser marking unit 500 may comprise e.g. a second rotatable mirror 200 which can be rotated about an axis AX2 by an actuator 220 at an angular speed ω_2. The rotatable mirror 100 may comprise one or more reflecting facets F1a, F1b. The rotatable mirror 200 may comprise one or more reflecting facets F2a, F2b. The mirror 100 and/or 200 may be a rotating polygon mirror. A laser 400 may provide a primary beam LB0. The first rotatable mirror 100 may provide an intermediate beam LB1 by reflecting light of the primary beam LB0. The second rotatable mirror 200 may provide a marking beam LB2 by reflecting light of the intermediate beam LB1. The light of the marking beam LB2 may be focused to the web WEB1 by focusing optics 350, e.g. by a lens.

The laser marking unit 500 may comprise a control unit CNT1 arranged to control the intensity of the laser beam LB2 based on the position of the laser spot SP2 with respect to the web WEB1. The intensity of the laser beam LB2 may be controlled based on the position of the laser spot SP2 with respect to a reference point REF0 moving with the web WEB1.

The control unit CNT1 may be arranged to provide control signals S_{100}, S_{200}, S_{400} to the laser module 400 and to the actuators 120, 220. The signals S_{100}, S_{200}, S_{400} may be delivered e.g. via cables CA1, CA2, CA3.

The laser marking apparatus 500 may be arranged to produce markings MRK1, MRK2, which comprise a dot-matrix pattern. In other words, the apparatus 500 may be arranged to produce a covert marking MRK1 and/or an overt marking MRK2, which comprise a plurality of dots DOT1, DOT2 arranged in a two-dimensional array.

Referring to Fig. 12b, a laser marking apparatus 500 may comprise a plurality of individually controllable lasers. The laser marking apparatus 500 may be arranged to produce markings MRK1, MRK2, which comprise a dot-matrix pattern. The number N of individually controllable lasers 400a, 400b, 400c, 400d, 400e may be e.g. in the range of 4 to 10. A higher number of lasers may provide a marking, which is visually more pleasant. A lower number of lasers may be less expensive.

Each laser 400a, 400b, 400c, 400d, 400e may provide a marking laser beam LB2a, LB2b, LB2c, LB2d, LB2e. The intensity of each laser beam LB2a, LB2b, LB2c, LB2d, LB2e may be individually controllable so as to produce a plurality of different dot-matrix patterns. The intensity of each laser beam LB2a, LB2b, LB2c, LB2d, LB2e may be controlled individually based on time and/or based on the position of a moving reference point fixed to the web WEB1. A covert marking MRK1 and/or an overt marking MRK2 produced by the laser marking apparatus 500 may consist of e.g. 5 x 5 dots or 7 x 5 dots. A covert marking MRK1 and/or an overt marking MRK2 may be e.g. selected from the group consisting of the latin alphabets from A to Z and the arabic numerals from 0 to 9.

In an embodiment, the laser marking apparatus 500 may be arranged to produce markings MRK1, MRK2 on a moving web WEB1, which moves at a velocity v_1. In an embodiment, the laser marking apparatus 500 does not need to comprise any moving parts.

Each laser beam LB2a, LB2b, LB2c, LB2d, LB2e may be focused to the web WEB1 by common focusing optics 350. Alternatively, each laser may have its own focusing optics, i.e. a first focusing optics may be used for focusing a first beam LB2a, and a second focusing optics may be used for focusing a second beam LB2b.

The apparatus 500 may simultaneously provide a plurality of laser spots SP2a, SP2b, SP2c, SP2d, SP2e such that the intensity of each spot SP2a, SP2b, SP2c, SP2d, SP2e is individually controllable.

Referring to Fig. 12c, the laser marking apparatus 500 of Fig. 12b or Fig. 12d may also comprise a beam-splitting unit, which is arranged provide a plurality of laser beams LB2a, LB2b, LB2c, LB2d, LB2e by distributing light of a primary laser beam LBC. The intensity of each beam LB2a, LB2b, LB2c, LB2d, LB2e may be rapidly modulated e.g. by using a high-speed modulator 420a, 420b, 420c, 420d, 420e. The primary laser beam LBC may be provided by a single laser 400. The laser beam LBC may be a substantially continuous-wave beam. Alternatively, the laser beam LBC may be pulsed in synchronization with producing the portions DOT1, DOT2. Alternatively, the laser beam LBC may be pulsed at a frequency, which is substantially higher than the maximum modulation frequency of the modulators 420a, 420b, 420c, 420d, 420e.

Also in this case, the intensity of each beam LB2a, LB2b, LB2c, LB2d, LB2e may be individually controllable so as to produce the desired dot-matrix patterns. The control unit CNT1 may be arranged to control the intensity of the beams LB2a, LB2b, LB2c, LB2d, LB2e.

The beam-splitting unit may comprise a plurality of beam splitters 415a, 415b, 415c, 415d. The power division ratios of the splitters 415a, 415b, 415c, 415d may be selected so that each beam LB2a, LB2b, LB2c, LB2d, LB2e may have equal maximum intensity. The power division ratio of the first splitter 415a may be e.g. 20%/80%. The power division ratio of the second splitter 415b may be e.g. 25%/75%. The power division ratio of the third splitter 415b may be e.g. 33%/67%. The power division ratio of the fourth splitter 415b may be e.g. 50%/50%. The component 415e may be a reflector, which reflects 100% of the power into the beam LB2e.

An intensity modulator 420a, 420b, 420c, 420d, 420e may be e.g. an acousto-optic modulator or a MEMS modulator (i.e. a modulator based on a Micro Electro Mechanical System). Each laser beam LB2a, LB2b, LB2c, LB2d, LB2e may be focused to the web WEB1 by common focusing optics 350. Alternatively, each beam may have its own focusing optics, i.e. a first focusing optics may be used for focusing a first beam LB2a, and a second focusing optics may be used for focusing a second beam LB2b.

The power of the laser 400 may be substantially increased and/or the price of the laser 400 may be substantially decreased if there is no need to rapidly modulate the power of the primary beam LBC provided by the laser 400.

Referring to Fig. 12d, the maximum modulation frequency f_{MOD} of the marking beams LB2a, LB2b, LB2c, LB2d, LB2e may be substantially reduced when the beams LB2a, LB2b, LB2c, LB2d, LB2e are arranged to move in the same direction as the web WEB1. Each marking beam LB2a, LB2b, LB2c, LB2d, LB2e may provide a laser spot SP2 on the web WEB1. The longitudinal velocity of a spot SP2 may be slightly different from the velocity v_1 of the web WEB1 so as to allow writing of two-dimensional markings MRK1, MRK2.

The laser spots may be arranged to move e.g. by using one or move rotating beam deflecting facets F2a. A facet F2a may provide the marking beams LB2a, LB2b, LB2c, LB2d, LB2e by deflecting light of intermediate beams LB1a, LB1b, LB1c, LB1d, LB1e. In particular, the beam deflecting facet F2a may be reflective surface of a rotating mirror 200. The facet F2a may be rotated by an actuator 220, which may be e.g. an electric motor. All beams LB2a, LB2b, LB2c, LB2d, LB2e may be moved simultaneously by the same facet F2a or by using several facets. The beams LB2a, LB2b, LB2c, LB2d, LB2e may be focused by a common focusing optics 350 to form the laser spots. The apparatus 500 may simultaneously provide a plurality of laser spots SP2a, SP2b, SP2c, SP2d, SP2e such that the intensity of each spot SP2a, SP2b, SP2c, SP2d, SP2e is individually controllable. The intensity of each beam LB2a, LB2b, LB2c, LB2d, LB2e may be individually controlled. Each laser 400a, 400b, 400c, 400d, 400e may be individually controllable. Control signals to for controlling the intensity of the beams may be provided by a control unit CNT1. A signal for controlling the rotation of the facet F2a may be provided by a control unit CNT1. The control unit CNT1 may receive a position signal from the actuator 220.

The set-up of Fig. 12c may be used also in the laser marking apparatus 500 of Fig. 12d, i.e. a common laser 410 and a plurality of intensity modulators 420a, 420b, 420c, 420d, 420e may be arranged to provide the individually controllable beams LB1a, LB1b, LB1c, LB1d, LB1e instead of using several individually controllable lasers.

The chemical structure of an optical brightener contained in a product may be locally changed by means of a laser that emits ultraviolet radiation, i.e. by a so-called UV laser. As a result, a product may have a first area and a second area wherein the first area treated with the UV laser may look different from the second area, which is not treated with the UV laser, when viewed under UV light.

A variety of products may be marked by using the UV laser beam. A marking can be provided e.g. in a product that comprises one or more of the following materials at the location of the marking:

- paper,
- cardboard,
- paperboard,
- plastic, and
- textile (fabric).

The material, on which the marking is made, may also be a laminated structure formed of *e.g.* two or more materials. The laminated structure may be formed of two or more of the above-mentioned materials. The laminated structure may be formed of e.g. paper coated with plastic

The product to be marked may also be a garment or another product that comprises textile. Thus, the manufacturer of the garment and/or the fabric may provide the textile with an authentication marking already at the factory, wherein customs authorities can relatively easily see whether the product is authentic or counterfeited.

In an embodiment, a product comprising an optical brightener may be coated before making the marking with a coating substance, which does not comprise an optical brightener. Such a coating substance may be, for example, a plastic film. In this way it is very difficult or impossible to remove and/or to change the marking, for example mechanically or by heating, for example through said plastic.

In an example, the product to be marked is paper which can be coated with, for example, plastic. Thus, the documents accompanying a product can be authenticated, thanks to the marking.

The optical brightener may be included in various products e.g. by admixing it to a raw material of a product to be made, and/or by applying it onto the surface of the product to be made. One aim of including the optical brightener may be to obtain an effect of the optical brightener, said effect in the product being as uniform as possible. For that reason, the optical brightener may be provided substantially evenly everywhere in the product.

When the marking is formed on a product, which already contains an optical brightener, it is not necessary to add any further material to the product or remove material from the product. After forming the marking, the product may still comprise a layer of the optical brightener at the location of formed marking; just the chemical structure of the optical brightener may have been changed in such a way that the area treated with the laser looks different from an untreated area under UV light. This is because a change in the chemical structure of the optical brightener may cause that a point marked with a UV laser no longer reflects UV radiation. For that reason, a point treated with the UV laser may look darker under UV light than a point comprising the optical brightener having the normal chemical structure, the point treated with the UV laser and the point comprising the optical brightener being in the product.

By using the UV laser, a product may be provided with e.g. safety markings and/or trademarks, by means of which the product can be authenticated at a later stage.

The use of the UV laser may make it possible to provide the product with a well-defined marking. For example, in the case of a product based on natural fibres, such as paper, cardboard or paperboard, the use of the UV laser may be particularly advantageous, because due to the short duration of UV laser radiation and due to the properties of UV laser radiation, cellulose fibres and inorganic pigments in said materials do not substantially absorb the UV laser radiation. Therefore, the properties and the structure of the product may remain substantially unchanged, except for the chemical structure of the optical brightener.

Furthermore, manufacturing costs of the product may be relatively low, in particular when the product already contains an optical brightener so that the optical brightener does not need to be separately added in order to provide the marking.

The marking method does not need to be tied to any method or place for manufacturing a product. The marking to be made by the method can be included in the product in connection with the manufacture of the product and/or after the manufacture of the product. For example, in the case of paper, cardboard or paperboard, the marking can be made in connection with the manufacture of said product, or it can be made at a later stage after the product has been manufactured.

When forming the marking, it is not necessary to produce structural deviations, such as holes, openings or other thinner or thicker spots, but the structure of the product may remain unchanged. When the total thickness of a paper remains constant, the paper may be processed without problems by using the same processing apparatuses of a paper machine, which apparatuses are used for processing corresponding paper grades without the marking. In a corresponding manner, risks are typically not caused by special chemicals, as forming of the marking does not require the use of the special chemicals, which are typically used e.g. in copy protected safety papers.

The following reference numerals are used:

1	a product, which contains an optical brightener before forming the marking,
2	a UV laser device,
2a	a UV laser beam,
3	a product containing an optical brightener, and having areas marked with a UV laser,
3a	a product containing an optical brightener and having areas marked with a UV laser, photographs taken under natural light,
3b	a product containing an optical brightener and having areas marked with a UV laser, photographs taken under UV light,
4	a product or raw material, which does not contain an optical brightener,
5	an optical brightener;
20a,20b,20c	a lense,
21	a mirror with y-axis,
22	a motor for the mirror with y-axis,
23	a mirror with x-axis, and
24	a motor for the mirror with x-axis.

The method may comprise using a UV laser beam 2a to cause a chemical effect on the structure of the optical brightener 5 so that the *trans* form of the optical brightener is transformed to the *cis* form of the optical brightener. The trans form of the optical brightener may react under the influence of the UV laser beam so that the *trans* form of the optical brightener is transformed to the cis form of the optical brightener. The *trans* form of the optical brightener may absorb light at a short wavelength by re-emitting light again at a longer visible wavelength, e.g. in the blue range. The *cis* form of the optical brightener, unlike the *trans* form, does not absorb light at a short wavelength by re-emitting light at a longer visible wavelength, e.g. in the blue range.

Optical brighteners 5 may be called e.g. as
- optical brightening agents, OBA,
- optical whitening agents, OWA,
- optical bleaching agents, OBA,
- fluorescent whitening agents, FWA,

The optical brighteners 5 are pigment-like compounds which may absorb light in the ultraviolet range of the electromagnetic spectrum, which is not visible to the human eye. The optical brighteners 5 may re-emit light in a range of longer wavelengths, often in the blue range. In other words, optical brighteners make a material look less yellow to the human eye, the change being interpreted as increased whiteness by the human eye. Further, the optical brightener typically makes the product “shine” under UV light when the product containing the optical brightener is exposed to UV radiation. Optical brighteners 5 are used, among other things, in paper products, to obtain better optical properties for the produced paper, for example to obtain a bleaching effect on the produced paper, for which reason nearly all manufactured papers contain optical brighteners. In addition to paper products, optical brighteners may also be used in textiles and detergents to provide a “brilliant white” impression.

Some types of optical brightener are, for example, di-, tetra- and hexasulphonated stilbene compounds. The number of sulphonated groups may have an effect on the chemical properties of the optical brightener. Some other commercially available optical brighteners may be based on the chemical properties of coumarin and pyrazoline. Said types of optical brightener are only a few examples, and the marking with the UV laser may be suitable for products containing other types of optical brighteners.

In an embodiment, the product to be marked may comprise one or more of the following types of chemicals as the optical brightener: stilbene, coumarin, and pyrazoline. Of these chemicals, anionic stilbene compounds may be most advantageous.

UV radiation, *i.e.* ultraviolet radiation, is electromagnetic radiation whose wavelength is shorter than the wavelength of visible light. Ultraviolet radiation can be classified into UVA radiation, UVB radiation and UVC radiation. The wavelength of UVA radiation may be defined to be in the range between 310 and 380 nm (or 400 nm), the wavelength of UVB radiation may be defined to be in the range between 280 and 315 nm, and the wavelength of UVC radiation may be defined to be in the range between 100 and 280 nm. Of these radiations, UVA radiation has the lowest energy and UVC radiation has the highest energy. As the purpose of the treatment is not to substantially generate heat, low energy UV radiation may be used in an advantageous embodiment. Heat may have a harmful effect on the product, for example making a paper darker and/or yellowish. In an example, the product to be treated is a paper or a cardboard, wherein thanks to marking with the UV laser, it may be possible to avoid undesired changes caused by heat, such as darkening or becoming yellowish.

A short treatment time may be preferably used, e.g. a short effective time of the laser beam on the product to be marked, to minimize any possible negative effect of the treatment on the quality of the product.

In an advantageous example, a UV laser having a wavelength in the range of 100 nm to 400 nm, more advantageously in the range of 250 nm to 380 nm, may be used. In an example, a UV laser having a wavelength in the range of 350 nm to 360 nm, for example about 355 nm, may be used. In an example, the product to be marked may contain a stilbene-based optical brightener, and the marking may be carried out by using a UV laser having a wavelength in the range of 350 nm to 360 nm.

The method may be suitable for marking various products. The product to be marked may be made of, for example, paper, cardboard, paperboard, plastic, plastic fibre laminate, or textile. Advantageously, the product to be marked may be paper or cardboard, because most papers of prior art already contain an optical brightener. In this case, the optical brightener does not need to be added separately, but normal paper of prior art may be treated with the UV laser. Thus, because cellulose fibres do not significantly react to the short pulse of UV light produced by a UV laser, the optical brightener may be changed without substantially changing the changing the paper itself. In other words, the treatment by UV light may be carried out in such a way that it does not, for example, make the paper visibly darker or yellowish. When the paper contains an optical brightener, the method may be used both for papers in which the optical brightener has been applied onto the surface of the paper, and for papers in which the optical brightener has been added to the paper pulp before forming the web.

When a product to be marked does not already contain an optical brightener, the optical brightener may be added to the product before the product is marked. Similarly, it may be possible that the content of the optical brightener is increased before the marking a product which already contains an optical brightener.

Figures 13a to 13b show systems for marking a product 1. Figures 14 to 16 show some products 3 marked by treating with the UV laser. Figure 17 shows an example of a laser device 2 with a UV laser suitable for forming the marking. Figure 18 shows the structure of a suitable optical brightener 5.

Figures 13a to 13b show some embodiments for marking a product in simplified schematic views. The marking may be carried out at many different stages of the process. For example, in the case of paper, the marking may be carried out in the dry section of a paper machine, at a re-reeler, before coating, after coating, in connection with calendering, in connection with a slitter-winder, in connection with packing, *etc.* Correspondingly, in the case of *e.g.* textile, the marking may be provided in connection with the manufacture of the textile, or not until on the finished textile.

The laser device 2 may comprise lenses, e.g. 2 to 4 lenses, and one or more mirrors, e.g. 2 to 4 mirrors, for directing a laser beam to the product 1 to be marked.

In the method, the chemical structure of the optical brightener may be changed in such a way that the active *trans* form of the optical brightener is transformed to the inactive *cis* form. In other words, by using the UV laser, the chemical structure of the optical brightener may be changed so that the optical brightener reacts from the active *trans* form to the inactive *cis* form. The formed marking may be preferably invisible to the human eye under indoor lighting in such a way that it can be made visible by using UV light. Particularly in the case that an authentication marking has been made on a spot which has a small surface area, it may be very unlikely that the authentication marking is discernible to the naked eye under indoor lighting without separate UV light, and the product looks unmarked on the face of it. Figure 18 shows a possible optical brightener, by means of which the marking with the UV laser can be made, namely a stilbene-based optical brightener. In the figure, a broken line defines the location in the optical brightener 5 where the reaction from the active *trans* form to the inactive *cis* form takes place.

The mark imprint may be formed by changing the chemical structure of the optical brightener by using a laser that produces UV light. The marking made by the UV laser may be well controlled and focused, because e.g. the conduction of heat typically does not cause any blurring in the marking. In UV laser marking, the marking can be made not only very accurately but also quickly. Preferably, the marking may be made continuously, i.e. as an online solution.

In an advantageous example, the laser is a so-called Nd:YAG laser (=Tripled frequency $NdYVo_4$), whose wavelength may be 355 nm.

Figure 14 shows, under UV light, markings which have been made by a UV laser, and which are typically not visible under normal indoor lighting. Among other things, a logo UPM, a date and a bar code may be well visible in the photo. The photo has been taken after the product has been aged for 24 hours with a Xenotest® 150 S device, which corresponds to approximately 192 hours under the midday sun in Central Europe.

Figure 15a shows various bar codes made by a UV laser and photographed under UV light. Figure 15b, in turn, shows corresponding bar codes made by a UV laser and photographed in daylight.

Figure 16 shows various papers according to Fig. 15a, when photographed on the reverse side under UV light. As seen in Fig. 16, the bar codes may be very faint when photographed on the reverse side of the marking. In other words, it may be possible to mark a paper product, such as paper or cardboard, on one side only, that is, in such a way that the marking is visible under UV light on only one side of the product. Alternatively, the markings can be different on different sides of the paper product, or the markings can be made identical on both sides of the paper product.

The so-called negative marking may be very difficult to remove afterwards. The removal of the marking can be made even more difficult by protecting the marking with one or more protective layers, for example by a coating layer in such a way that said marking is left under the protective layer, i.e. "within the product". For that purpose, the product 3 marked by UV laser may be coated with a protective layer after the marking has been made. If the marked product 3 is paper, cardboard or paperboard, the product may be coated with e.g. paper coating pigments of prior art.

In addition to the above-mentioned facts, falsification of the marking may be made more difficult by the fact that the devices used for making the authentication markings are special devices, such as a UV laser that emits light at a wavelength required for marking the product. Thus, mere acquisition of the hardware may already be relatively difficult, may require special skills, and may be expensive. An advantage of the method, in turn, may be the fact that marking a product with the UV laser does not necessarily cause high additional costs to the manufacturer of the product and does not necessarily slow down the production, because the marking can be made even in connection with the normal manufacture of the product, and in many cases even without changing the normal speed used in the product line. Furthermore, providing the marking (*i.e.* a sign) does not normally require adding special and expensive materials to the product. For example, when the product to be marked is paper, cardboard or textile that already contains an optical brightener, the material costs do not significantly differ from the material costs of a corresponding conventional product. When the product remains structurally unchanged, the paper may be processed without any problems by the same product processing apparatus, which are used for processing corresponding products, which do not comprise the marking made with the UV laser.

In an example, the method may be used for making marked paper which can be, for example, safety paper. Said paper may be printable by any conventional techniques, because the paper does not have such mechanical or chemical properties which are typically caused by marking and which make printing more difficult. For example, bulges or lower spots, which are often provided in safety papers of prior art, may seriously hinder the offset printing process, because such a spot deviating from the overall thickness of the paper may adhere to rubber rollers. Similar risks may be involved if special chemicals are added, which are commonly used e.g. in safety papers to prevent copying.

When the product to be marked is paper, cardboard, or paperboard, the UV laser device 2 may be installed, for example, in a production line downstream of a drying section and upstream of coating steps in a paper machine or a cardboard machine. In this way, a laser beam may be used to make the markings in paper/cardboard during the running of the paper/cardboard machine. The device 2 may be installed in, for example, a girder extending across the paper or cardboard web in the cross direction so that the girder comprises a carriage that is movable back and forth across the paper or cardboard web. The carriage may also comprise second guides extending in the longitudinal direction of the paper or cardboard web, on which guides a device generating a UV laser beam 2a may be mounted to be movable by a predetermined distance in the running direction of the paper or cardboard web. The predetermined distance can be, for example, between 0.5 and 2 m. The UV laser can also be mounted in a carriage movable in the cross direction of the paper or cardboard web, to be swivelled with respect to an axis transverse to the running direction of the paper web, wherein the point of intersection of the laser beam and the paper or cardboard web in the running direction of the paper or cardboard web may be adjusted by turning the beam. The devices used for moving and/or swivelling the laser beam can implemented by methods known as such, driven by electricity, hydraulics, and/or pneumatics. The laser beam can be generated by using a UV laser of prior art. When making markings in a paper or cardboard web, the laser beam can be moved in the cross direction and/or the longitudinal direction with respect to the running direction of the paper or cardboard web. During the processing of the marking, the laser beam may be, for example, moved at a speed, which corresponds to the speed of the base paper or base cardboard in the direction of movement of the base paper or base cardboard.

In a corresponding manner, the UV laser device 2 can also be installed for marking other products 1 in connection with and/or after the actual product line of each product 1.

The marking made with the UV laser may constitute a text or a figure. The figure may be, for example, a trademark or a machine readable code, such as a bar code. It should be noted that the product may also contain other, additional markings which may make counterfeiting more difficult.

The various aspects of the invention may be illustrated by the following examples.

Example 1. A method for marking a product (1), the product comprising an optical brightener, the method comprising:
- providing the product (1) with a marking by using a UV laser beam to cause an effect on the structure of the optical brightener such that the *trans* form of the optical brightener is transformed to the *cis* form of the optical brightener, wherein a marked product (3) is provided, the marking formed in the product (3) being discernible as a dark spot in the product (3) under UV light, the *trans* form of the optical brightener being capable of absorbing light at a short wavelength, and the *trans* form of the optical brightener being capable of re-emitting light in a visible range of longer wavelengths,

Example 2. The method according to example 1, wherein said product (1) comprises, in the area to be marked, one or more of the materials listed below:
paper,
cardboard,
paperboard,
textile, and

plastic.

Example 3. The method according to example 1 or 2, wherein a UV laser is used, whose wavelength is in the range between 100 nm and 400 nm.

Example 4. The method according to any of the examples 1 to 3, wherein the marking forms a text and/or a figure, such as a trade mark and/or a machine readable code.

Example 5. The method according to any of the examples 1 to 4, wherein said product (1) comprising an optical brightener has been coated, prior to providing the marking, with a coating agent that does not comprise an optical brightener.

Example 6. The method according to any of the examples 1 to 5, wherein said product (3) is coated, after providing the marking, with a coating agent that comprises a polymer.

Example 7. The method according to any of the preceding examples 1 to 6, wherein the marking is made in the product (1) by means of a UV laser in connection with the manufacture of the product.

Example 8. A system for marking a product, the product comprising an optical brightener, wherein the system comprises a UV laser device (2) comprising a UV laser, the UV laser device (2) being installed in such a way that the UV laser belonging to said UV laser device can be focused on the product (1) to be marked in such a way that said UV laser can be used to have an effect on the chemical structure of the optical brightener in said product, for marking the product, wherein the marking formed is discernible as a dark spot in the product (3) under UV light.

Example 9. The system according to example 8, wherein the UV laser device (2) is installed in the production line of the product (1) to be manufactured.

Example 10. A product (3) manufactured by a method according to any of the examples 1 to 7.

An aim may be to provide a method and a system for marking a product, as well as a product made by the method. To achieve the aim, the method for marking a product may be primarily characterized in what is presented in the above-mentioned example 1. The system for marking a product may be primarily characterized in what is presented in the above-mentioned example 8. The product may be primarily characterized in what is presented in the above-mentioned example 10.

For the person skilled in the art, it will be clear that modifications and variations of the products, methods, and devices according to the present invention are perceivable. The figures are schematic. The particular embodiments described above with reference to the accompanying drawings are illustrative only and not meant to limit the scope of the invention, which is defined by the appended claims.

CLAIMS

1. A method for producing a marking (MRK1, MRK2) on a web (WEB1), the method comprising forming a first altered portion (DOT1) by directing a laser beam (LB2) to the web (WEB1) so as to locally reduce the fluorescence yield of the web (WEB1) at the location of the first altered portion (DOT1), wherein the web (WEB1) comprises cellulose fibers and a fluorescent substance (OB1), and wherein the visual contrast $((L_{REF,1}-L_{1,1})/L_{REF,1})$ between the first altered portion (DOT1) and a reference portion (REF1) is smaller than or equal to 5% when the web (WEB1) is illuminated by substantially white visible light (VIS0), which does not contain ultraviolet light (UV0).

2. The method of claim 1 wherein the intensity of the laser beam (LB2) and the chemical composition of the fluorescent substance (OB1) has been selected such that exposure to the laser beam (LB2) locally reduces the fluorescence yield of the web (WEB1) without altering the color of the web (WEB1).

3. The method of claim 2 wherein the wavelength of the laser beam (LB2) is in the range of 180 to 400 nm.

4. The method of claim 3 wherein the intensity and/or the pulse duration of the laser beam (LB2) has been selected such that an increase of temperature of the fluorescent substance (OB1) caused by the laser beam (LB2) is smaller than or equal to 10°C.

5. The method according to any of the claims 1 to 4 wherein the wavelength of the laser beam (LB2) substantially matches with a peak of spectral absorbance of the fluorescent substance (OB1).

6. The method according to any of the claims 1 to 5 wherein the intensity of the laser beam (LB2) and the chemical composition of the fluorescent substance (OB1) has been selected such that a trans-isomer of the fluorescent substance is converted into a cis-isomer of the fluorescent

substance (OB1), the fluorescence yield of the cis-isomer being smaller than the fluorescence yield of the trans-isomer.

7. The method according to any of the claims 1 to 6 wherein the fluorescent substance (OB1) has been selected from a group consisting of pyrazoline, coumarin and stilbene.

8. The method according to any of the claims 1 to 7 comprising forming a second altered portion (DOT2), which is detectable by the naked eye (E1) when the web (WEB1) is illuminated by white visible light (VIS0), which does not contain ultraviolet light (UV0).

9. The method of claim 8 wherein the color of the second altered portion (DOT2) is different from the color of the reference portion (REF1).

10. The method of claim 9 wherein the second altered portion (DOT2) appears darker than the reference portion (REF1) when viewed by the naked eye.

11. The method of claim 8 wherein the second altered portion (DOT2) is a hole or a depressed portion formed by laser ablation.

12. The method of claim 11 wherein the reference portion (REF1) has a first thickness of the web, the second altered portion (DOT2) has a second thickness of the web, and the second thickness is substantially smaller than the first thickness.

13. The method of claim 8 wherein the gloss value of the second altered portion (DOT2) is different from the gloss value of the reference portion (REF1).

14. The method according to any of the claims 8 to 13 comprising forming the first altered portion (DOT1) by a first laser beam (LB2, LB2') having a first intensity ($I_{MIN,1}$) and a first wavelength (λ_0), and forming the second altered portion (DOT2) by a second laser beam (LB2) having the first wavelength

(λ_0) and a second intensity ($I_{MIN,2}$), the second intensity ($I_{MIN,2}$) being higher than the first intensity ($I_{MIN,1}$).

15. The method of claim 14 wherein the first laser beam (LB2) and the second laser beam (LB2') are provided by the same laser (400).

16. The method according to any of the claims 1 to 15 comprising forming the first altered portion (DOT1) and the second altered portion (DOT2) substantially simultaneously by distributing light of primary laser beam into a first sub-beam (LB2') and a second sub beam (LB2), the intensity of the first sub-beam (LB2') being substantially lower than the intensity of the second sub beam (LB2), the first sub-beam (LB2') and the second sub-beam (LB2) having the same wavelength (λ_0).

17. The method according to any of the claims 1 to 16 wherein the velocity (v_1) of the web (WEB1) during the exposure to the laser beam (LB2) is in the range of 5 to 50 m/s.

18. A web (WEB1) comprising cellulose fibers and a fluorescent substance (OB1), the web (WEB1) further comprising a first altered portion (DOT1) formed by directing a laser beam (LB2) to the web (WEB1) so that the fluorescence yield of the web (WEB1) has been locally reduced at the location of the first altered portion (DOT1), wherein the visual contrast between the altered portion (DOT1) and a reference portion (REF1) of the web (WEB1) is smaller than or equal to 5% when the web (WEB1) is illuminated by substantially white visible light (VIS0), which does not contain ultraviolet light (UV0).

19. The web (WEB1) of claim 18 wherein the chemical composition of the fluorescent substance(OB1) has been selected such that exposure to a laser beam (LB2) causes conversion of a trans-isomer of the fluorescent substance (OB1) into a cis-isomer of the fluorescent substance (OB1), the fluorescence yield of the cis-isomer being smaller than the fluorescence yield of the trans-isomer.

20. The web (WEB1) of claim 18 or 19 wherein the fluorescent substance (OB1) has been selected from a group consisting of pyrazoline, coumarin and stilbene.

21. The web (WEB1) according to any of the claims 18 to 20 further comprising a second altered portion (DOT1), which is detectable by the naked eye (E1) when the web (WEB1) is illuminated by white visible light (VIS0), which does not contain ultraviolet light (UV0).

22. An apparatus (1000) for producing markings (MRK1, MRK2) on a web (WEB1), the apparatus (1000) comprising:

- a supply unit (600) arranged to add a fluorescent substance (OB1) to a paper or cardboard web (WEB1), and
- a laser marking device (500) arranged to form a first altered portion (DOT1) by directing a laser beam (LB2) to the web (WEB1) so as to locally reduce the fluorescence yield of the web (WEB1) at the location of the first altered portion (DOT1), wherein the visual contrast $((L_{REF,1}-L_{1,1})/L_{REF,1})$ between the first altered portion (DOT1) and a reference portion (REF1) is smaller than or equal to 5% when the web (WEB1) is illuminated by substantially white visible light (VIS0), which does not contain ultraviolet light (UV0).

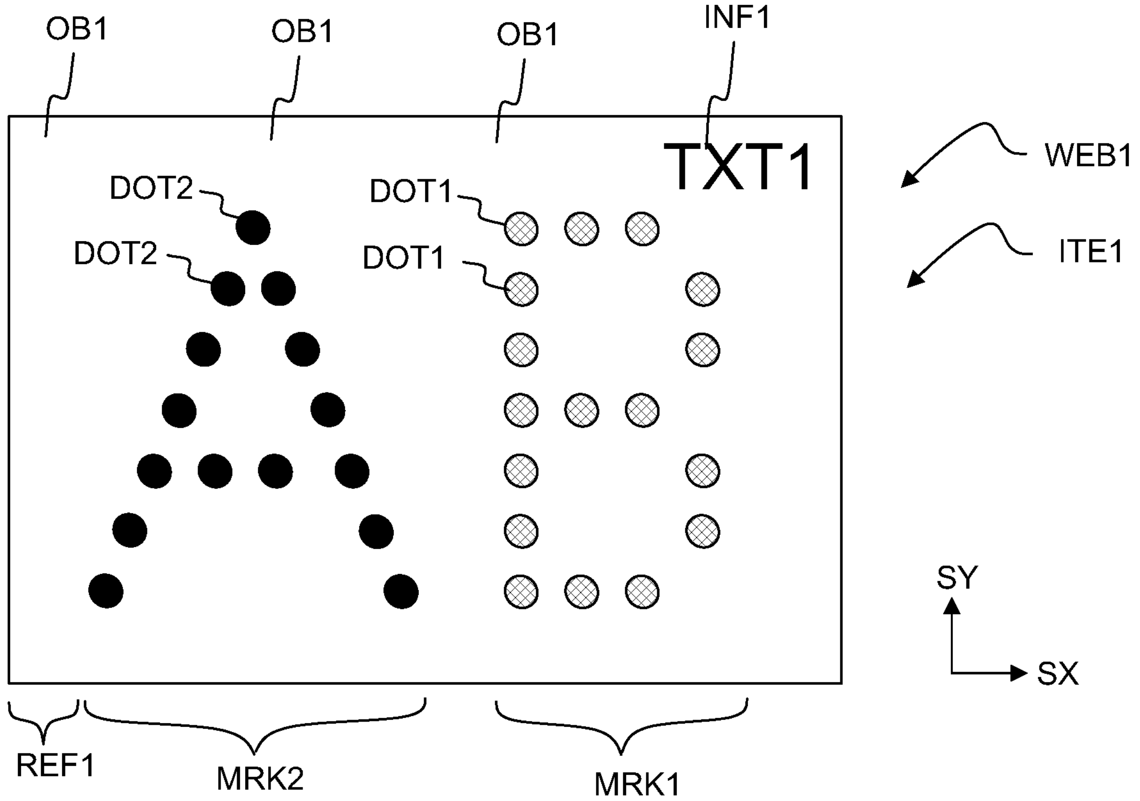

OB1
OB1
OB1
INF1
TXT1
WEB1
ITE1
DOT2
DOT2
DOT1
DOT1
SY
SX
REF1
MRK2
MRK1

Fig. 1

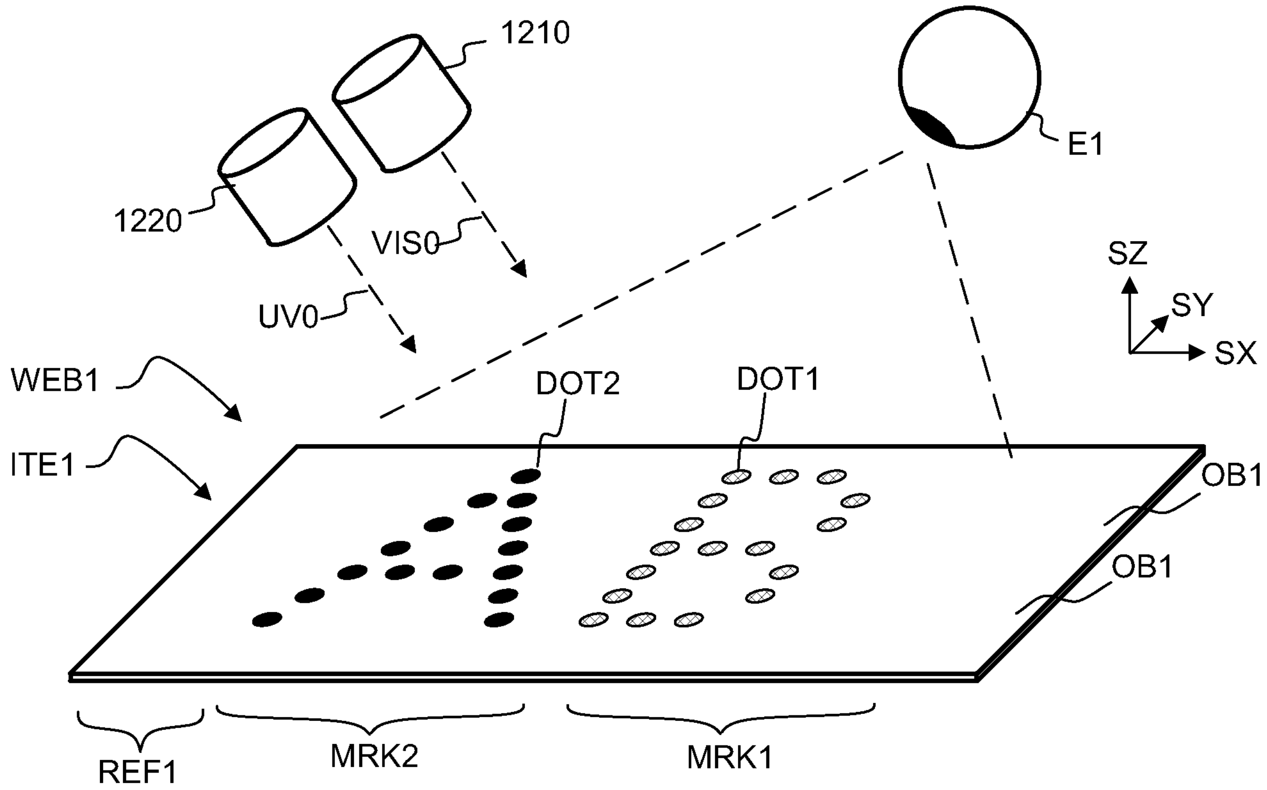

1210
E1
1220
VIS0
SZ
SY
SX
UV0
WEB1
DOT2
DOT1
ITE1
OB1
OB1
REF1
MRK2
MRK1

Fig. 2a

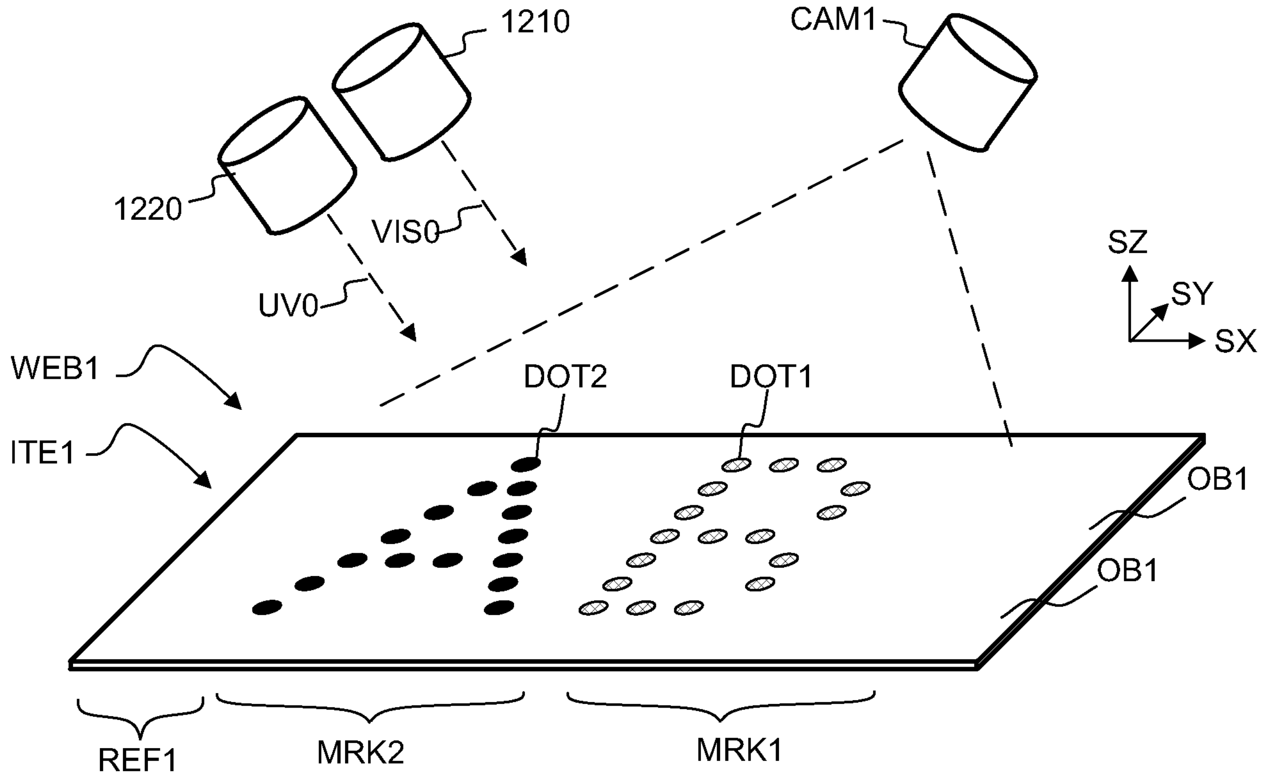

1210
CAM1
1220
VIS0
SZ
SY
SX
UV0
WEB1
DOT2
DOT1
ITE1
OB1
OB1
REF1
MRK2
MRK1

Fig. 2b

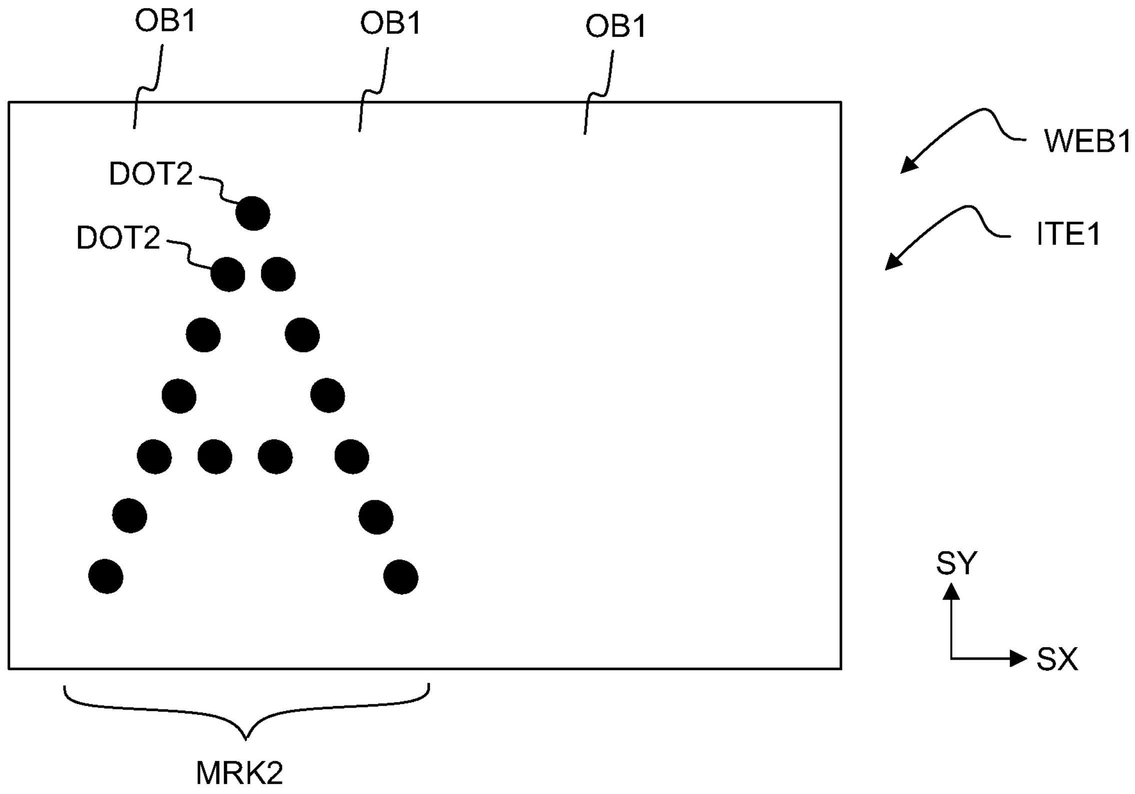

OB1
OB1
OB1
WEB1
ITE1
DOT2
DOT2
SY
SX
MRK2

Fig. 3a

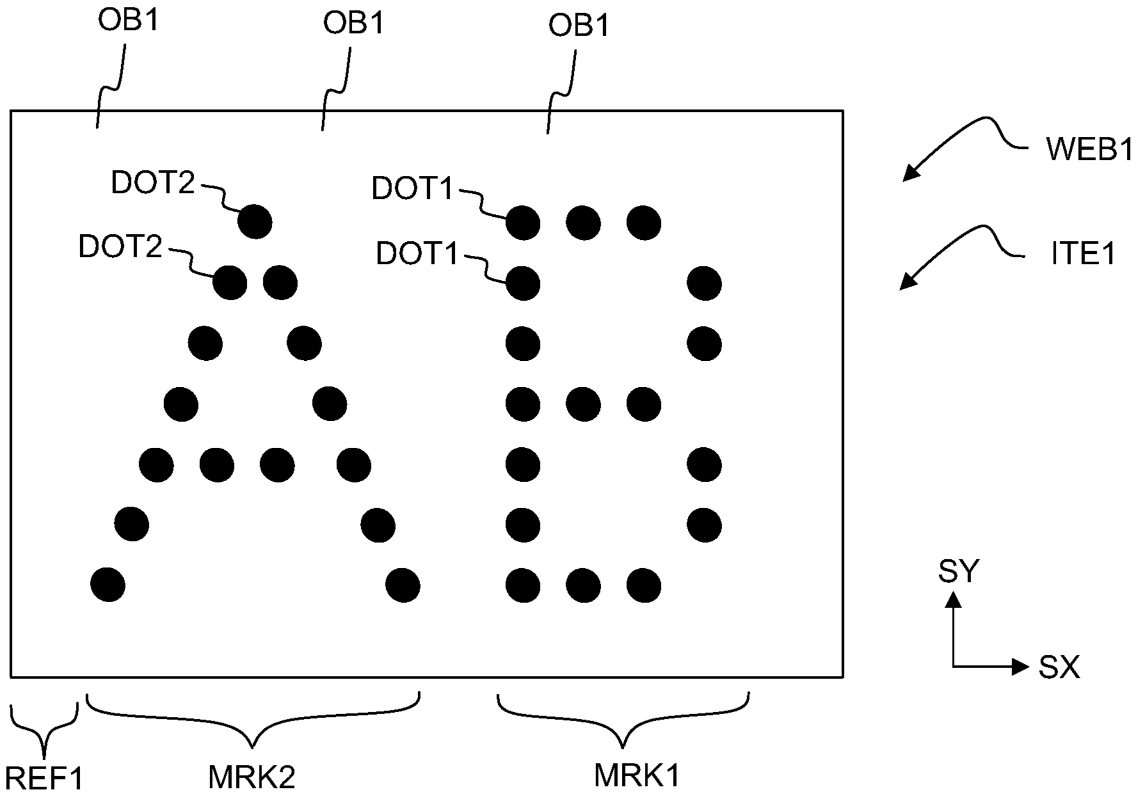

OB1
OB1
OB1
WEB1
ITE1
DOT2
DOT2
DOT1
DOT1
SY
SX
REF1
MRK2
MRK1

Fig. 3b

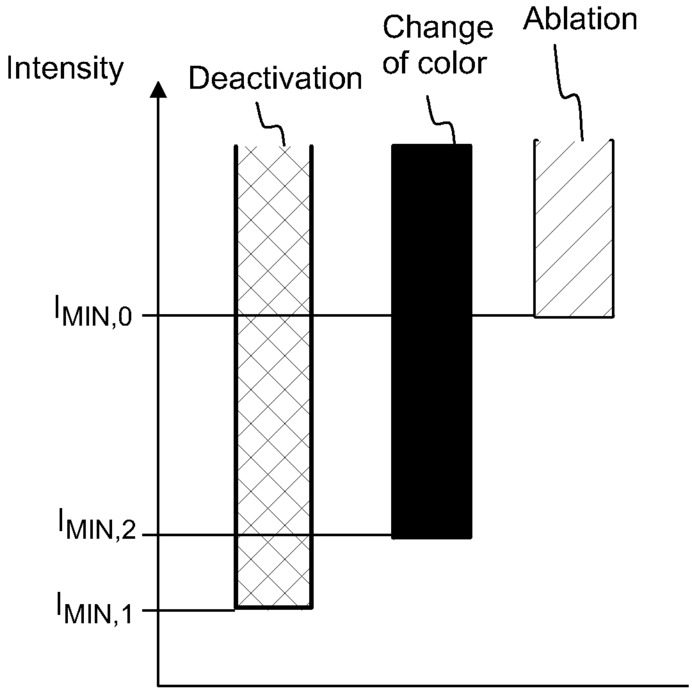


Fig. 4a

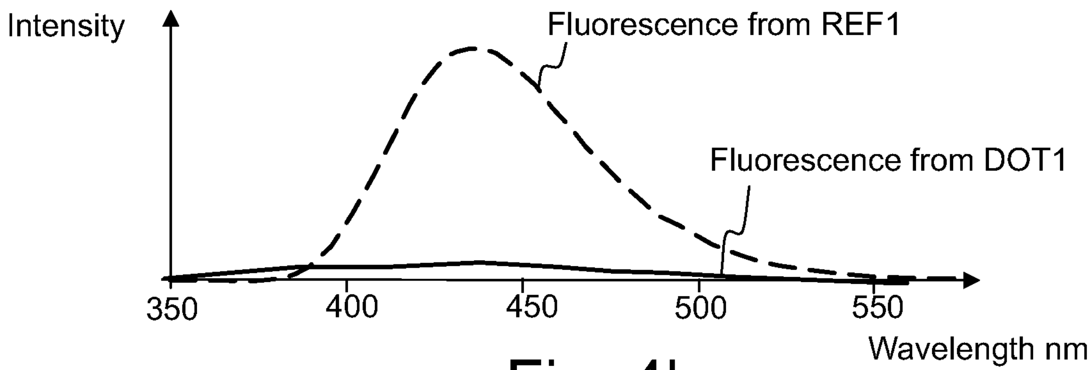


Fig. 4b

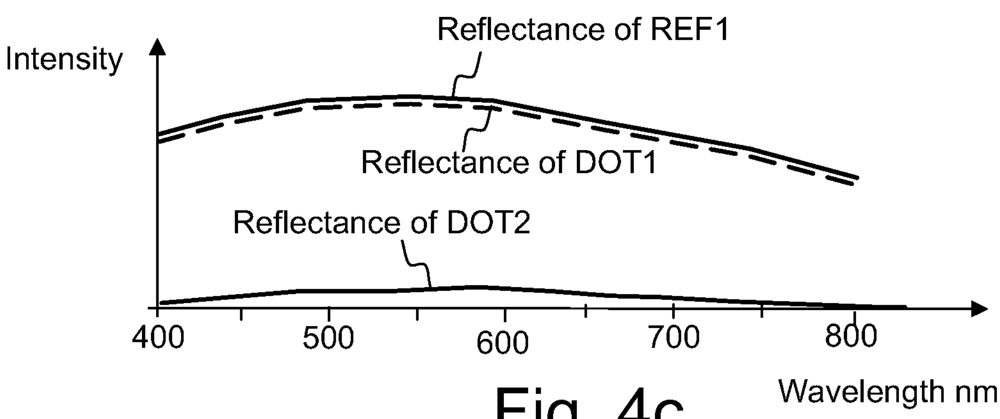
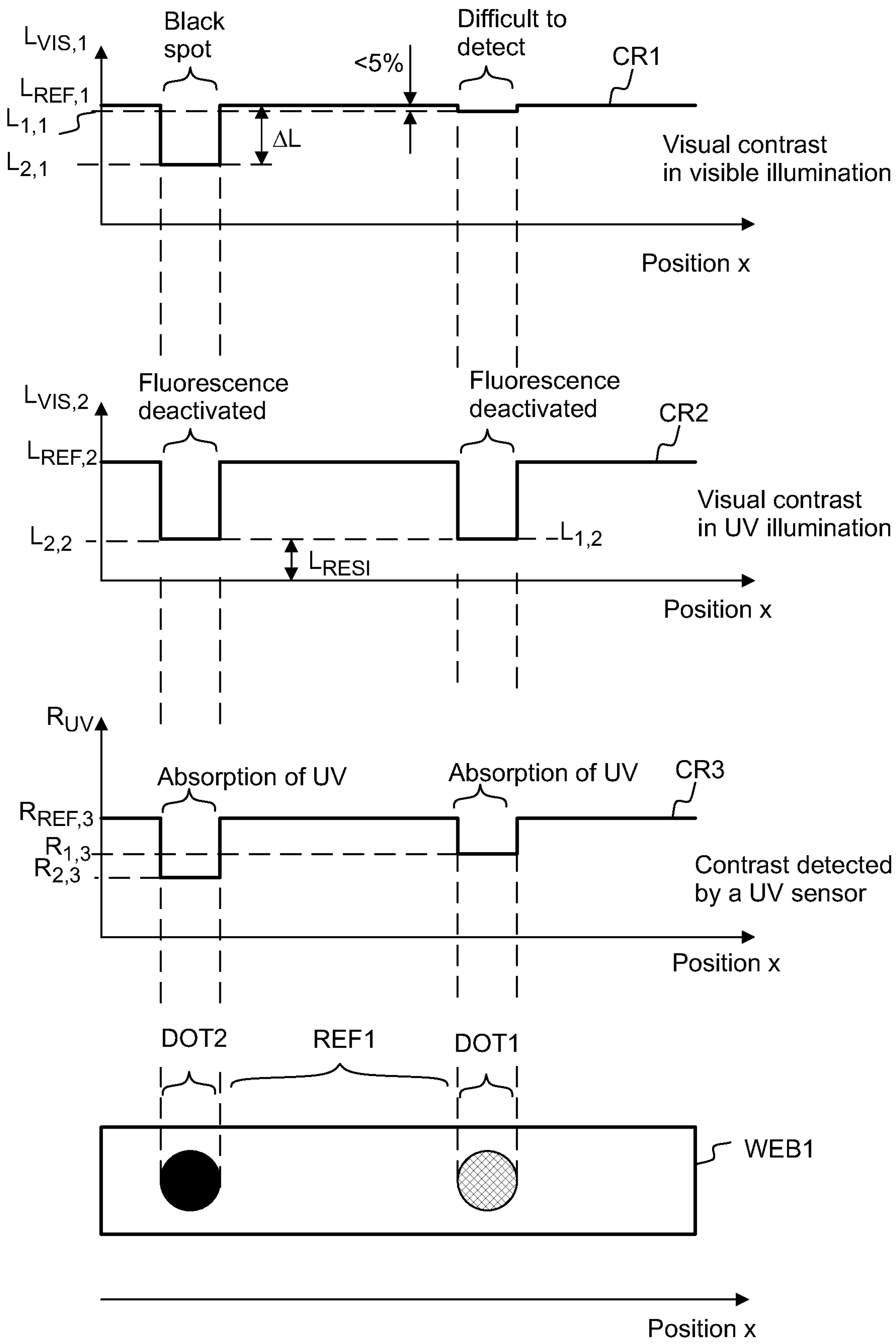


Fig. 4c



L_VIS,1
Black spot
<5%
Difficult to detect
CR1
L_REF,1
L_1,1
L_2,1
ΔL
Visual contrast in visible illumination
Position x
L_VIS,2
Fluorescence deactivated
Fluorescence deactivated
CR2
L_REF,2
Visual contrast in UV illumination
L_2,2
L_1,2
L_RESI
Position x
R_UV
Absorption of UV
Absorption of UV
CR3
R_REF,3
R_1,3
R_2,3
Contrast detected by a UV sensor
Position x
DOT2
REF1
DOT1
WEB1
Position x

Fig. 5

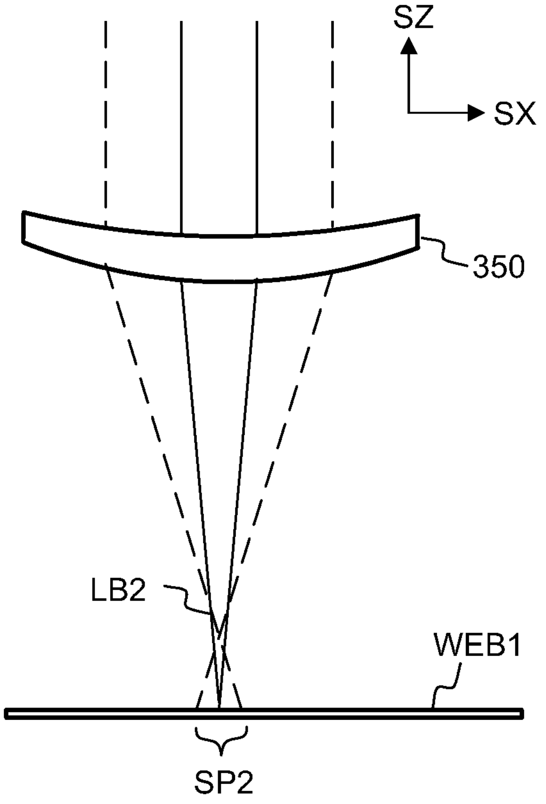


Fig. 6a

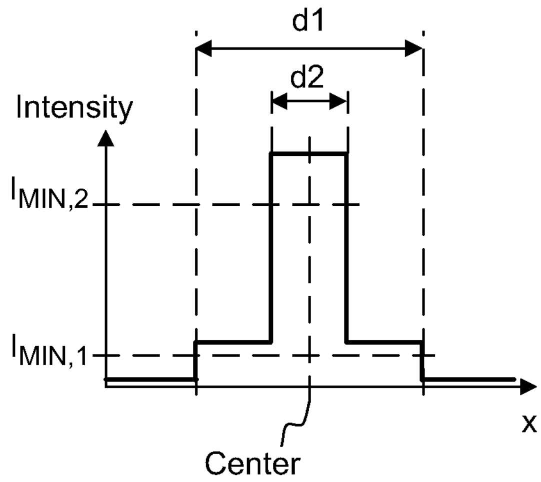


Fig. 6b

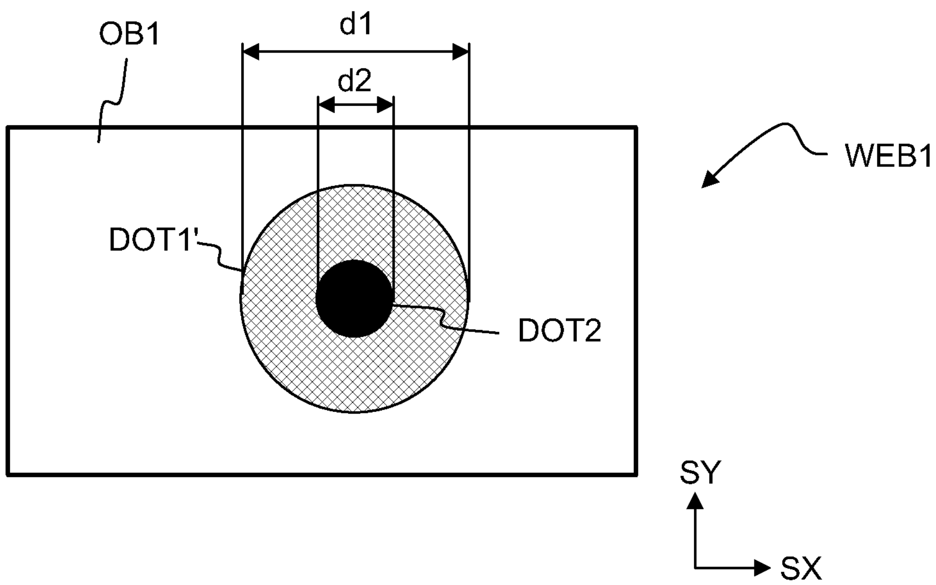


Fig. 6c

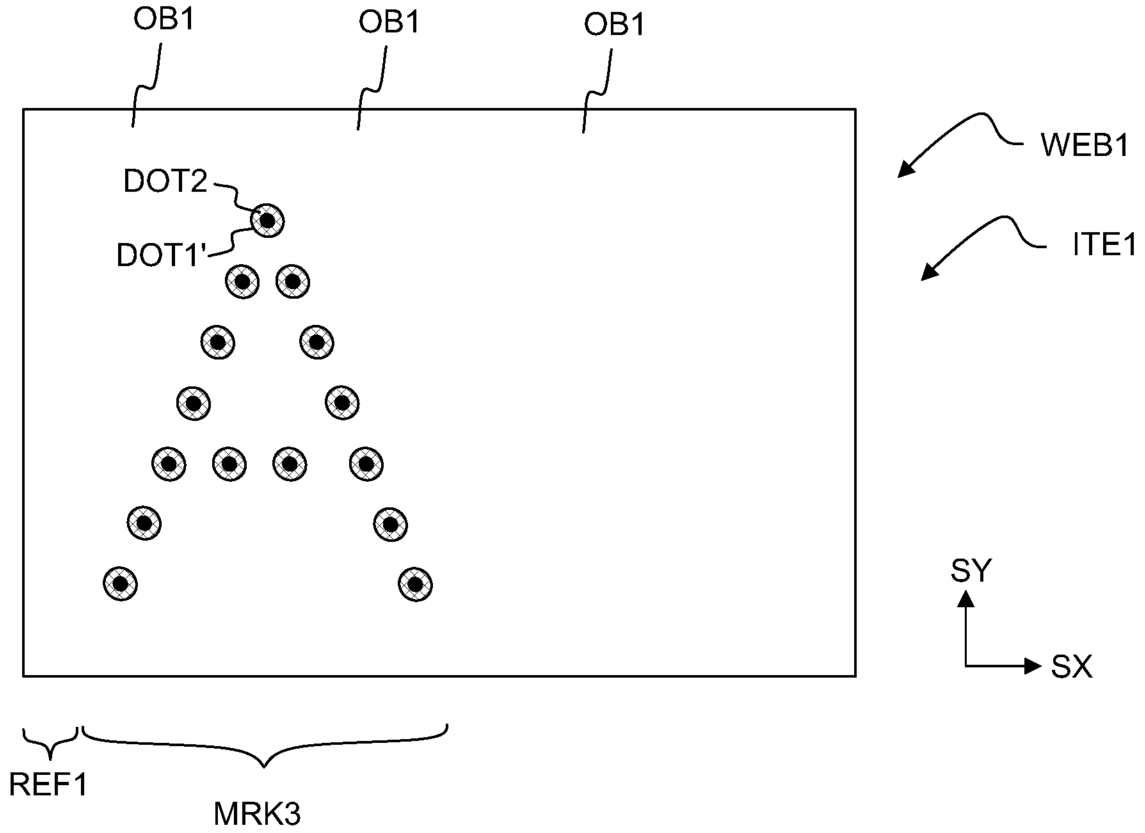


Fig. 7a

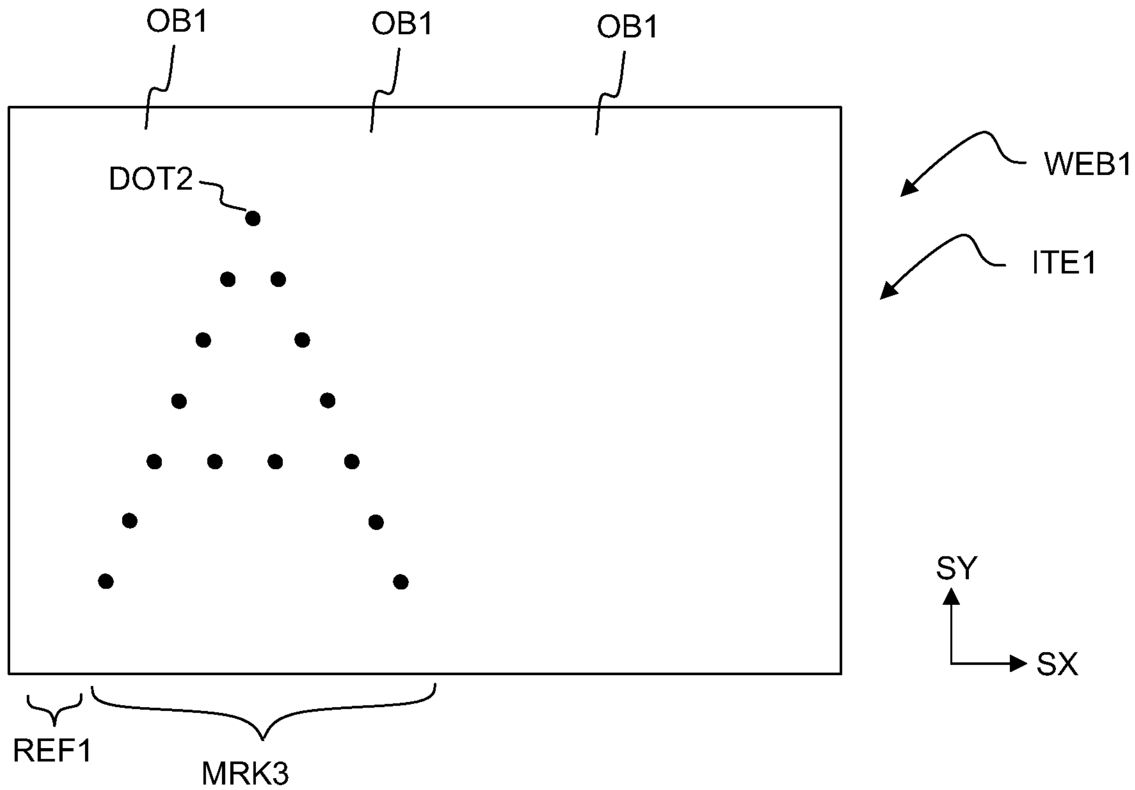

OB1
OB1
OB1
WEB1
ITE1
DOT2
SY
SX
REF1
MRK3

Fig. 7b

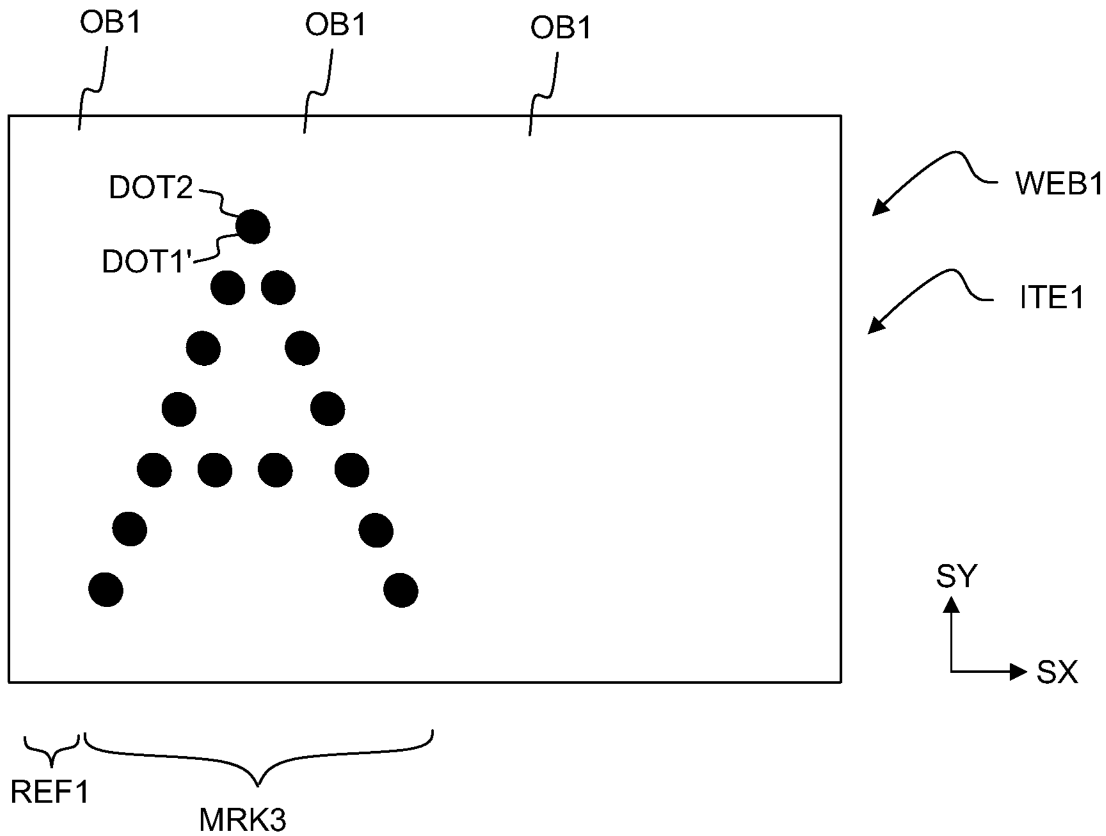

OB1
OB1
OB1
WEB1
ITE1
DOT2
DOT1'
SY
SX
REF1
MRK3

Fig. 7c

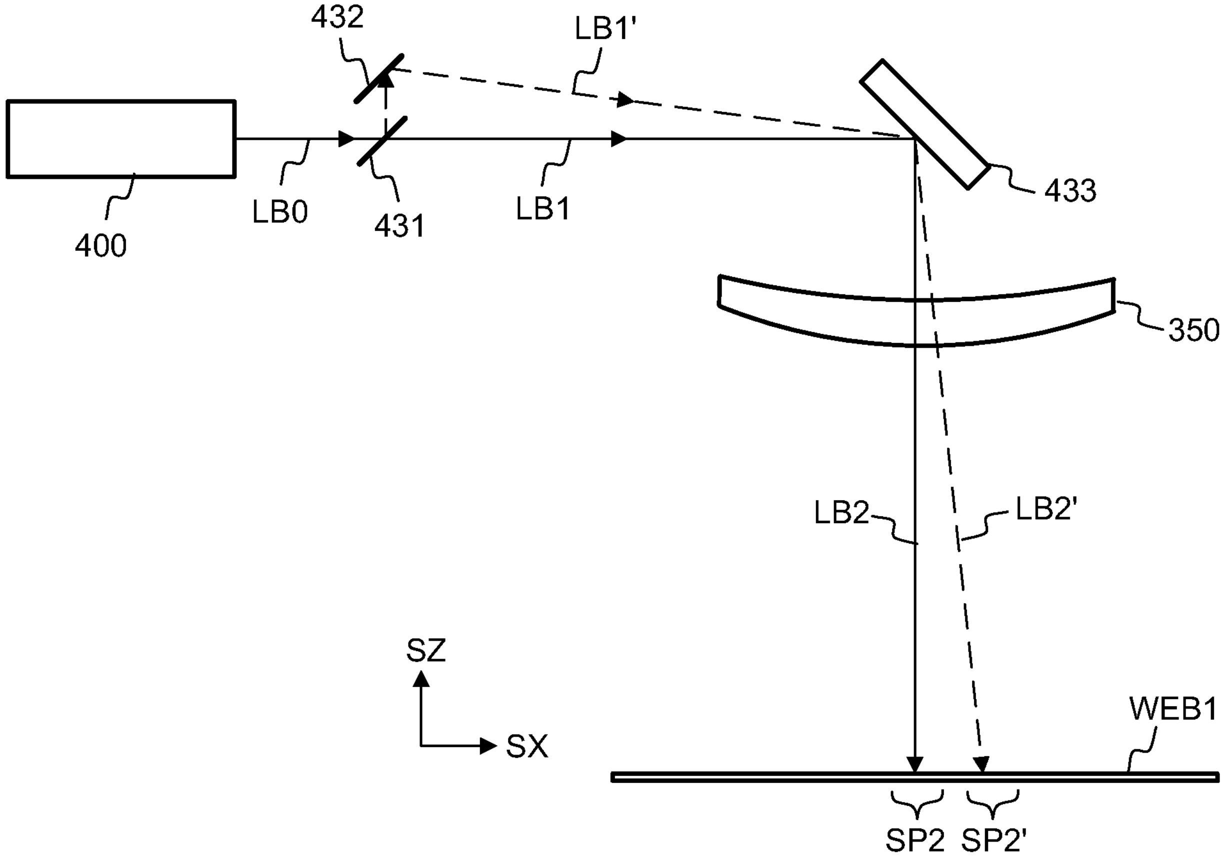

432
LB1'
433
400
LB0
431
LB1
350
LB2
LB2'
SZ
SX
WEB1
SP2
SP2'

Fig. 8a

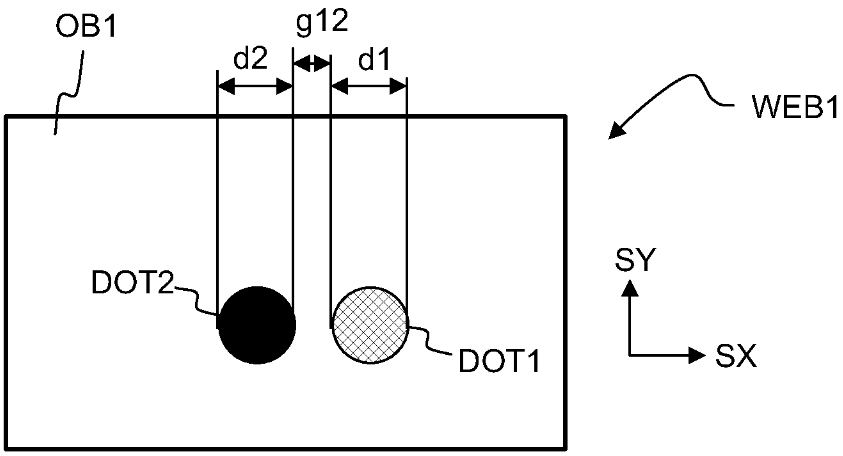

OB1
g12
d2
d1
WEB1
DOT2
DOT1
SY
SX

Fig. 8b

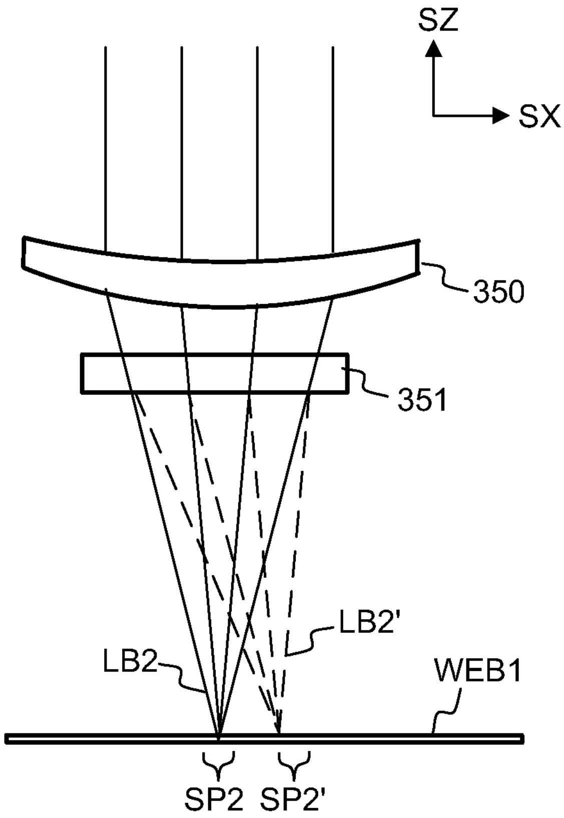


Fig. 8c

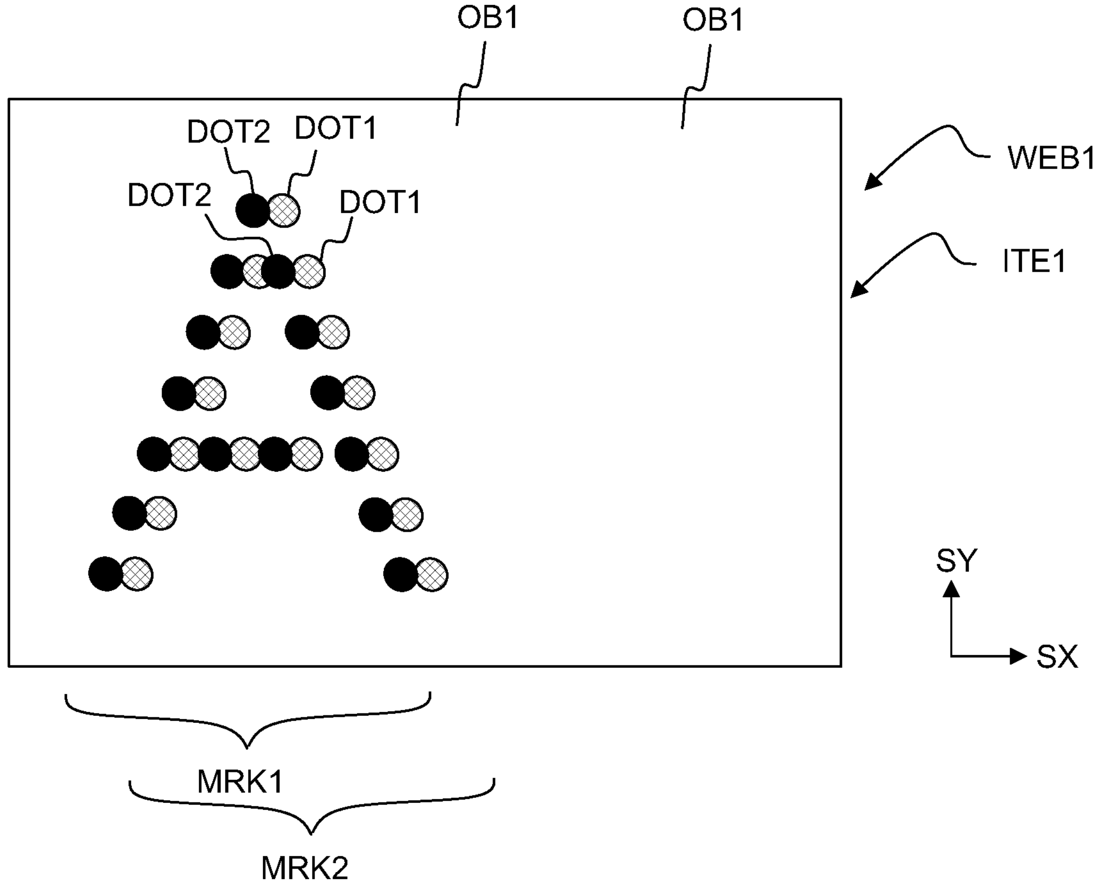


Fig. 9a

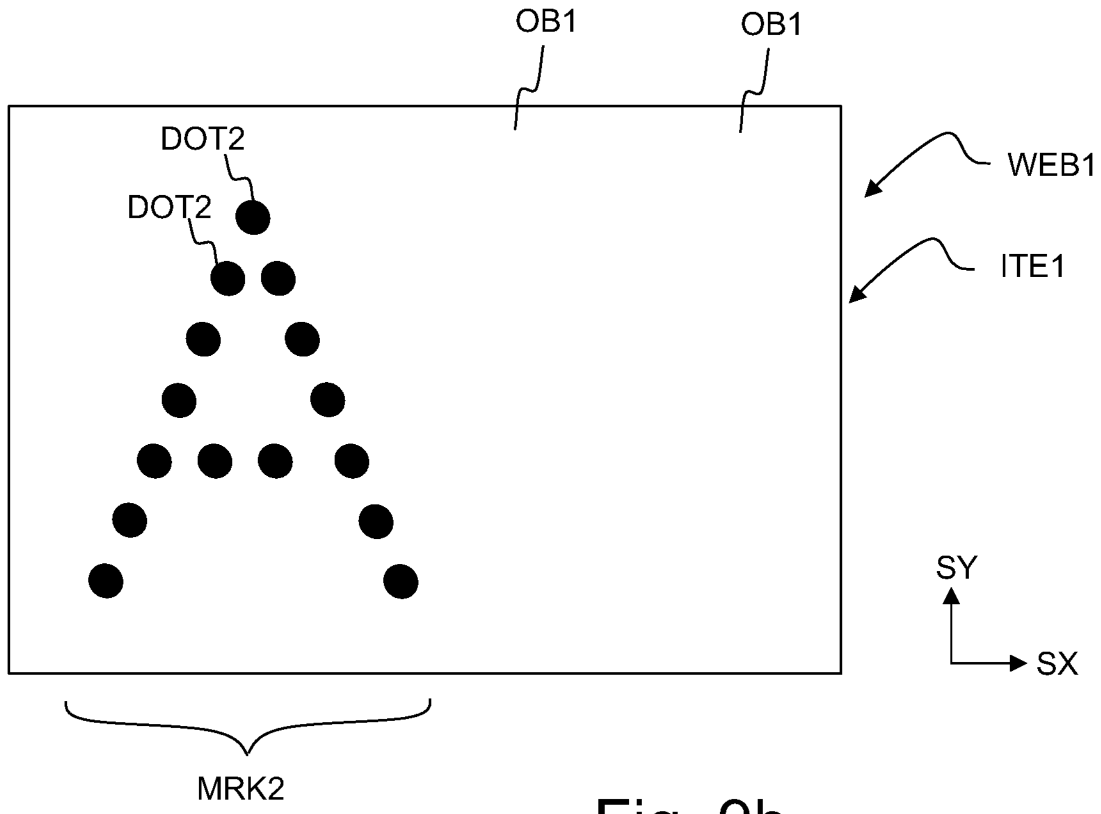

OB1
OB1
DOT2
DOT2
WEB1
ITE1
SY
SX
MRK2

Fig. 9b

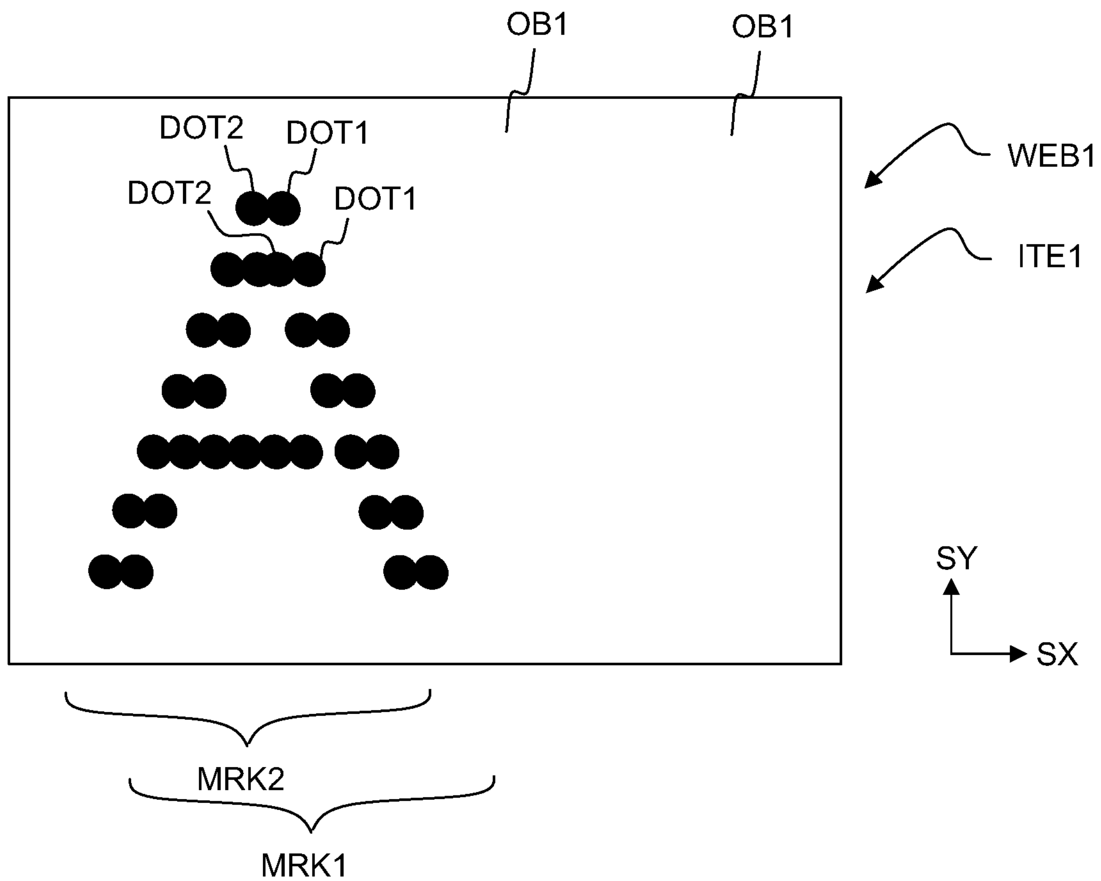

OB1
OB1
DOT2
DOT1
DOT2
DOT1
WEB1
ITE1
SY
SX
MRK2
MRK1

Fig. 9c

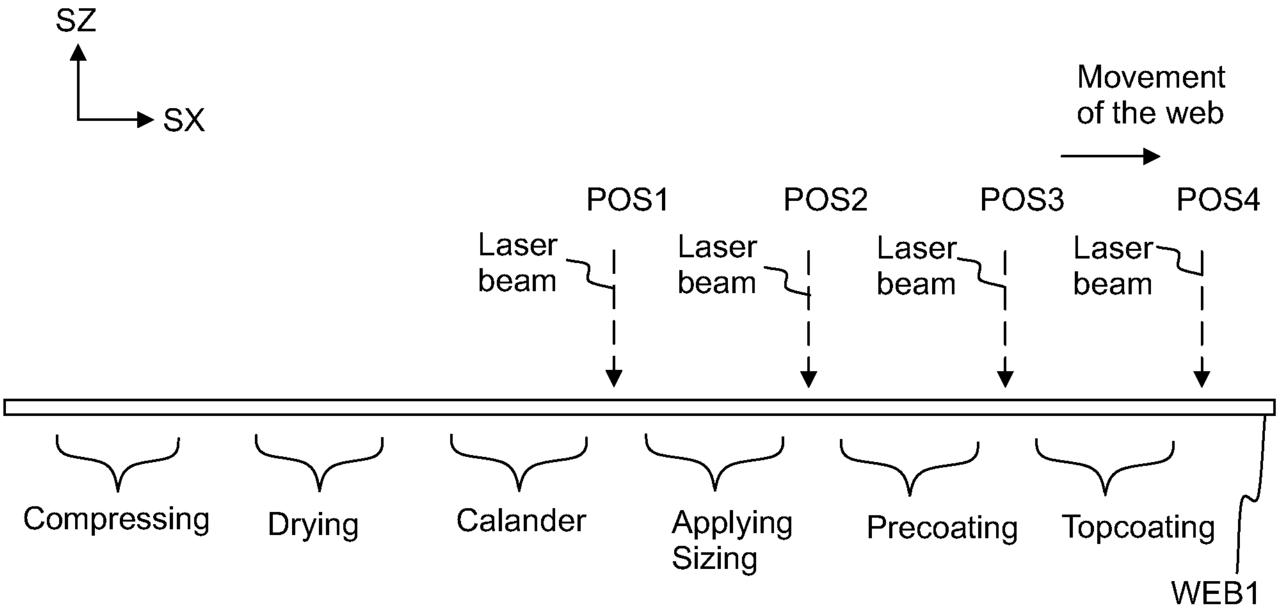

SZ
SX
Movement of the web
POS1
POS2
POS3
POS4
Laser beam
Laser beam
Laser beam
Laser beam
Compressing
Drying
Calander
Applying Sizing
Precoating
Topcoating
WEB1

Fig. 10

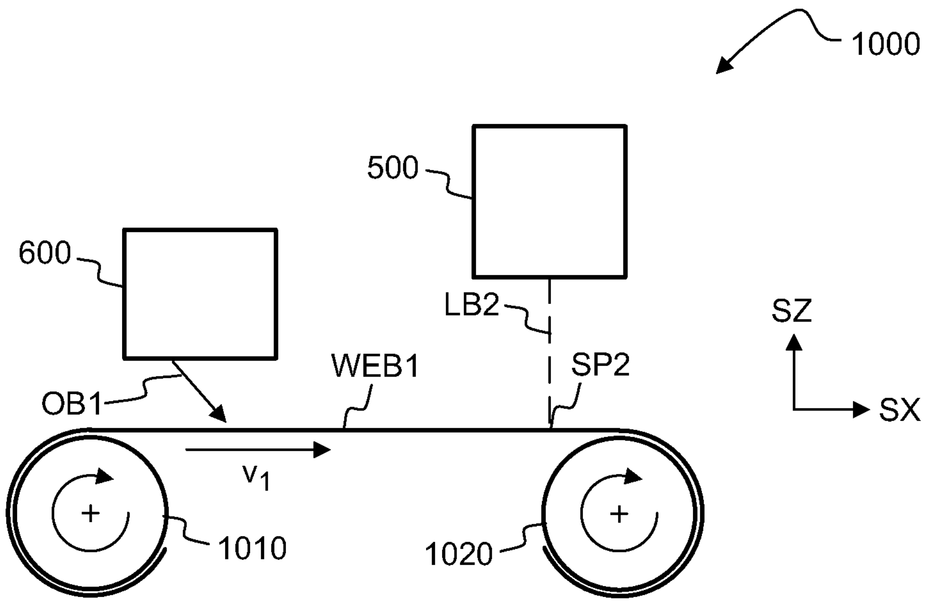

1000
500
600
LB2
WEB1
SP2
OB1
SZ
SX
v_1
1010
1020

Fig. 11

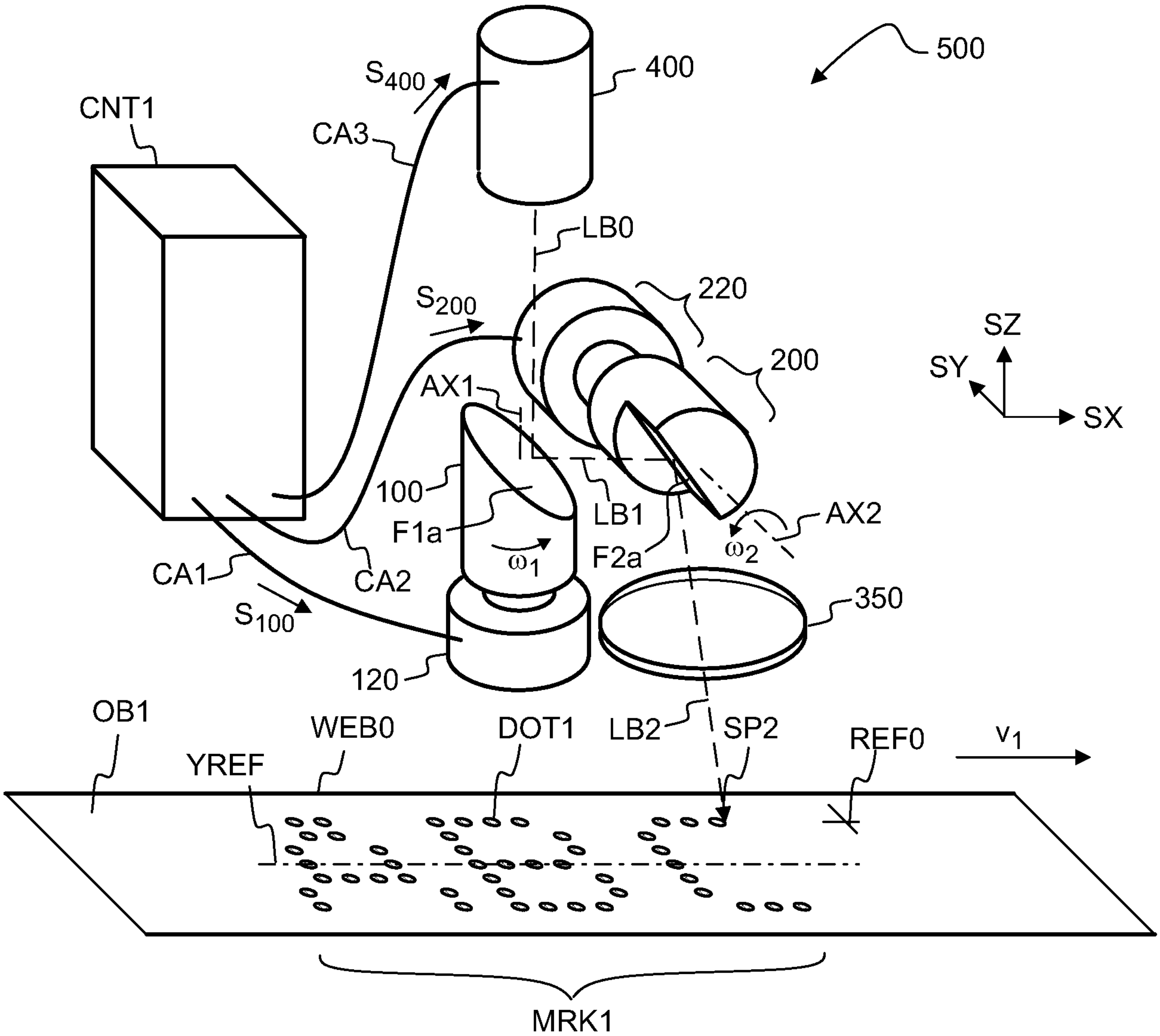

500
400
S400
CNT1
CA3
LB0
S200
220
200
SZ
SY
SX
AX1
100
LB1
F1a
F2a
AX2
ω2
ω1
CA1
CA2
350
S100
120
OB1
WEB0
DOT1
LB2
SP2
REF0
v1
YREF
MRK1

Fig. 12a

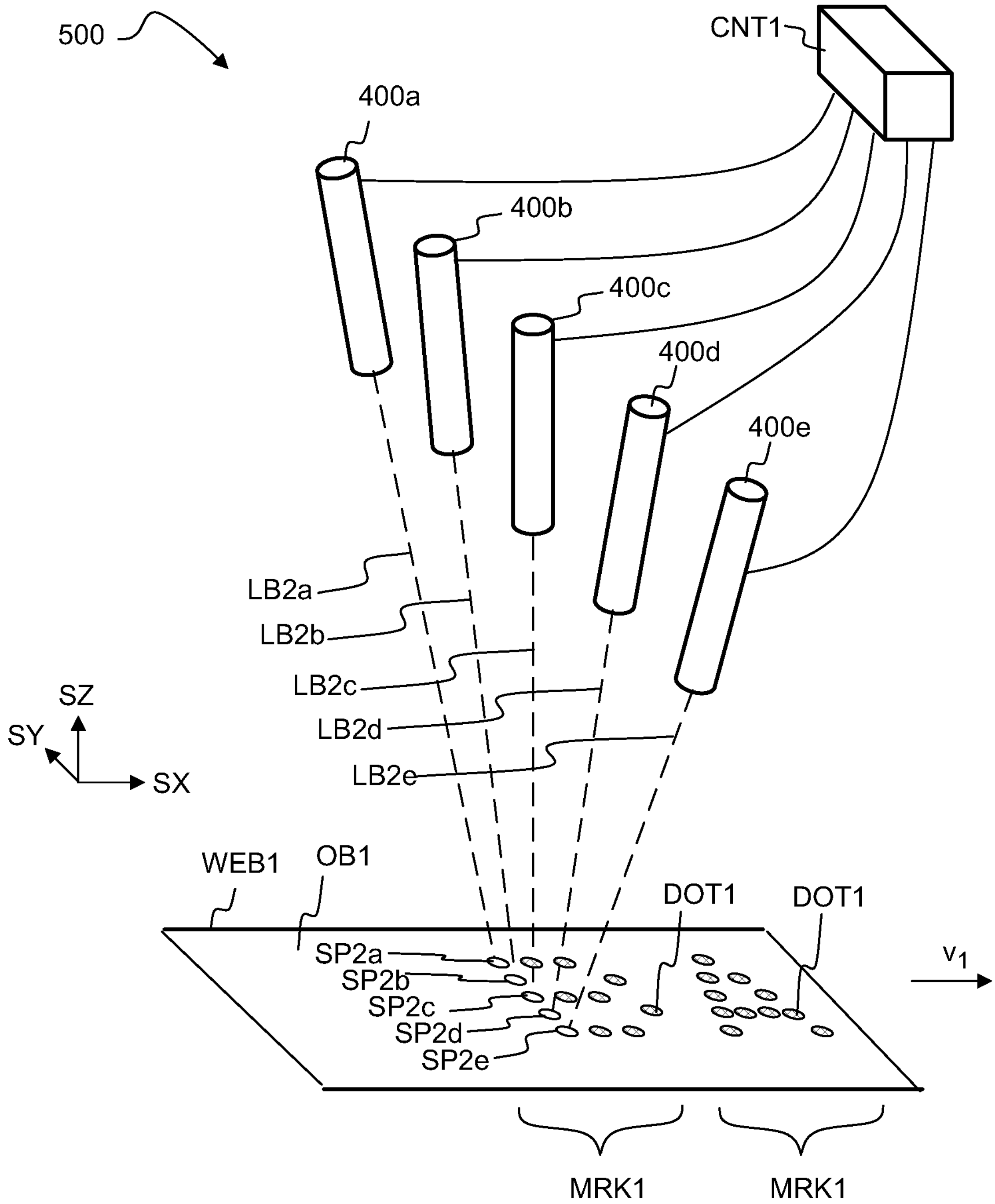

500
CNT1
400a
400b
400c
400d
400e
LB2a
LB2b
LB2c
LB2d
LB2e
SZ
SY
SX
WEB1
OB1
DOT1
DOT1
SP2a
SP2b
SP2c
SP2d
SP2e
v_1
MRK1
MRK1

Fig. 12b

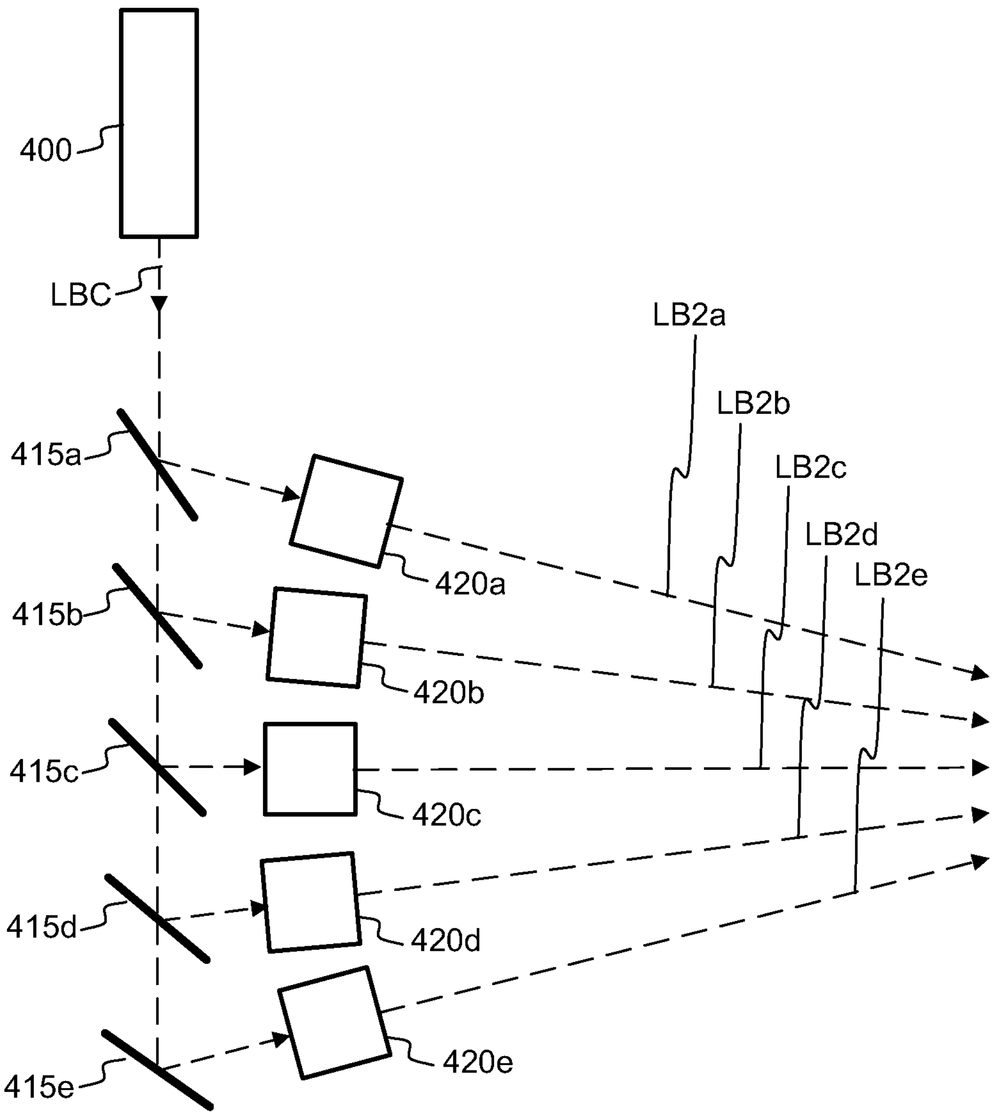

400
LBC
LB2a
LB2b
LB2c
LB2d
LB2e
415a
415b
415c
415d
415e
420a
420b
420c
420d
420e

Fig. 12c

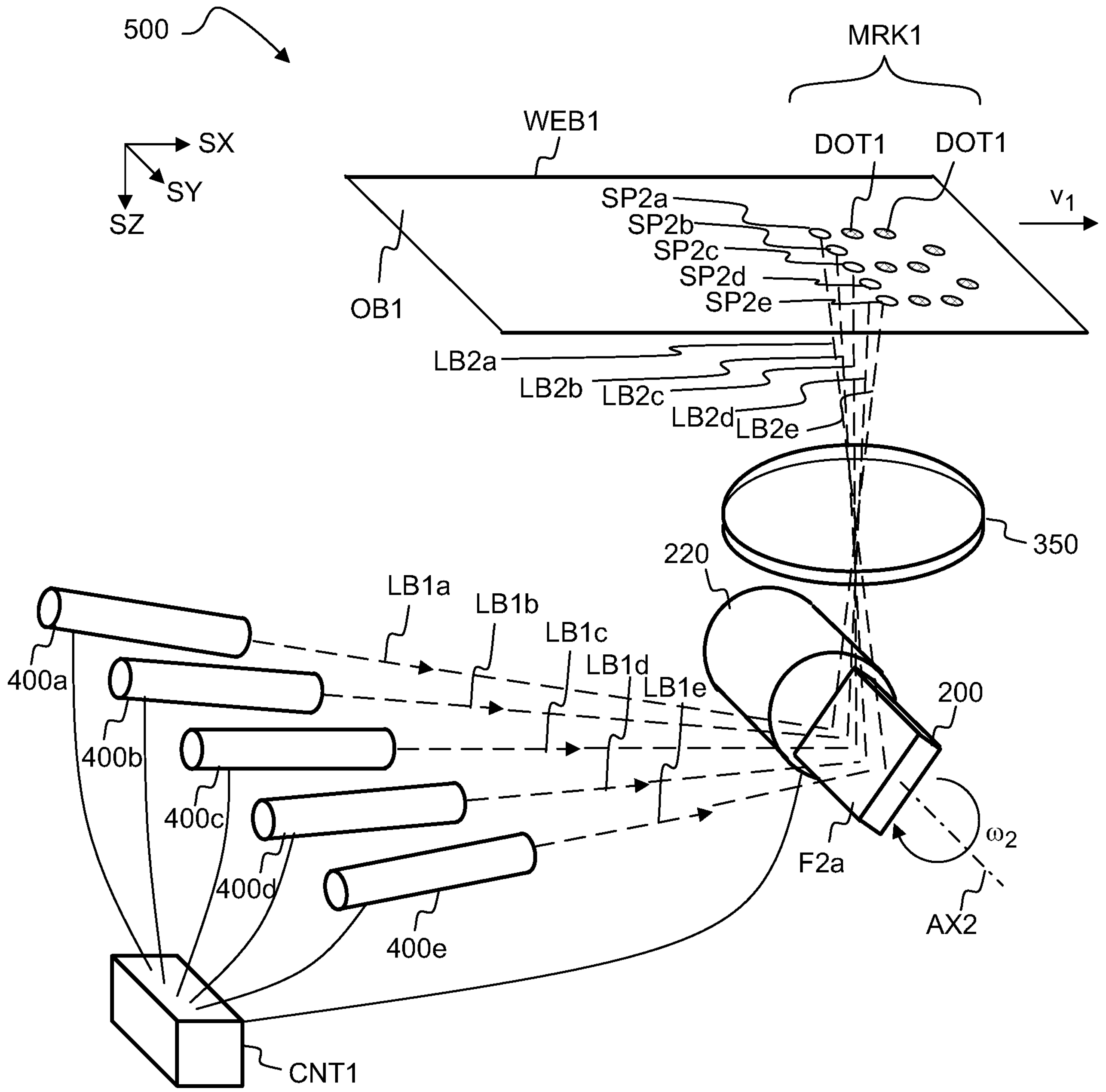

500
MRK1
WEB1
DOT1
DOT1
SX
SY
SZ
SP2a
SP2b
SP2c
SP2d
SP2e
v1
OB1
LB2a
LB2b
LB2c
LB2d
LB2e
350
220
LB1a
LB1b
LB1c
LB1d
LB1e
200
400a
400b
400c
400d
400e
F2a
ω2
AX2
CNT1

Fig. 12d

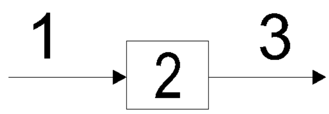


Fig.13a

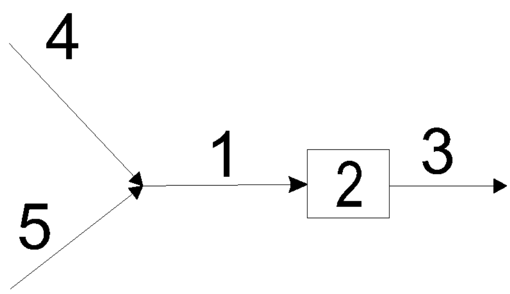


Fig.13b

Fig. 14

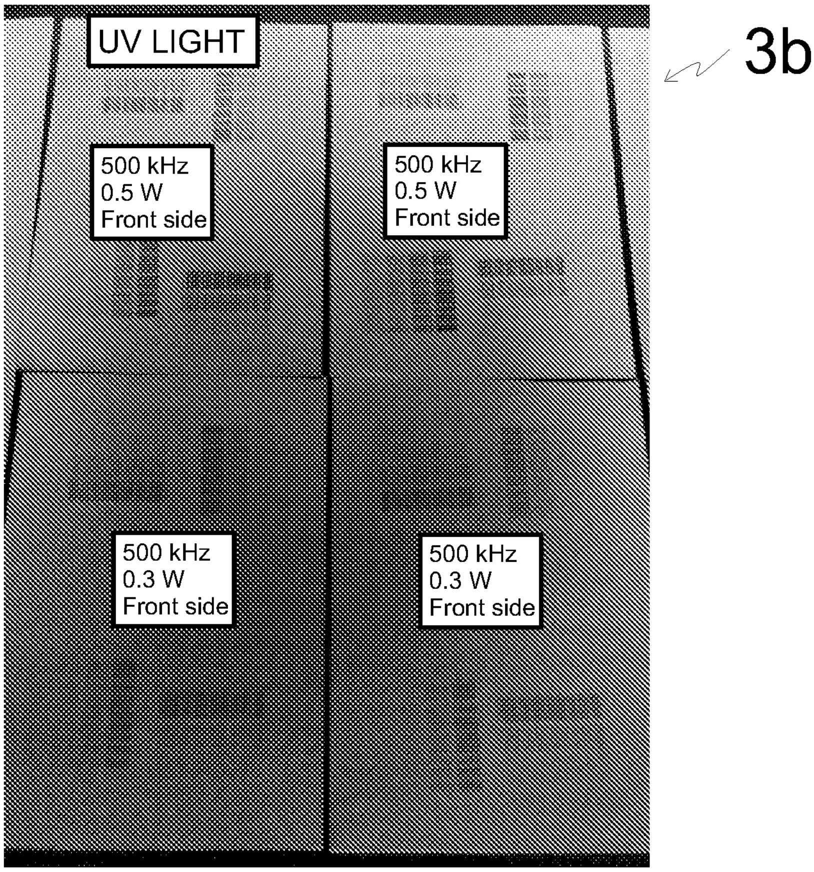


Fig. 15a

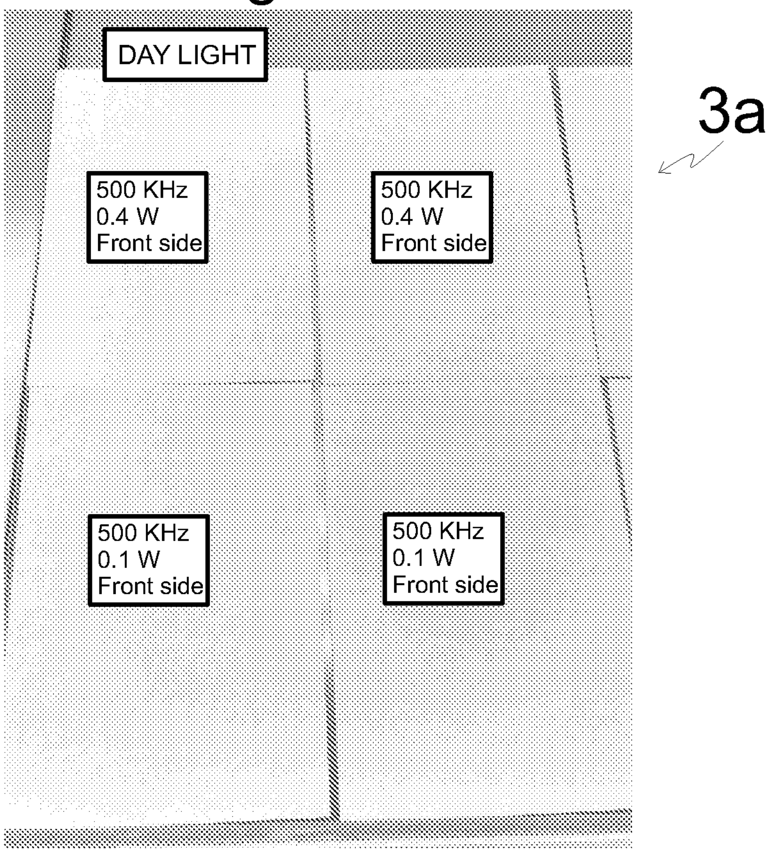


Fig. 15b

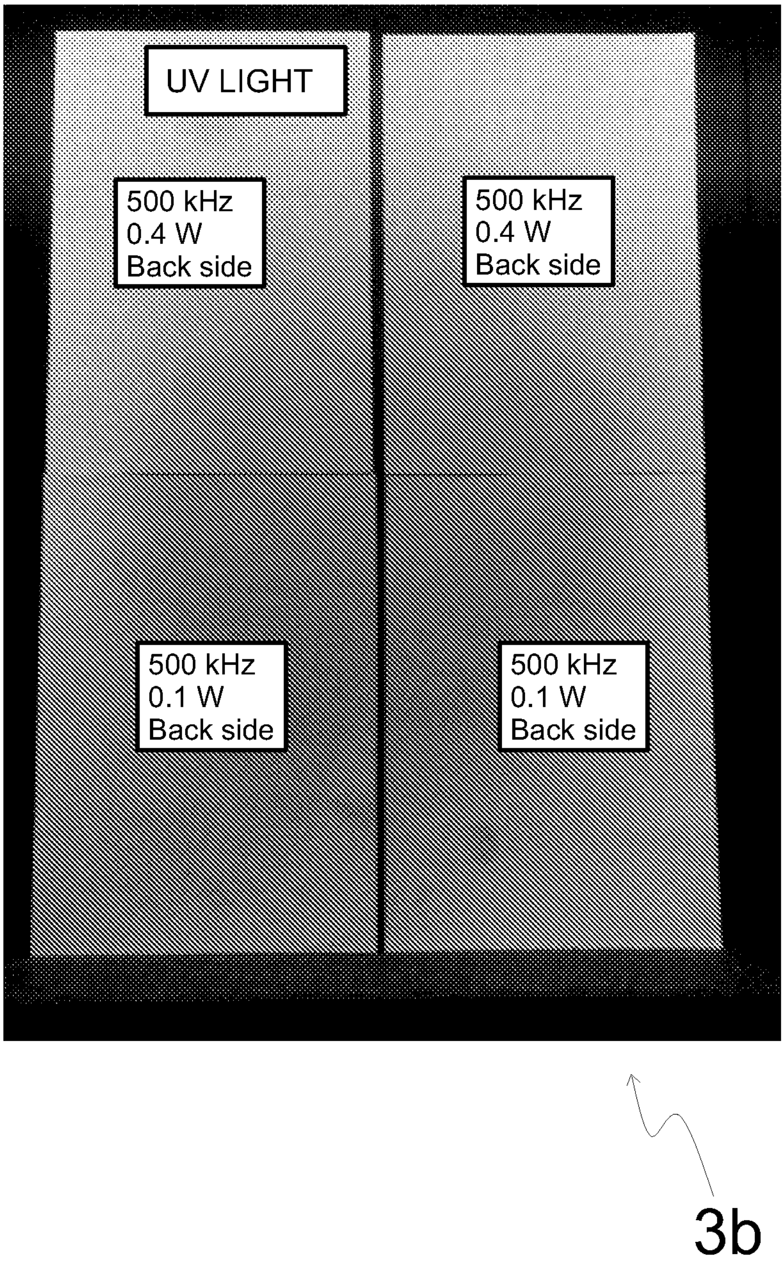

UV LIGHT
500 kHz
0.4 W
Back side
500 kHz
0.4 W
Back side
500 kHz
0.1 W
Back side
500 kHz
0.1 W
Back side
3b

Fig. 16

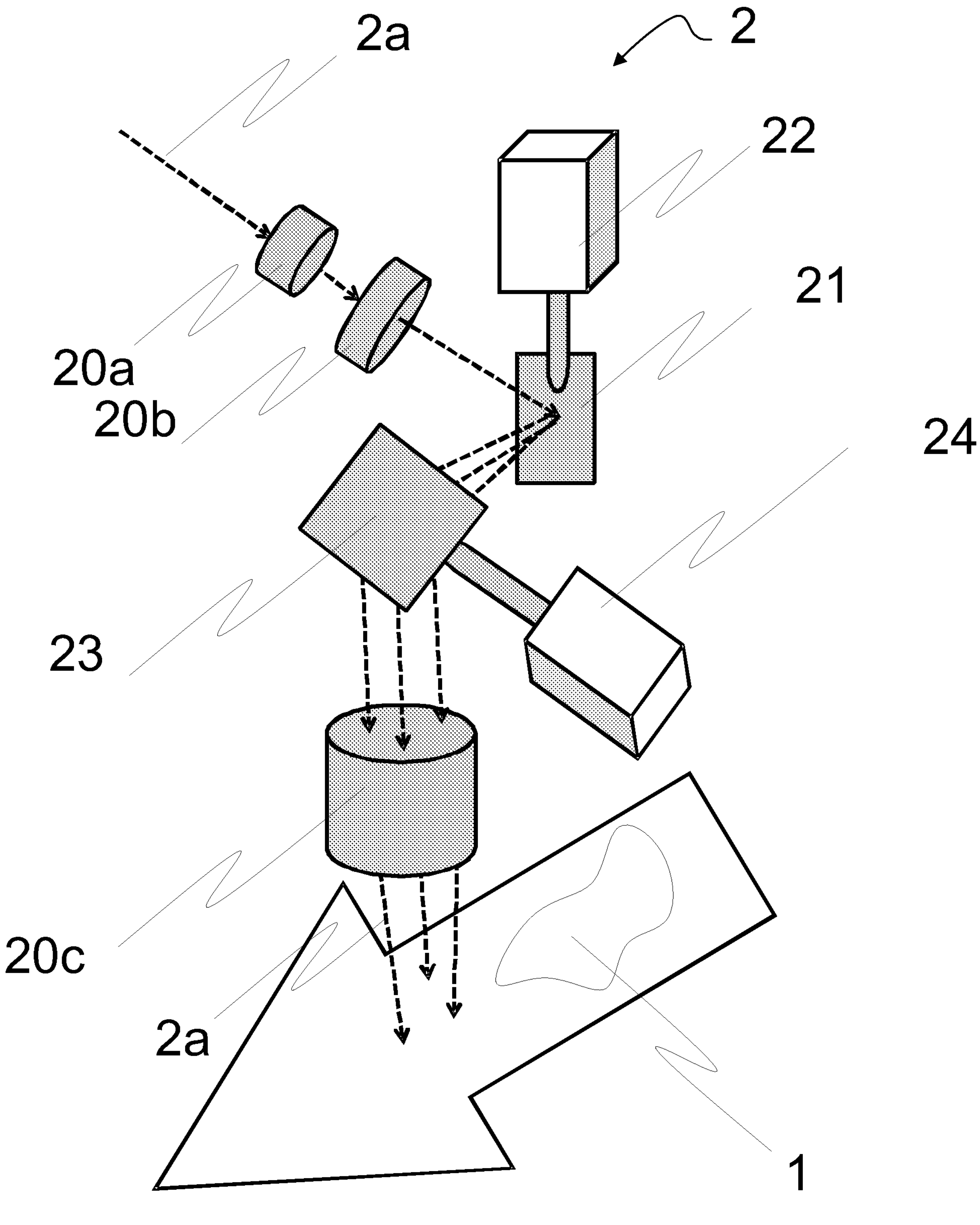


Fig. 17

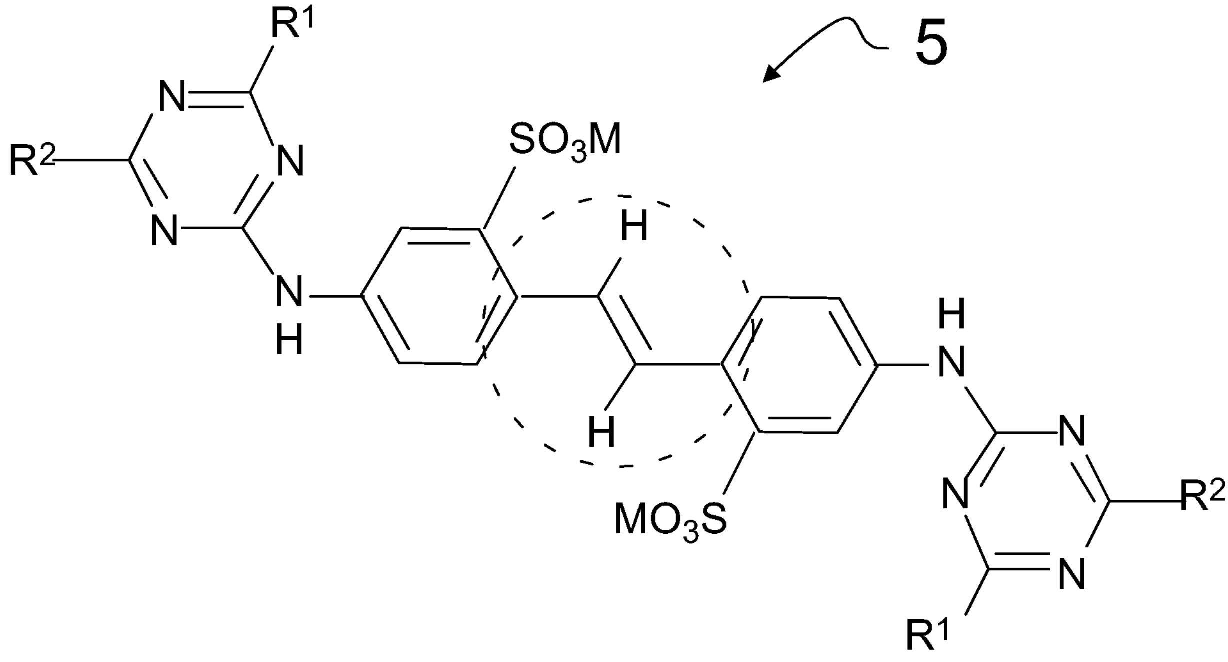


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2012/050765

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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)

IPC: D21H, B41M, B42D, B44F

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

FI, SE, NO, DK

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

EPO-Internal, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006027418 A1 (STORA ENSO OYJ et al.) 16 March 2006 (16.03.2006) examples; claims; page 2, lines 9-18; page 4, lines 1-7, Figure 1	1, 2, 7, 18, 20, 22
A	CA 1284125 C (GUGGER HEINRICH) 14 May 1991 (14.05.1991) page 2, examples 16-18, claims	1-22
A	GB 2234601 A (COOKSON GROUP PLC) 06 February 1991 (06.02.1991) example, claim 1	1-22

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 December 2012 (18.12.2012)	19 December 2012 (19.12.2012)

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National Board of Patents and Registration of Finland
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Authorized officer
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Telephone No. +358 9 6939 500

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.
D21H 21/40 (2006.01)
D21H 21/48 (2006.01)
B41M 3/14 (2006.01)
B42D 15/00 (2006.01)
B44F 1/12 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2012/050765

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
WO 2006027418 A1	16/03/2006	US 2008187851 A1	07/08/2008
		JP 2008512278 A	24/04/2008
		ES 2357135T T3	19/04/2011
		EP 1786976 A1	23/05/2007
		CA 2579745 A1	16/03/2006
		AT 494424T T	15/01/2011
		FI 116949B B1	13/04/2006
CA 1284125 C	14/05/1991	AR 244599 A1	30/11/1993
		JP 61192737 A	27/08/1986
		ZA 8600802 A	24/09/1986
		NZ 215036 A	24/02/1989
		MX 167831 B	15/04/1993
		KR 920007677B B1	14/09/1992
		IE 57213 B1	03/06/1992
		ES 8706000 A1	01/08/1987
		DK 54086 A	06/08/1986
		BR 8600463 A	21/10/1986
		PT 81957 A	01/03/1986
		IL 77772 A	31/10/1989
		FI 860493 A	06/08/1986
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		EP 0190997 A2	13/08/1986
		AT 68138T T	15/10/1991
		AU 5281286 A	24/12/1987
		AU 597240B B2	31/05/1990
GB 2234601 A	06/02/1991	None	