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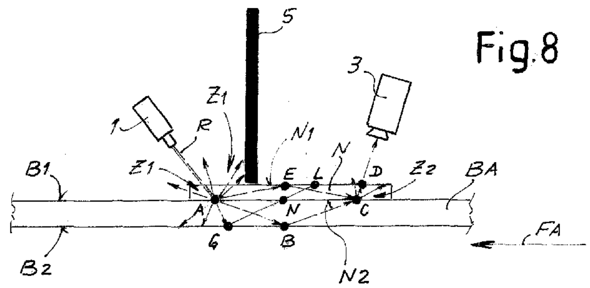


Fig.8

(57) **Abstract**: A method is described, for detecting the presence of a foreign first material (N) randomly applied on an object (BA) under examination formed by a second material, wherein the foreign first material (N) is transparent or semi-transparent and the second material is absorbent and/or scattering at at least one wavelength of an optical radiation. The method provides for lighting a first area (Zl) of the object (BA) by means of at least one optical source (1). The method also provides for framing a second area (Z2) of the object (BA) by means of an optical receiver (3). The optical receiver (3) and the optical source (1) are designed and arranged so that the first area (Zl), lighted by the optical source (1), is different from the second area (Z2) framed by the optical receiver (3). The presence of the foreign first material (N) on a surface of the object (BA) is detected through a change in the optical signal on the optical receiver (3) due to optical radiation emitted by the optical source (1) and conveyed through the foreign first material (N) from the first area (Zl) up until the second area (Z2).

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# METHOD AND DEVICE FOR DETECTING A TRANSPARENT OR SEMI-TRANSPARENT MATERIAL APPLIED ONTO AN ABSORBENT AND/OR SCATTERING MATERIAL

## Description

### Technical Field

The present invention relates to methods and devices for detecting a material, for instance a sheet or web material, applied onto a base material or substrate, wherein these two materials have different optical characteristics. The method relates in particular to the detection of a transparent or semi-transparent and/or semi-reflective material on an opaque material, i.e. on an absorbent material with scattering surface. More in particular, but not exclusively, the invention relates to a method and a device for detecting a transparent or semi-transparent adhesive tape applied on paper sheets, for example on banknotes, checks or other paper documents.

### Background Art

In many applications it is necessary to detect materials applied on a base material surface simply, reliably, automatically and quickly. In the bank field, for instance, it is often necessary not only automatically to verify the banknote authenticity, but also to detect pieces of adhesive tape applied on it, if any. In fact, adhesive tape applied on a banknote indicates that the banknote is damaged and shall be therefore taken out of circulation.

Various devices have been developed to this end, which are based upon different detection methods.

For instance, US-A-2009/0133502 discloses a system using ultrasonic sensors for detecting adhesive tape on a banknote. These sensors are expensive and sensitive to air movements. They are therefore particularly critical when applied to devices, inside which banknotes move very quickly; in fact, the fast motion creates an air flow interfering with the ultrasonic sensor detection.

US-A-2010/0117295 describes an apparatus using capacitance sensors for detecting adhesive tape on banknotes. In this case again, the sensors are expensive and not very reliable.

Optical devices have been also developed for detecting transparent or semi-transparent adhesive tape applied on the banknotes. US-A-2011/0052082 discloses an example thereof. This known device, as well as other optical devices, is substantially based upon the different reflection features of the adhesive tape with respect to the paper material of the banknote. In this known device, an optical receiver is provided in combination with at least two optical sources; these sources are inclined by different angles with respect to the banknote advancing plane. Both the sources fall, each by its incidence angle, on the same area of the banknote, and light it. The area lit by these two sources is framed by the receiver. The change in the scattering and reflection signal generated by the two different sources, which are differently inclined with respect to the banknote advancing path, is used for detecting the presence of adhesive tape. In fact, the adhesive tape is shinier than the opaque surface of the banknote, and hence causes a change in the signal detected by the receiver, thus indicating the presence thereof. These optical detection systems have several drawbacks; among other things, more optical sources with different angles are required, and this entails difficulties in the mechanical arrangement. Moreover, the detection system is very sensitive to the presence of folds on the base material, a banknote for instance. Furthermore, two opposite systems shall be provided to check both the banknote sides, with consequently increased costs and bulk.

US-A-2009/0310126 discloses an optical system based again on using a light source and an optical receiver, wherein this latter is arranged in front of the area lit by the light source. The source is strongly inclined with respect to the banknote advancing plane. The adhesive tape presence is detected thanks to the reflection of its reflective surface and the shadow it generates on the banknote because of the strong inclination of the light source. As already said, the used sources are strongly inclined with respect to the banknote advancing plane; therefore, the signal largely depends upon the height of the raised surface; moreover, folds or other irregularities on the base material surface may result in a false positive signal. In addition, also this system requires two groups arranged on the two banknote sides to examine both the document sides.

US 2003/0234362 discloses a thermal technique for detecting the presence of a foreign material, in particular adhesive tape, applied on a banknote. This technique is based upon the thermal features of the adhesive tape, which are different than in the other banknote areas. For the detection, this technique uses the thermal radiation emitted by the banknote when there is a thermal gradient between banknote and detector. The detected radiation is comprised between 3 and 12 micrometers. The banknote may be heated or cooled, and the emitted radiation is detected after a certain time interval after heating or cooling. A time interval occurs between the source application and the emitted radiation detection, because of the banknote transport speed. The adhesive tape detection is based upon the fact that the areas with the adhesive tape have a greater thermal inertia. The mutual position of heater and detector depends upon the banknote transport speed. The radiation must be detected after a certain time interval after heating.

Summary of the Invention

According to one aspect, the object of the invention is to provide a method and a device for detecting a first material, for instance an adhesive tape or other transparent or semi-transparent material, such as paint, lacquer or the like, randomly or accidentally applied on a substrate constituted by a second material with different optical characteristics, for instance a scattering material such as a paper sheet and, more in particular, a banknote or the like, the method and the device being particularly efficient, reliable and inexpensive.

The invention is based on the fact that the transparent or semi-transparent and/or semi-reflective material, for instance an adhesive tape, acts as a light pipe with losses, that can be used to transfer an optical signal from a first area, lit by an optical source, towards a second area, framed by an optical receiver. The object to be examined, for instance a paper sheet, a note or the like, is optically opaque and scattering, so that substantially no light energy is transferred between the first and the second area. Vice versa, a portion of a semi-transparent and/or semi-reflective material, when arranged between these two areas and thus acting as a light pipe with losses, transfers an optical signal, that can be detected by the receiver, from the first area, lighted by the source, to the second area, framed by the receiver. The optical signal detected by the receiver therefore indicates the presence of semi-reflective and/or semi-transparent material applied on the scattering and opaque base material of the object under examination.

Anti-counterfeiting security systems are currently used, using light pipes built into the paper forming the banknote. The position and optical features of these light pipes, usually in the form of optical fibers, are known a priori. Machines for verifying authenticity of the banknotes are designed to inject an optical radiation in a position, for instance an end, of these light pipes and to detect the optical signal in a different position, for instance at the opposite end. The concepts upon which these systems are based differ from those upon which the present invention is based. In the first case, in fact, the light pipes are expressly embedded in the banknote structure, and their presence is verified knowing a priori their position on the banknote. Vice versa, the system according to the present invention is designed to verify the accidental and completely random presence of an object or foreign material applied on the banknote in an unknown position. The invention is substantially based upon the fact that the foreign material is more transparent than the substrate onto which it is accidentally applied.

The features of semi-transparency or transparency, scattering and opacity of the materials in question shall be intended as relative. This means that the foreign material feature of being transparent or semi-transparent and/or reflective or semi-reflective is relative to the lower transparency and greater opacity of the material of the substrate or object on which this foreign material is applied.

According to an advantageous embodiment, the method therefore comprises the steps of:

- lighting a first area of an object under examination with at least one first optical source;
- framing a second area of the object by means of an optical receiver; said optical receiver and said optical source being designed and arranged so that the first area, lit by the optical source, is not directly framed by the optical receiver;
- detecting the semi-transparent and semi-reflective material through a change in the optical signal on the optical receiver due to optical radiation conveyed through said semi-reflective and semi-transparent material.

The materials may be sheet or web materials, i.e., generally speaking, substantially two-dimensional materials. The method according to the invention may be also used to examine three-dimensional objects and materials, i.e. objects and materials provided with a non-negligible thickness with respect to the other two dimensions. As already highlighted, in some embodiments the material forming the object under examination and the material that is applied on it and must be detected through the optical analysis differ from one another as far as the capability of reflecting or scattering the optical radiation and/or of guiding the optical radiation through the thickness thereof are concerned.

The method according to the invention may be integrated in a more complex system designed also to acquire a (transparent or reflective) image of the object under examination. In this case, the method may comprise the steps of:

- selectively lighting the first area by means of the first optical source and a second optical source, said second optical source being designed and arranged to light an area of the second material framed by the optical receiver;
- by means of said optical receiver, selectively acquiring a first image formed by the radiation emitted by the first optical source and a second image formed by the radiation emitted by the second optical source.

In other embodiments, the method may comprise the steps of:

- arranging a second optical receiver so as to frame the first area lit by the optical source;
- by means of the second optical receiver, acquiring an image of the area framed by the second optical receiver and lit by the optical source.

In this way again it is possible to obtain an image of the object under examination by means of the second optical receiver, and also an image of the first material applied on the object by means of the first optical receiver. In this case the selective acquisition of the two images is not required, as two distinct receivers and a single source are used to this end. The acquired images are different, as they are obtained by means of receivers framing different areas of the object.

The optical characteristic of transmittance and reflectance used to detect the material applied on the object vary according to the wavelength. This means that the characteristic of the material of being transparent or semi-transparent and/or reflective or semi-reflective is referred to the wavelength of the optical radiation used.

Usual adhesive tape is a semi-transparent and semi-reflective material in the visible and infrared spectrum. As the adhesive tape thickness is nearly 50 micrometers, the adhesive tape is:

- semi-transparent and semi-reflective in the NIR, i.e. in the range: 780-1400 nm
- more transparent and less reflective in the MIR, i.e. in the range

1400-3000 nm

- transparent in the FIR, i.e. in the range 3000-1.000.000 nm.

Paper, in particular paper used for banknotes, is less transparent and more scattering, i.e. it has a more diffuse reflectance than the adhesive tape, both in the visible and the infrared spectrum.

Briefly, adhesive tape is semi-transparent and semi-reflective in the visible and infrared spectrum; as the wavelength increases, transparency increases and reflectance decreases. Banknote is an opaque, i.e. absorbent and scattering material in the visible and infrared spectrum: the absorption capacity increases as the wavelength decreases, the scattering increases as the wavelength increases until the ratio between thickness and wavelength is lower than about 0.1. For values above this limit, the banknote reflects and refracts. For high wavelengths, i.e. for thickness/wavelength ratios lower than $10^{-3}$ - $10^{-4}$ the banknote is transparent.

When the method is applied for detecting adhesive tape onto banknotes or other paper supports, the optical source may therefore emit in the visible and/or infrared spectrum.

According to a different aspect the invention also relates to a device for detecting a first material (for instance adhesive tape) having at least one first optical characteristic and applied on a second support material (for instance a banknote) having at least one second optical characteristic, different from the first optical characteristic, the device comprising a first optical source and a first optical receiver. The first optical source and the first optical receiver are designed and arranged so that the optical source lights a first area of the object under examination, and the optical receiver frames a second area of the object, wherein the second area and the first area are different and spaced from each other, said first area being not directly framed by the optical receiver.

The above brief description sets forth features of the various embodiments of the present invention in order that the detailed description that follows may be better understood and in order that the present contributions to the art may be better appreciated. There are, of course, other features of the invention that will be described hereinafter and which will be set forth in the appended claims. In this respect, before explaining several embodiments of the invention in details, it is understood that the various embodiments of the invention are not limited in their application to the details of the construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

Moreover, those skilled in the art will appreciate that the conception, upon which the disclosure is based, may readily be utilized as a basis for designing other structures, methods, and/or systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

Brief description of the drawings

The invention and its advantages can be better understood with reference to the detailed description below and to the attached drawings, wherein:

figure 1 shows a diagram of a usual arrangement of light source and receiver in a reflection imaging device;

figure 2 schematically shows a usual arrangement of light source and receiver in a transmission imaging device;

figure 3 shows a diagram of a first embodiment of a device according to the invention;

figure 4 shows a diagram of a second embodiment of the device according to the invention;

figure 5 shows a diagram of a third embodiment of the device according to the invention;

figure 6 shows a diagram of a fourth embodiment of the device according to the invention;

figures 7, 8, 9, 10, and 11 show diagrams illustrating the optical principle upon which the invention is based, in different configurations and use conditions;

figures 12A, 12B; 13A, 13B; 14A, 14B show diagrams illustrating the image acquisition method by means of a device according to the invention;

figure 15 schematically illustrates the acquisition of two types of image of the same banknote according to an embodiment of the invention;

figure 16 shows an arrangement of the main mechanical members of a device according to the invention in a possible embodiment;

figure 17 shows a perspective view of the arrangement of figure 16 with some parts removed; and

figures 18 to 23 show diagrams of further embodiments of the device according to the invention.

It should be understood that the drawings are schematic and generally not scale, as the dimensional ratios of the various components and elements illustrated have been altered for the sake of clarity of the drawings.

Detailed Description of Embodiments of the Invention

Throughout the description, the reference to "an embodiment" or "some embodiments" indicates that a particular characteristic, structure or property described in relation to an embodiment is included in at least one embodiment of the described invention. Therefore, the phrases "in an embodiment" or "in some embodiments" in different points of the description do not necessarily refer to the same embodiment or the same embodiments. Moreover, the particular characteristics, structures or elements can be combined in any adequate way in one or more embodiments.

The invention will be described below with specific reference to the detection of pieces of adhesive tape applied on banknotes, the adhesive tape being transparent or semi-transparent to the wavelength used for the detection. It should be however understood that the invention may be also used for detecting transparent or semi-transparent adhesive tape applied on other documents or products, for instance cheques or the like. More in general, it should be also understood that the invention may be applied every time it is necessary to detect a first material applied on a second material, wherein the two material differ in terms of optical transparency and reflection.

The device comprises light sources and receivers. Particular reference will be made below always to a single source and a single receiver, even if they can be replaced by linear arrays of sources and receivers.

Figure 1 schematically shows a traditional arrangement used to acquire images of a sheet material, for instance a banknote, in a known device by means of a reflection or scattering system.

In figure 1, BA schematically indicates a banknote advancing along an advancing path according to the arrow FA. During the forward movement according to FA, each portion of the banknote BA passes through an image acquisition area Z. The area Z is lit by a source S. The light beam F1 generated by the source S lights the area Z. The banknote reflects and scatters the incident radiation by the angle $\theta_I$. Figure 1 shows the reflection $\theta_R$ and scattering $\theta_{D1}$, $\theta_{D2}$ angles.

A receiver R is provided to frame the same area Z; it is positioned according to the reflection direction $\theta_R$ to acquire the reflected image of the banknote BA, or according to the scattering direction $\theta_{D1}$ or $\theta_{D2}$ to acquire the scattered image of the banknote BA. By advancing the banknote BA along the advancing path according to FA, it is possible to acquire subsequent images of the banknote by means of the light source S and the receiver R, each of these images corresponding to a thin strip of the banknote orthogonal to the advancing direction FA. The whole image of the banknote, of a sufficiently high resolution, can be therefore reproduced through subsequent acquisition steps controlled by a central control unit. The source S and the receiver R may be practically constituted by a series of optical emitters and receivers respectively.

Usually, to this end the so-called contact image sensors (CIS) may be used, generally used in copiers, faxes and scanners. A linear matrix of light emitters, typically LEDs, forming the light source, is arranged in a housing adjacent to a linear matrix of optical sensors, forming the optical receiver. The housing, in which source and receiver are arranged, is provided with a window, usually into contact with the sheet, whose image shall be acquired. In the figure, source and receiver are shown spaced with respect to the object plane for the sake of simplicity and clarity of the drawings.

Figure 2 shows a similar arrangement for transparency imaging. The same numbers indicate identical or equivalent parts to those in figure 1. In this case, the optical source S is arranged in a half plane and the receiver R in the opposite half plane, said half planes being defined by and separated from the plane whereon the banknote BA is placed or advances. Z indicates again the area under examination. The banknote BA advances along the advancing path according to the arrow FA. The light radiation F1 emitted by the source S passes across the banknote BA. A part of the radiation is directly transmitted to the receiver R, whilst a part is scattered according to the angles $\theta_{D1}$ and $\theta_{D2}$.

In general, the image acquisition systems currently used have therefore source and receiver framing the same portion of the object under examination. In the case of transparency-based systems, the receiver is aligned according to the direction of propagation of the central ray of the beam of optical radiation coming from the source or according to any one of the possible scattering directions.

Figure 3 shows the diagram of one embodiment of the invention, only as regards the general arrangement of the main components forming the detection device. Further details about the operation and the optical principles used will be explained below with particular reference to figure 7 and the following.

In the arrangement of figure 3, BA indicates again a banknote advancing according to the arrow FA along an advancing path P. In this embodiment, an optical or light source 1 and a receiver 3 are arranged on a same side of the advancing path P. Optical source means any source of electromagnetic radiation in a useful spectrum comprised between IR and UV.

The optical source 1 is advantageously a linear source, able to emit a light beam whose height, orthogonal to the figure plane, is equal at least to one of the maximal dimensions (height or width) of the banknote BA. To this end, the optical source 1 can be constituted by a light bar or by a linear array or matrix of LEDs or laser sources. The light bar may be a light pipe made of glass or other suitable material, for instance a synthetic resin, transparent to the used wavelength. The bar has a diffusing strip along its longitudinal development on the lateral surface thereof, allowing the optical radiation to exit, to form an optical radiation barrier. A source of this kind is described for instance in WO-A-00/77447, to which reference is made for further details on the light pipe structure.

The optical receiver 3 may be constituted by a linear array or matrix of optical sensors, of the type commonly used in scanners, copiers and the like. In a modified embodiment, the receiver may be formed by a light pipe constituted for instance by a bar in a material transparent to the used wavelength. The bar may be worked along a longitudinal line or strip to collect the optical radiation. The optical radiation is collected by a single optical sensor or by a pair of optical sensors arranged at the ends of the bar forming the light pipe. However, this solution has some limits as it does not allow to obtain an image of the banknote; it only allows to collect a single optical signal that may be modulated by the presence of a piece of adhesive tape, as it will be more apparent below. A bar of this type for collecting the optical radiation is described in WO-A-00/77447.

As it is shown in the diagram of figure 3, the optical source 1 is arranged at a certain distance from the receiver 3 in the advancing direction FA of the banknote BA. In the illustrated example the light beam F1 generated by the optical source 1 lights an area Z1 of the banknote BA. The area Z1 is separate and spaced from an area Z2 framed by the receiver 3. This separate arrangement of the lit area Z1 and of the framed area Z2 is an important feature of the present invention, distinguishing the method and the device according to the invention from the optical devices and methods of the prior art.

The distance between the areas Z1 and Z2 shall be compatible with the dimension of the foreign material, for instance adhesive tape, that is applied on the banknote BA and shall be detected by the device. The distance shall be for instance equal to, or lower than, the minimum width the adhesive tape may have, typically in the order of one centimeter.

In the embodiment of figure 3 the device has also a barrier 5 with a first aperture 5A and a second aperture 5B. The first aperture 5A allows the passage of the light beam F1 lighting the area Z1 from the source 1. The second aperture 5B allows the area Z2 to be framed by the receiver 3, thus allowing the optical radiation to pass from the surface of the area Z2 to the receiver 3. The radiation lobe of the beam F1 extends orthogonally to the plane of the figure for a length equal at least to the height or the length of the banknote BA; therefore, also the apertures 5A and 5B shall be elongated. These apertures are, practically, slots preferably orthogonal to the advancing direction FA of the banknote BA.

In other embodiments, instead of a system of barriers and apertures associated with the optical source and with the receiver, it is possible to use so-called directional sources, for instance laser sources, having the intrinsic feature of generating a directed beam without the need for shields or optical barriers.

The barrier 5 with the apertures or slots 5A and 5B allows reducing or eliminating the radiation generated by the source 1 that can be directly detected by the receiver 3. To this end, the barrier 5 may be advantageously provided with a strongly absorbent surface at the wavelength used for the detection. In other embodiments, the barrier may have a reflective surface, so as to reflect the optical radiation falling on the barrier surface towards a useful path. In other embodiments, the barrier may have a scattering surface. It is only important that it does not allow the incident radiation from the source to pass across the barrier thickness and reach the receiver.

In some embodiments, the receiver 3 may be constituted by a contact image sensor (CIS), the source of which has been adequately deactivated and no longer lights the same area framed by the receiver, as usually occurs in these sensors. In other embodiments, as will be better explained below, the inner source of the CIS is used in combination with the optical source 1 outside the receiver to obtain further functions.

However, the suggested solution is useful both when arranging receiver and source into contact with the object plane, defined by the advancing plane of the banknote BA, as well as when arranging them, or one of them, spaced from the plane. The figures refer to the configuration in which receiver and source are arranged spaced from the object plane, only for the sake of clarity of the drawings.

Figure 4 shows the diagram of a different embodiment of the invention. The same numbers indicate identical or equivalent parts to those in figure 3. In this embodiment the barrier 5, instead of being nearly parallel to the advancing plane of the banknote BA, is arranged orthogonal to said plane and interposed between the optical source 1 and the optical receiver 3. The front edge 5C of the barrier 5 is arranged directly adjacent to the banknote BA, preferably at a distance just sufficient to allow the banknote, which could be provided with an adhesive tape strip, to pass without interference. In this way the possibility is significantly reduced that the optical radiation generated by the optical source 1 directly reaches the receiver 3.

In the two diagrams of figures 3 and 4 the receiver 3 and the optical source 1 are arranged on the same side of the advancing path P of the banknote BA. This arrangement is however not binding. For instance, figure 5 schematically shows a third embodiment of the device according to the invention. The same numbers indicate parts identical or equivalent to those in figures 3 and 4. In this embodiment the optical source 1 is arranged on one side of the path P, and the optical receiver 3 on the opposite side. Substantially, the optical source 1 and the receiver 3 are in two distinct half planes, said half planes being separated by the advancing plane of the banknote BA. Z1 and Z2 indicate again respectively the area lit by the optical source 1 and the area framed by the optical receiver 3. F1 is the light beam of the source 1 lighting the area Z1.

Moreover, in the diagram of figure 5 there are two barriers 6 and 8 respectively, provided with a first aperture or slot 6A and with a second aperture or slot 8A respectively. The barrier 6 with the aperture 6A allows the passage of the beam F1, and the barrier 8 with the aperture 8A allows the passage of the optical radiation coming from the area Z2 and collected by the receiver 3. The two barriers 6 and 8, similarly to the barrier 5 of figure 3, prevent the optical radiation generated by the source 1 from directly reaching the receiver 3, or anyway they reduce the quantity of radiation that can directly reach the receiver 3.

Figure 6 shows the diagram of a further embodiment of the device according to the invention. Equal numbers indicate the same or equivalent parts to those of the previous embodiments. In this case again, similarly to what indicated in figure 5, the optical source 1 is arranged on one side of the advancing path P of the banknote BA, and the receiver 3 is arranged on the opposite side. F1 indicates the optical beam with which the source 1 lights the area Z1, whilst the area Z2 framed by the receiver 3 is spatially separated from the area Z1, similarly to figures 3, 4, and 5.

6 and 8 indicate two barriers arranged on the two sides of the advancing path P of the banknote BA. In this case the two barriers 6 and 8 are orthogonal to the banknote advancing plane and have the same purposes described in connection with figure 5. Only the barrier 6 may be provided in this configuration.

The arrangement of the main members of the device according to the invention in different embodiments has been schematically illustrated above. Below, with reference to figures 7 to 11, the physical principal will be detailed, upon which the detection method according to the invention is based.

Figure 7 shows a schematic enlargement of the lighted and framed area of the banknote BA in the embodiment of figure 4. BA indicates the banknote that, as in the other figures, is shown in a sectional view.

In the diagram of figure 7 the banknote BA is devoid of transparent or semi-transparent adhesive tape. In the diagram the wave vector is illustrated of a single light ray R emitted by the optical source 1. Below it will be described how this ray is used to generate a signal useful to detect the presence of transparent or semi-transparent adhesive tape. It should be understood that what is described with reference to the wave vector of a single ray R applies to each wave vector of each ray of optical radiation generated by the optical source 1, lighting the area Z1 of the banknote BA advancing along the path P.

Figure 7 shows how the ray R is partially scattered by the outer surface of the side B1 of the banknote facing the optical source 1. Vice versa, another part of the optical radiation of the ray R is reflected. The barrier 5, preferably absorbent or specular at the used wavelength, prevents the radiation scattered or reflected by the side B1 from reaching the receiver 3 arranged on the opposite side of the barrier 5 with respect to the optical source 1. A part of the optical radiation of the ray R scattered in the point A propagates and diffuses through the thickness of the banknote BA. A part of this radiation is reflected by the inner surface of the side B2 of the banknote BA facing the opposite side with respect to the optical source 1. Another part of the radiation propagating through the thickness of the banknote BA exits from the side B2.

In the diagram of figure 7, A indicates the point of incidence of the ray R on the surface B1. B indicates a generic point of the inner surface of the side B2 on which a ray, propagating from the point A through the thickness of the banknote BA, falls. This ray is reflected at B and reaches the point C, which is again arranged on the side B1 in the area Z2 framed by the receiver 3. A part of the radiation falling in C is scattered towards the outside. This part of optical radiation scattered towards the outside is very small, and a part thereof is collected by the receiver 3.

Figure 8 shows the same diagram of figure 7, but in this case a piece of semi-transparent and semi-reflective material, for instance adhesive tape, indicated with N, is applied on the banknote BA.

In the diagram of figure 8 the path A, B, C is indicated again, followed by a part of the optical radiation of the ray R that is scattered through the thickness of the banknote BA, reaches the point C on the outer surface of the side B1 and is scattered outside the banknote BA in the area Z2 framed by the receiver 3. In the diagram of figure 8 a further optical path is indicated, extending within the thickness of the adhesive tape N. This optical path is defined by the points A, E, C, and D. The point E is on the face N1 of the adhesive tape N opposite to the face N2 of the adhesive tape applied to the side B1 of the banknote. The adhesive tape N has a more reflective surface than the banknote BA, and the material of which it is made is more transparent than the paper forming the banknote BA. Therefore, a significant part of the optical energy contained in the ray R is conveyed along the path A, E, C, D. In the diagram of figure 8 a further path AG is also shown that, through the presence of the adhesive tape N, is conveyed through the path AGHLCD to the area Z2 framed by the receiver 3. As a result, in the point D, arranged in the area Z2 framed by the receiver 3, it diffuses towards the receiver 3 a significantly greater quantity of optical energy than that in the point C framed by the receiver 3 in the situation of figure 7, where there is no adhesive tape N.

As a result, the receiver 3 sees the adhesive tape N as an area that is brighter than the substantially dark background defined by the banknote BA.

From what has been disclosed with reference to figures 7 and 8, it is clearly apparent that the arrangement of the optical source 1 and of the receiver 3, arranged so as to light and frame different areas Z1 and Z2 of the banknote, allows to detect the adhesive tape N thanks to the optical characteristics of this latter, that differ from the optical characteristics of the banknote BA. Practically, the adhesive tape N is used like a light pipe with losses, conveying a part of the optical radiation incident on the area Z1, lighted by the optical source 1, towards the area Z2, framed by the receiver 3.

The presence of the barrier 5 and the arrangement of the optical source 1 and the receiver 3, spaced from each other, prevent the receiver 3 from receiving the optical radiation from the optical source 1; if it occurred, in fact, the receiver 3 would be "blinded", thus preventing the correct detection of adhesive tape N on the banknote BA.

What described above allows not only to detect a semi-transparent and semi-reflective material, such as a portion of adhesive tape N, applied on the side B1 of the banknote BA facing the optical source 1 and the optical receiver 3. In fact, as shown in figure 9, the same optical phenomenon described above allows also detecting a portion of adhesive tape N applied on the side B2 of the banknote BA opposite the optical source 1 and the optical receiver 3. In figure 9 the same numbers indicate identical or equivalent parts to those in figure 8. The adhesive tape N is applied with its face N2 on the side B2 of the banknote BA, opposite to the optical source 1 and to the optical receiver 3. Figure 9 shows again the optical path A, B, C of the part of light radiation of the ray R, which is scattered through the thickness of the banknote BA, is reflected in the point B, falls in the point C and partially exits in the area Z2 framed by the receiver 3. A part of the light radiation falls in the point D on the side B2 of the banknote BA, passes across the thickness of the adhesive tape N and is reflected in the point E on the face N1 of the adhesive tape N. The part of radiation that from the point E is reflected again towards the inside of the adhesive tape N falls on the banknote side B2 in the point F, passes through the thickness of the banknote BA and falls in the point C framed by the receiver 3. In this point C the small quantity of optical energy following the path A, B, C is added therefore to the greater quantity of optical energy following the path A, D, E, F, C, allowing again the detection of the adhesive tape N through the signal of the receiver 3.

Figure 10 shows a diagram of the device in the configuration of figure 6, where the optical paths of the radiation of a single ray R generated by the optical source 1 are represented, to show the operation of the method according to the invention in the case of detection in transmission instead of reflection.

In figure 10 the adhesive tape N is applied on the side B1 of the banknote BA facing the optical source 1. A, B, C, D is the path followed by a part of the radiation of the ray R that, falling in the point A of the lighted area Z1, is reflected, propagates through the adhesive tape N, is reflected in the point B on the inner surface N1, propagates again inside the adhesive tape N, exits from the point C, is scattered through the thickness of the banknote BA, and then exits from the point D in the area Z2 framed by the receiver 3.

If there were no adhesive tape N, there would be no radiation following the path A, B, C, D, and the signal detected by the receiver 3 would be therefore lower and almost null.

Figure 11 shows the same principle, but with the adhesive tape N applied on the side B2 of the banknote BA facing the receiver 3 and not on the side B1 facing the optical source 1. In this case the adhesive tape N generates an optical radiation path defined by the points A, B, C, D, and E. If there were no adhesive tape N, this part of optical radiation wouldn't be collected in the area framed by the receiver 3. In this case, in fact, the collected radiation would be only the radiation that from the point A, crossing the banknote BA, directly reaches the point D.

In all the illustrated configurations, it is therefore possible to obtain an increase in the optical radiation collected by the receiver 3 in the framed area Z2 when a portion of banknote BA, on which an adhesive tape N is applied, passes in front of the optical source 1 and the receiver 3.

Figures 12, 13, and 14 schematically show what occurs in terms of acquired image when there is no banknote BA (figure 12), when there is an undamaged banknote BA without adhesive tape (figure 13) and when there is a banknote BA with adhesive tape N applied on one of the two sides thereof (figure 14).

The results in figures 12 to 14 can be obtained with any one of the configurations illustrated in figures 8 to 11.

Figure 12A shows a substantially black acquired image; this indicates that in front of the receiver 3 there are no objects allowing the light radiation from the optical source 1 to reach the receiver 3. Figure 12B shows a pattern of the signal acquired by the receiver 3 as a function of the time (on the x-axis). Actually, if the receiver 3 is formed by an array of optical sensors, each sensor generates a signal like that indicated in the lower part of figure 12B. The image of figure 12A is completely dark as the source 1 lights an area Z1 of the object plane different than the area Z2 framed by the receiver 3. As source 1 and receiver 3 are not aligned, the only signal received is the noise.

In figure 13 a banknote BA is moving along the advancing path P. The banknote BA is undamaged, i.e. devoid of adhesive tape on both the sides B1 and B2. Figure 13A schematically shows the acquired image. With respect to the situation of figure 12, here the receiver 3 receives a quantity of optical radiation - even if a small quantity; the image is therefore clearer than that of figure 12A. Figure 13B represents the signal collected by the receiver 3 as a function of time. More exactly, the figure shows the trend over time (on the x-axis) of the amplitude of the signal (on the y-axis) generated by the light collected by the single receiver 3 or by a single element of the array forming the receiver 3. If the banknote has no alterations, the signals of the single sensors will be substantially equal to one another. The instants indicated with t1 and t2 on the x-axis indicate the instants when the initial edge and final edge of the banknote pass in front of the sensor generating the signal indicated on the y-axis. In the interval t1-t2 the acquired signal is greater than the signal acquired in absence of banknote, and it is due to the optical radiation, which propagates inside the paper material of the banknote BA from the area lit by the optical source 1 towards the area framed by the receiver 3, is scattered outside the banknote in said framed area, and is collected by the receiver 3 or more exactly by the single sensor forming it. As the banknote moves forward along the path P, through subsequent acquisitions it is possible to re-construct the whole image of the banknote.

In the situation shown in figure 14, an adhesive tape N is applied on one side or on the other side of the banknote BA. In figure 14A a light rectangle is superimposed on the banknote image acquired by the receiver 3; this rectangle represents the image of the piece of adhesive tape N applied on the banknote BA. The time-signal diagram of figure 14B shows the instants t1 and t2 when the initial edge and the final edge of the banknote BA pass in front of the optical sensor. Within this time interval, the points t3 and t4 show the instants when the initial edge and the final edge of the adhesive tape N pass in front of this sensor.

It should be understood that both in figure 14B and in figures 13B and 12B the signal in the diagram is that of a single sensor or of one of the various sensors or photo-detectors that, arranged in the form of a linear matrix, form the receiver 3. In the case of a linear matrix array, the position of the time instants t3 and t4 along the x-axis can vary from photo-detector to photo-detector and depends upon the inclination with which the adhesive tape N is applied on the surface of the banknote BA. Collecting and processing the signals provided by the single sensors or photo-detectors, a central processing unit can generate the whole image that will be formed by a substantially homogeneous background, on which the light rectangle corresponding to the piece of adhesive tape N stands out.

If the receiver is formed by a linear light pipe associated with a receiver, designed to collect on the same receiver all the radiation collected by the light pipe, only one output signal will be obtained, whose pattern nearly corresponds to that of figure 12B, 13B, or 14B depending upon the situation. In this case no image of the adhesive tape is generated on the background of the banknote.

Considering that the banknote surface is strongly scattering and that the semi-reflective and semi-transparent material of the adhesive tape N is both a light conveyor and a light pipe with losses, in some embodiments it is provided to convey again towards the material all the propagation directions of the optical radiation that would be scattered in the space outside the lobe, and would be therefore lost. The solutions may be various. The simplest solution is a distribution of specular surfaces between source and receiver on one or both the banknote sliding surfaces of the configurations of figures 8 to 11. This leads to images with a higher signal/noise ratio and a greater contrast between the situation of presence and the situation of absence of semi-reflective and semi-transparent material on the banknote. In some embodiments the optical source or sources 1; 23, 123 may be controlled through coded signals to decrease the optical noise of the outside environment and/or the electronic noise, and increase the signal/noise ratio.

From the description above it is clearly apparent how the method of the present invention allows to acquire images of the piece of adhesive tape applied on the banknote, or on other material or paper substrate or of any other type, under examination.

The device can be integrated in an equipment that besides verifying the presence of adhesive tape on the banknote or other substrate, also acquires the image of the same document and/or to perform further controls. This is useful for instance in the case of equipment used for verifying the authenticity of the banknotes and, if necessary, for identifying their nomination and the wear levels, and consequently for distributing them in a series of drawers or containers provided to this end. Equipment of this type are known per se and their methods for identifying the authenticity, the nomination and the wear level do not required to be described herein.

Figure 15 schematically shows a configuration of a device allowing both to acquire the banknote image and to detect the presence of adhesive tape on one or the other banknote side. The same numbers indicate identical or equivalent parts to those of the previous figures. In this embodiment, one of the possible solutions is indicated for arranging a mirror surface along the feeding path P of the banknote BA . More in particular, in this embodiment a wall 21 is provided with a mirror surface 21A, which reflects at the used wavelengths. Obviously, this feature may be omitted. Number 5 indicates the absorbent or reflecting barrier separating the optical source 1 from the area in front of the optical receiver 3. On the opposite side of the path P with respect to the barrier 5, the wall 21 acts also as a barrier to prevent the receiver 3 from directly seeing the optical radiation coming from the source 1. A further barrier, not shown, may also be provided, similar to the barrier 5 orthogonal to the advancing plane of the banknote BA on the half plane containing the receiver.

Number 23 indicates a second optical source arranged in front of the receiver 3. The receiver 3 can therefore acquire images obtained through the optical radiation generated by the optical source 1 and images generated by the optical radiation coming from the optical source 23. The image obtained by the receiver 3 through the radiation generated by the optical source 1 is that for the detection of the adhesive tape on the banknote, and is acquired as described above.

The image obtained by the receiver 3 through the radiation generated by the optical source 23 is a normal transparent image obtained through methods known in the machines and equipment for banknote detection. In figure 15, number 20 schematically indicates a suitable central control unit interfaced with the optical sources 1, 23 and with the receiver 3. This unit makes the receiver acquire in subsequent steps and sequentially both the two images, activating in fast sequence and repeatedly at one time the optical source 1, at another time the optical source 23. The result is schematically illustrated in figure 15. On the right part of figure 15 a combination C1 is shown of the transparent images of the banknote BA obtained through the source 23 and of the images of the adhesive tape N obtained through the optical source 1. After having acquired subsequent image portions sequentially, the central unit 20 is able to re-construct on one hand the image C2 of the banknote through the optical radiation generated by the source 23 and on the other hand the image C3 of the adhesive tape N applied on the banknote BA.

The resolution required for acquiring the image C2 of the banknote and for acquiring the images C3 of the pieces of adhesive tape N is relatively low; it is therefore possible simultaneously to acquire the images C2 and C3 simply through a time scanning, sequentially activating the source 1, 23 in subsequent advancing steps of the banknote BA, without the need for stopping it during the motion thereof along the feeding path P. The image C2 will be substantially re-constructed through the sum of sub-images spaced from one another in the banknote advancing direction FA. With the spaced sub-images forming the image C2, sub-images are alternated, acquired through the optical radiation of the source 1, generated by the banknote and by the adhesive tape N to form the image C3. It is also possible to advance the banknote BA in subsequent steps, alternated with stop instants, during which it is possible sequentially to actuate the optical source 1 and the optical source 23 to acquire, for each banknote portion, two substantially linear sub-images that will be then processed by the central control unit 20 to form the image C2 of the banknote and the image C3 of the piece of adhesive tape N, if any. In this case, the acquisition is slower but the acquired image has a higher resolution, as each of the images C1 and C2 is constituted by the sum of sub-images that together cover the whole banknote. Even if in the figure the scan direction is according to the banknote height (smaller side), the method is also valid for a banknote advancing according to its width (longer side). It should be understood that in other embodiments the banknote, or other object under examination, may be kept in position and scanned moving the source and the receiver with respect to the object. Scanning may occur according to only one direction, using for instance a linear source and a linear receiver. In other embodiments one-dimensional sources and receivers may be used, moved according to two different scan directions, for instance orthogonal to each other.

Figure 16 shows a section of a device according to the invention, according to a plane orthogonal to the advancing plane of the banknote BA. Equal numbers indicate equal or equivalent parts to that described with reference to the previous schematic figures. Number 25 indicates, generically and as a whole, a CIS containing the optical receiver 3 and the second optical source 23 described with reference to figure 15. The optical source 1 is outside the CIS 25, in front of an aperture 30 formed in a wall 31 that, together with an opposite wall 33, defines the advancing path P of the banknote BA. Both the walls 31 and 33 may have a suitable distribution of reflecting surfaces. For instance the wall 33 may contain a mirror 34, equivalent to the reflecting surface 21A of the wall 21 described with reference to figure 15. 35, 37, and 39 schematically indicate members for moving the banknote BA along the path P. In the illustrated example these moving members are constituted by a first pair of rollers 35, 37, at least one of which is motorized, and by a second pair of rollers 39, 41, at least one of which is motorized. The arrangement of the sources 1, 23 and of the receiver 3 allows the acquisition of the images of adhesive tape N - source 1 and receiver 3 - and of the banknote BA - source 23 and receiver 3 - as described with reference to the previous figures. The source 1 may be a discrete or continuous source (of the type described in WO-A-00/77447) suitably fixed to the wall 25. A second CIS may be for instance used adjacent to the CIS 25 of figure 16, whose source is used together with the receiver 3 of the CIS 25 to produce images of the adhesive tape.

Figure 17 shows an axonometric view of some components of figure 16, to better illustrate their position in the space.

The arrangement of the sources 1, 23 in figure 16 is only one of the possible arrangements. Alternative arrangements are in fact also possible. For instance, the source 1 may be arranged on the opposite side with respect to the receiver 3, in such a position to fall in the situations described in figures 10 and 11. In this case the image obtained through reflection, with source 23 and receiver 3, is useful for producing images of the banknote BA. The image obtained through transparency using the source 1 and the receiver 3 represents the image for the detection of the adhesive tape N. The source 1 may be a continuous source (see WO-A-00/77447) or a discrete one or it may be the inner source of a further CIS arranged on the opposite side with respect to the receiver 3.

Figure 18 shows a section according to a plane orthogonal to the advancing plane of the banknote BA of a device according to the invention in a different configuration. The same reference numbers indicate equal or equivalent parts to those described with reference to the previous schematic figures. Figure 18 shows a configuration with two CISs suitably facing each other and indicated with 25A and 25B. Using the source 1 of the CIS 25B and receiving with the receiver 3A of the CIS 25A the transparent image is obtained for the detection of the adhesive tape N. Using the source 23 of the CIS 25A and receiving with the receiver 3B of the CIS 25B the transparent image is obtained of the banknote BA. Both the walls 31 and 33 defining the advancing path P of the banknote BA may have an adequate distribution of reflecting surfaces 34. Furthermore, in this configuration the two CISs 25A and 25B may be used to obtain reflection images of both the banknote sides. The central unit 20 manages the timing for the acquisition of the different types of images as described with reference to the previous figures.

The described device may be completed with further sensors and detecting means of the known type, arranged along the path P of the banknote BA, for instance a further CIS to acquire the image of the banknote side opposite that acquired by the sensor 25, magnetic sensors, capacitive sensors and the like.

Exploiting the idea of the present invention it is possible also to define a new family of contact devices as simplified in figure 19(A), (B) and (C), where three possible configurations according to the invention are illustrated. The same reference numbers indicate equal or equivalent parts to those described with reference to the previous schematic figures. Reflection images of the banknote may be obtained with source 23 and receiver 3 as indicated in the figures 19A and 19B and with source 123 and receiver 4 as indicated in figure 19C. Images for the detection of the adhesive tape N may be obtained with source 1 and receiver 3 as indicated in figures 19A and 19B and with source 123 and receiver 3 as indicated in figure 19C. The barrier 5 made of absorbent or reflective material ensures that source 1 and receiver 3 frame different areas of the object. The barrier 5 may be omitted using strongly directional sources and receivers. These new types of devices may be also used in the mechanical arrangements described above. In this case again an adequate distribution of reflecting surfaces 34, on the walls 31 and 33 defining the advancing path P of the banknote BA, allows improving the quality of the images.

Figures 20 and 21 show other configurations of detection systems according to the invention. In figure 20, a linear array of receivers 3 extends parallel to the advancing path P of the banknote BA. A single source 1 is arranged in an intermediate position along the extension of the linear array of receivers 3. The arrangement may be multiplied forming a two-dimensional matrix of receivers 3 and a linear array of sources 1. Considering a single linear array of receivers 3 and a single optical source 1, when a banknote or other object under examination passes along the advancing path P, the receiver in front of the source 1 shoots the transparent image. The adjacent receivers 3, arranged off-axis with respect to the source 1, may receive the optical radiation conveyed by the semi-transparent and semi-reflective material, if any, applied on the banknote BA, generating a corresponding signal.

In figure 21 a linear optical source 1, obtained for instance as described in WO-A-00/77447, is arranged in front of a single receiver 3, which is positioned in an intermediate position with respect to the linear extension of the optical source 1. In front of the receiver 3 a shield or barrier 8 is arranged, preventing the light emitted by the source 1 from directly achieving the receiver 3. The semi-transparent and semi-reflective material applied on the banknote BA advancing along the path P between the source 1 and the receiver 3 generates a signal due to the effect of the light conveyed through the semi-transparent material from the area of the uncovered source 1 (i.e. outside the shield 8) to the receiver 3.

It is understood that the drawing only shows an example provided by way of a practical arrangement of the invention, which can vary in forms and arrangements without however departing from the scope of the concept underlying the invention. Any reference numbers in the appended claims are provided for the sole purpose of facilitating reading of the claims in the light of the description and the drawing, and do not in any manner limit the scope of protection represented by the claims.

## Claims

1. A method for detecting a first foreign material (N) randomly applied on an object (BA) under examination formed by a second material, wherein said first foreign material (N) is transparent or semi-transparent and said second material is absorbent and/or scattering at at least one wavelength of an optical radiation, comprising the steps of:

- lighting a first area (Z1) of the object (BA) under examination by means of at least one optical source (1) emitting at least at said wavelength;
- framing a second area (Z2) of the object (BA) by means of an optical receiver (3), said optical receiver (3) and said optical source (1) being designed and arranged so that the first area (Z1), lit by the optical source (1), is different from the second area (Z2) framed by the optical receiver (3);
- detecting said first foreign material (N) on a surface of said object (BA) through a change in the optical signal on the optical receiver (3) due to optical radiation emitted by the optical source (1) and conveyed through said first foreign material (N) from the first area (Z1) up until the second area (Z2).

2. Method according to claim 1, wherein said first material and said second material are sheet or web materials.

3. Method according to claim 2, wherein said second material is a paper sheet.

4. Method according to claim 1, or 2, or 3, wherein said foreign first material is a sheet or web material, in particular an adhesive tape transparent or semi-transparent to said at least one wavelength of said optical source.

5. Method according to one or more of the previous claims, wherein said second material is a banknote.

6. Method according to one or more of the previous claims, wherein said optical source and said optical receiver operate in the infrared and/or visible spectrum.

7. Method according to one or more of the previous claims, comprising the steps of:

- lighting said first area (Z1) by means of said optical source (1);

– lighting said second area (Z2), framed by said receiver (3), by means of a second optical source (23);

– by means of said optical receiver (3), alternatively acquiring a first signal related to the radiation emitted by the first optical source (1) and a second signal related to the radiation emitted by the second optical source (23).

8. Method according to one or more of claims 1 to 7, comprising the step of framing said first area (Z1) by means of a second optical receiver (4) and acquiring the signal of said first area (Z1) through said second optical receiver (4).

9. Method according to one or more of the previous claims, comprising the steps of completely scanning the object (BA) moving said object with respect to said optical source (1) and to said optical receiver (3).

10. Method according to claim 9, comprising the step of re-constructing an image of said object (BA) and of the foreign first material (N) applied threon, if any, through the signals received by said optical receiver (3).

11. Method according to one or more of the previous claims, wherein said object (BA) under examination is shot through a plurality of sensors and the signals of said sensors are combined together to form an image of said object (BA) and of the material (N) randomly applied thereon, if any.

12. A device to detect the presence of a first foreign material (N) applied on a surface of an object (BA) under examination formed by a second material, comprising:

- at least one first optical source (1) emitting an optical radiation at at least one wavelength, to which said foreign first material (N) is transparent or semi-transparent and said second material is absorbent and/or scattering,
- and a first optical receiver (3);

wherein said first optical source (1) and said first optical receiver (3) are designed and arranged so that said optical source (1) lights a first area (Z1) of a surface of said object (BA) and said optical receiver (3) frames a second area (Z2) of a surface of said object (BA) different from the first area (Z1), said first area (Z1) being not framed by said optical receiver (3), and wherein said foreign first material (N) is detected through a change in the optical signal on the optical receiver (3) due to optical radiation emitted by the optical source (1) and conveyed through said foreign first material (N) from the first area (Z1) up until the second area (Z2).

13. Device according to claim 12, comprising an advancing path (P) of the object (BA) under examination and a transport system for moving the object along said advancing path, said optical source (1) and said optical receiver (3) being designed and arranged to scan the entire surface of said object (BA) whilst said object (BA) moves along said advancing path (P).

14. Device according to claim 12 or 13, wherein said first optical source (1) lights the surface of the object (BA) according to a direction that is an inclined or orthogonal to a direction (FA) of relative motion of said optical source and optical receiver with respect to said object (BA), and wherein said optical receiver is arranged to receive a radiation emitted by the object (BA) according to a direction orthogonal or inclined to said direction (FA) of relative motion

15. Device according to one or more of claims 12 to 14, wherein said first optical source (1) is arranged so as to be into contact with the object (BA) and/or said first optical receiver (3) is arranged so as to be into contact with said object (BA).

16. Device according to one or more of claims 12 to 15, wherein said first optical source (1) comprises a plurality of optical emitters forming a linear matrix of optical emitters and/or said optical receiver (3) comprises a plurality of optical sensors forming a linear matrix of optical sensors.

17. Device according to one or more of claims 12 to 16, wherein said optical source (1) comprises one or more light pipes and/or said optical receiver (3) comprises one or more light pipes, said light pipes being preferably optical fibers.

18. Device according to one or more of claims 12 to 17, wherein said optical source (1) comprises at least one laser diode.

19. Device according to one or more of claims 12 to 18, wherein said first optical receiver (3) and said first optical source (1) are arranged on opposite sides of an advancing path of the object (BA), or said first optical receiver (3) and said first optical source (1) are arranged on the same side of said advancing path.

20. Device according to one or more of claims 12 to 19, comprising a member preventing the optical radiation of said optical source (1) from lighting the second area (Z2) framed by said first optical receiver (3).

21. Device according to claim 20, wherein said member comprises an element chosen from the group comprised of: an optical barrier, optical systems, mirrors, lenses, diaphragms, or combinations thereof.

22. Device according to one or more of claims 12 to 21, comprising at least one reflecting surface (21A) to convey back toward said object (BA) optical radiation scattered by the second material forming the object (BA) or by the foreign material (N).

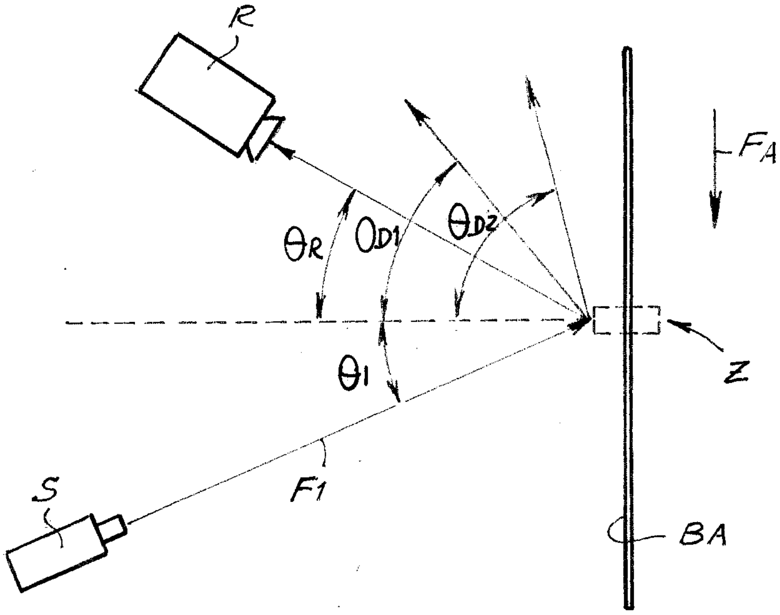
23. Device according to claim 22, comprising a mirror (21A) arranged parallel to a plane of laying of the object (BA), so as to reflect the optical radiation emitted by said first optical source (1) crossing the object (BA) and exiting from the surface thereof opposite to the entrance surface of the optical radiation emitted by the first optical source (1).

24. Device according to one or more of claims 12 to 23, comprising a second optical source (23) arranged relative to said first optical receiver (3) so as to light said second area (Z2) framed by said first optical receiver (3).

25. Device according to claim 24, comprising a control unit actuating selectively said first optical source (1) and said second optical source (23) so as to acquire through said first optical receiver (3) a first image of said object (BA) and a second image of the foreign first material (N), if any, applied on the object (BA).

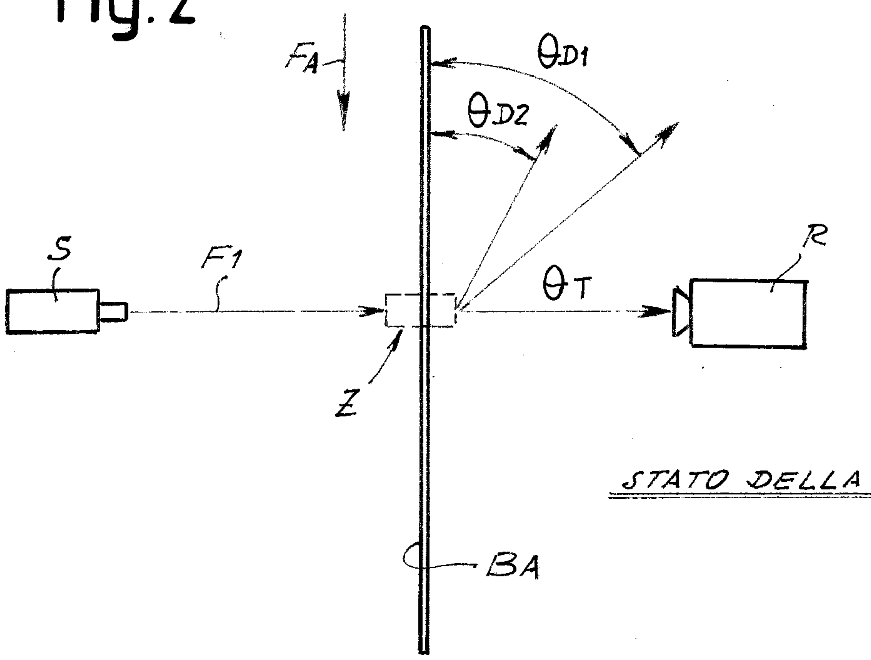
26. Device according to one or more of claims 12 to 25, comprising a second optical receiver (4), said first optical receiver (3), said second optical receiver (4), and said first optical source (123) being arranged so that: the first optical source (123) lights said first area (Z1) of said object (BA); said first optical receiver (3) frames said second area (Z2) of said object (BA); and said second optical receiver (4) frames said first area (Z1) lighted by the first optical source (123).

Fig.1




STATO DELLA TECNICA

Fig. 2




STATO DELLA TECNICA

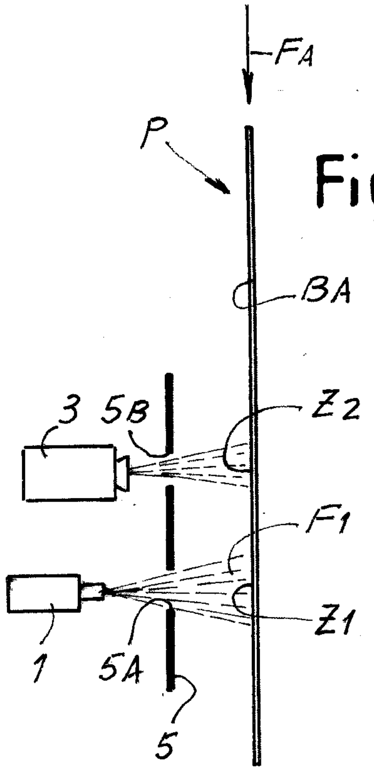



Fig.3

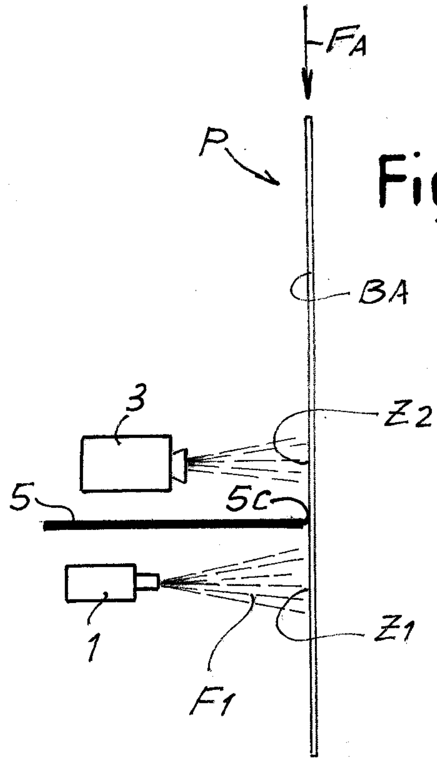



Fig.4

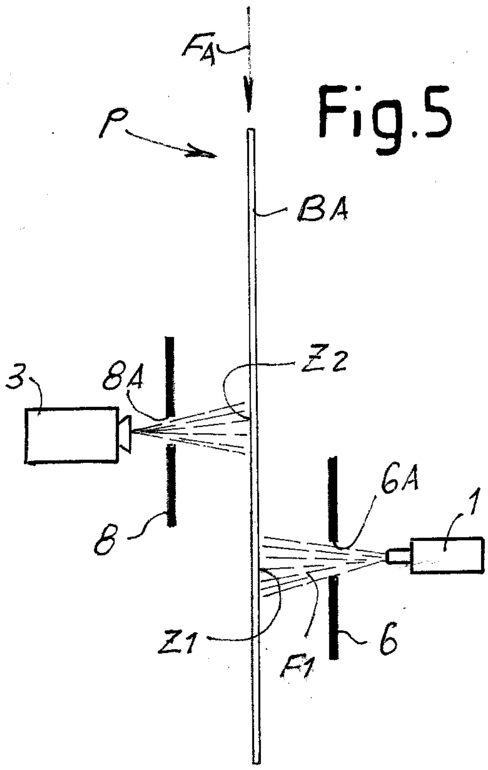



Fig.5

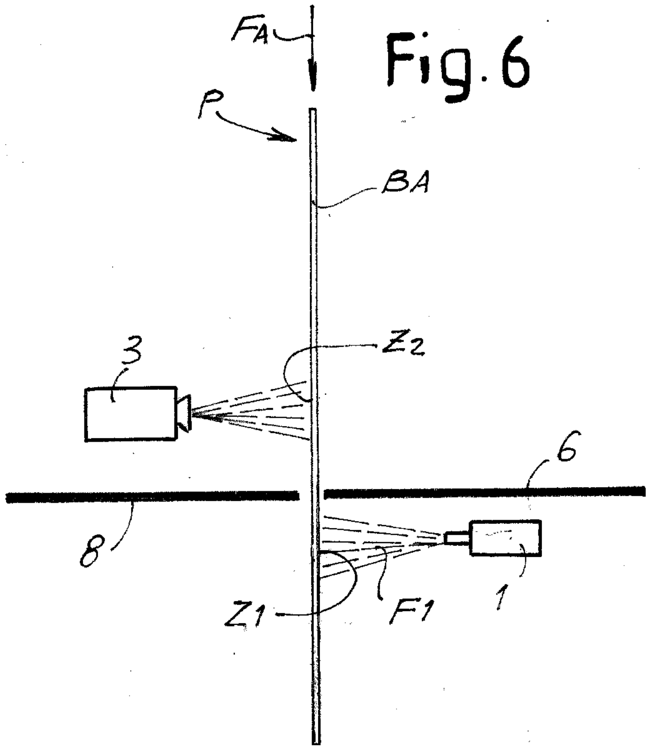



Fig.6

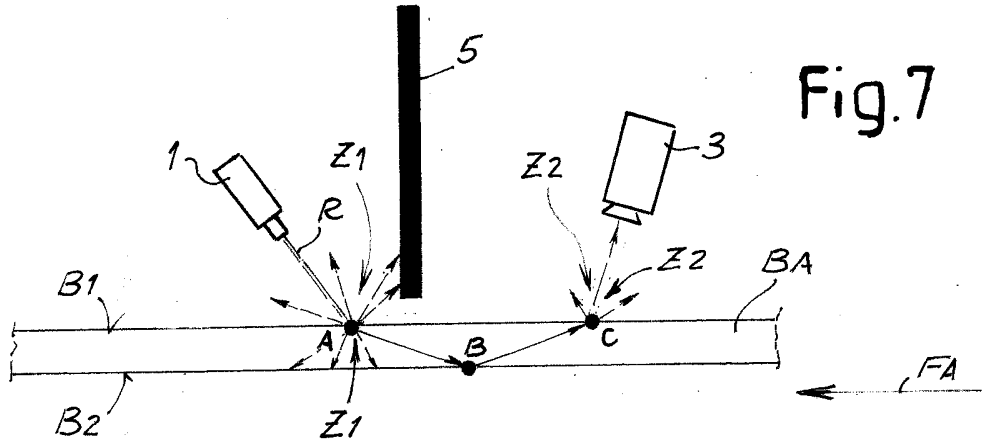



Fig.7

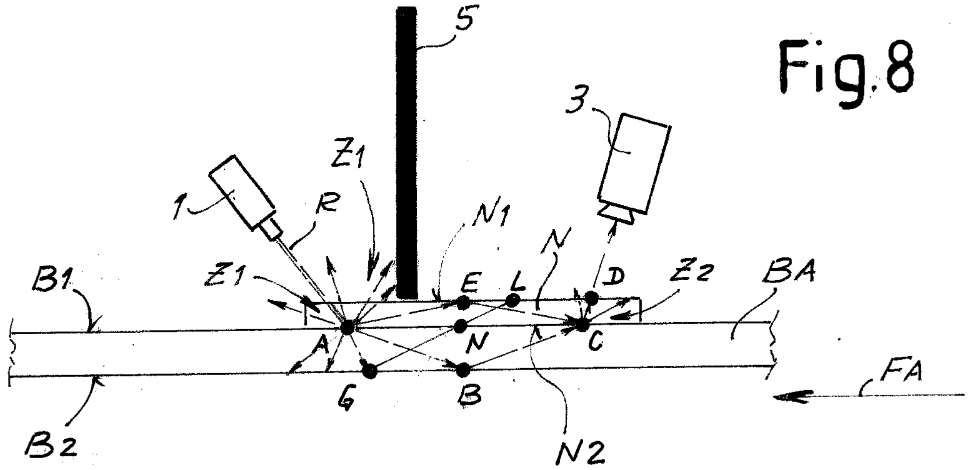



Fig.8

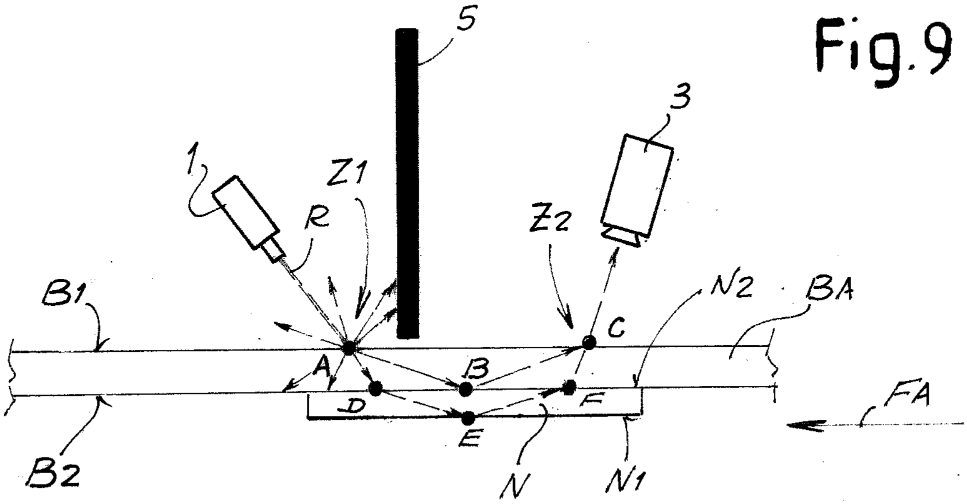



Fig.9

Fig.10

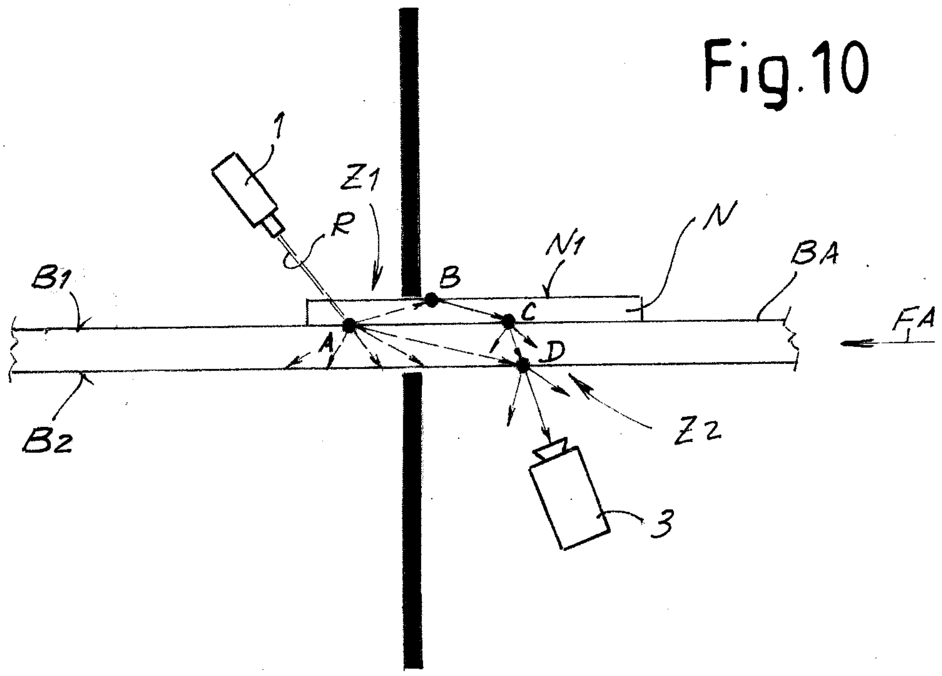
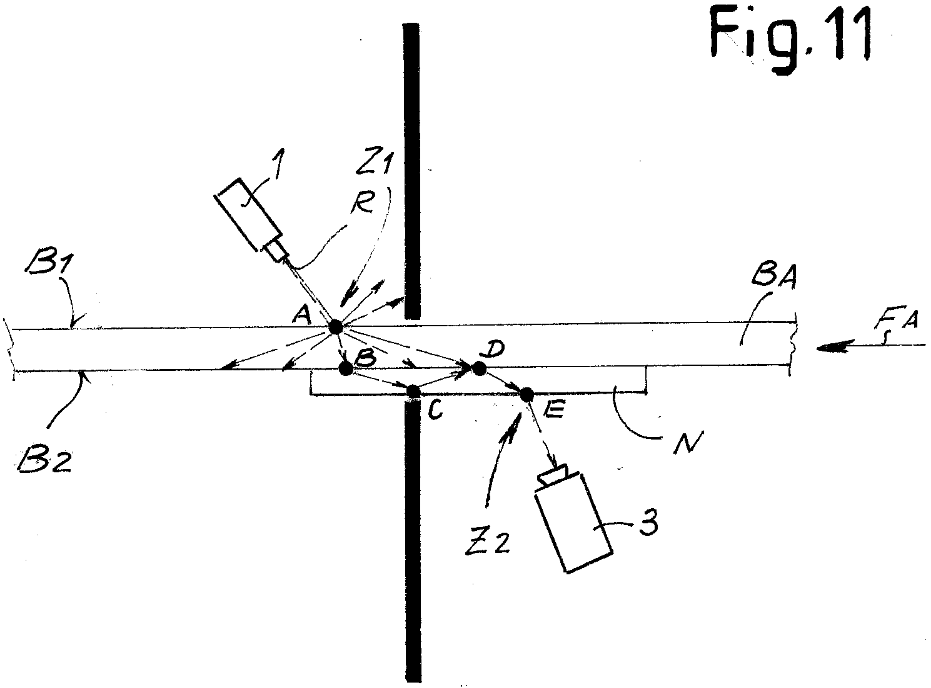



Fig.11



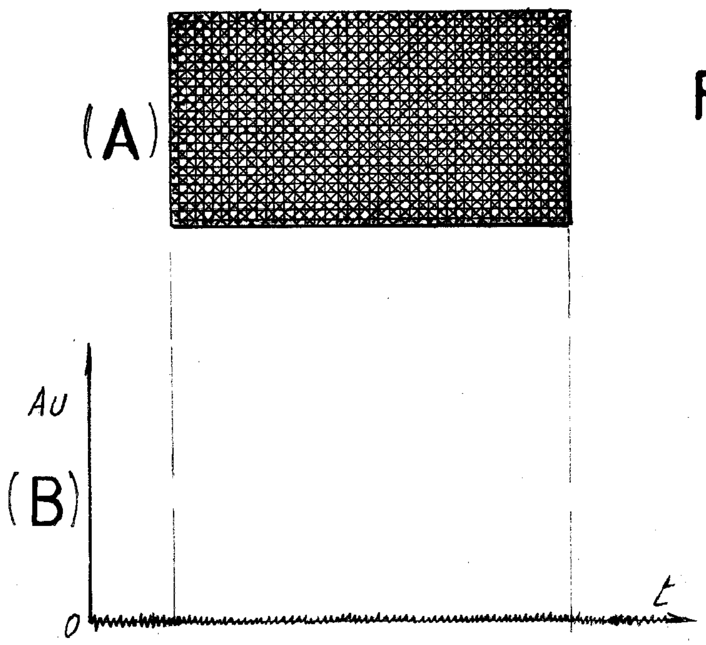



Fig.12

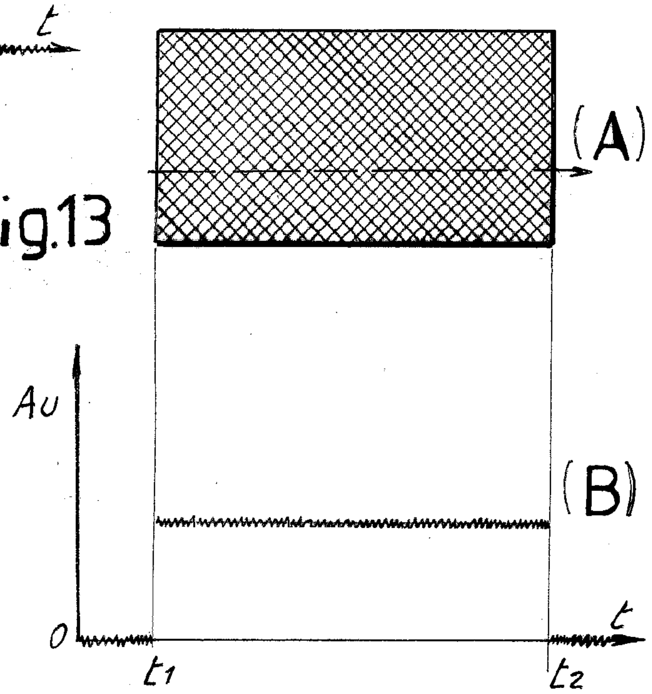



Fig.13

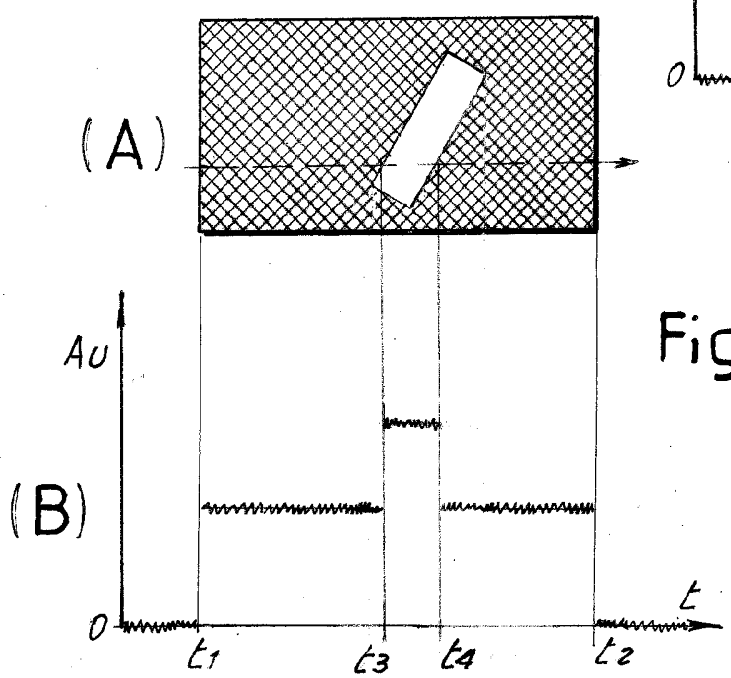
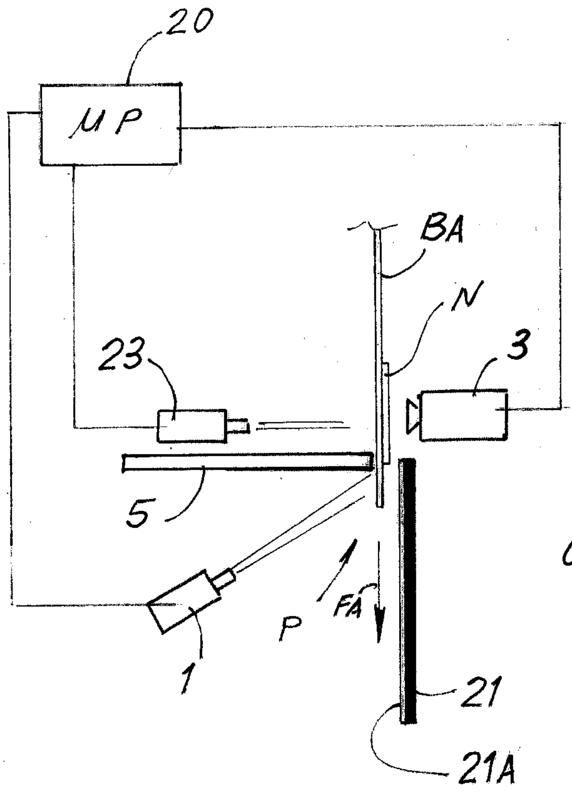



Fig.14

Fig. 15



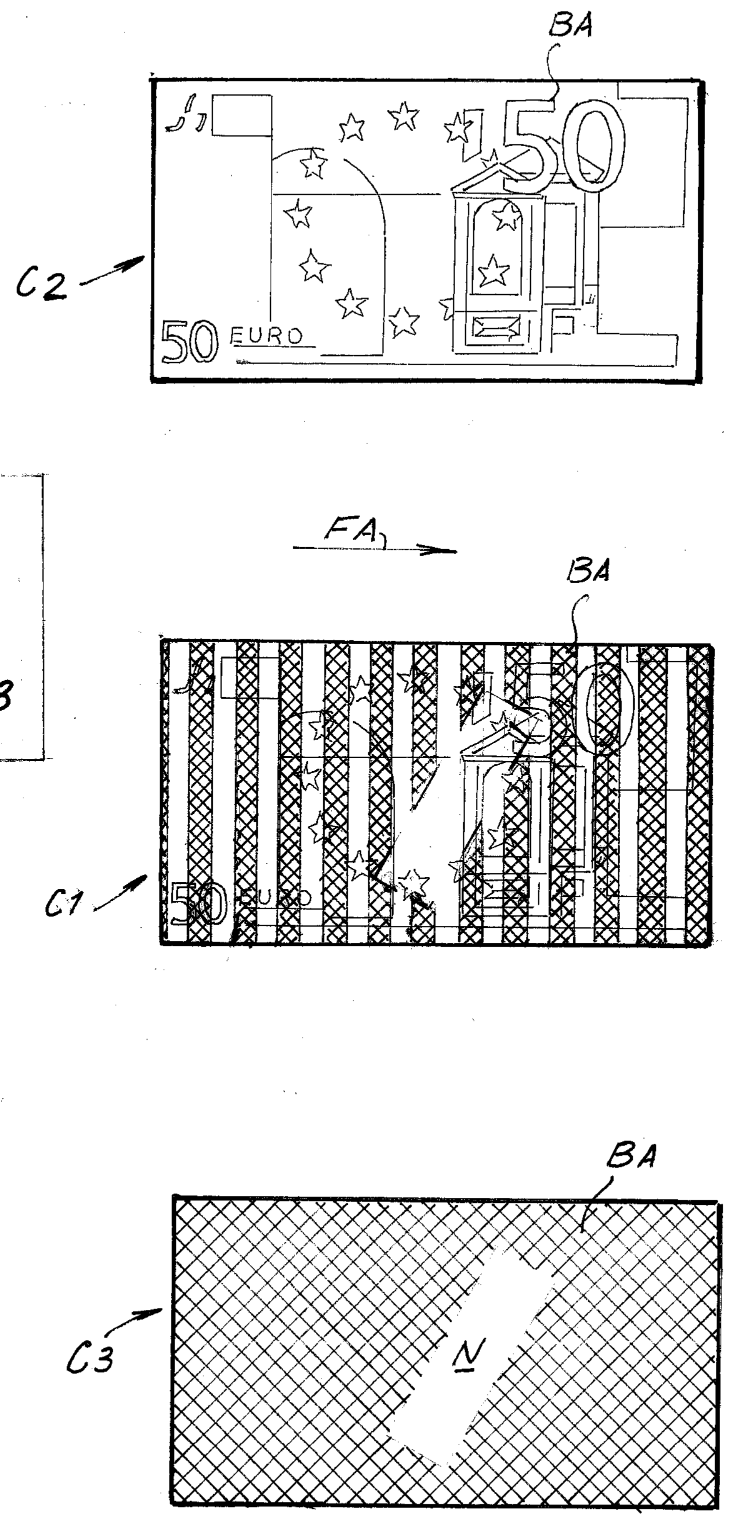
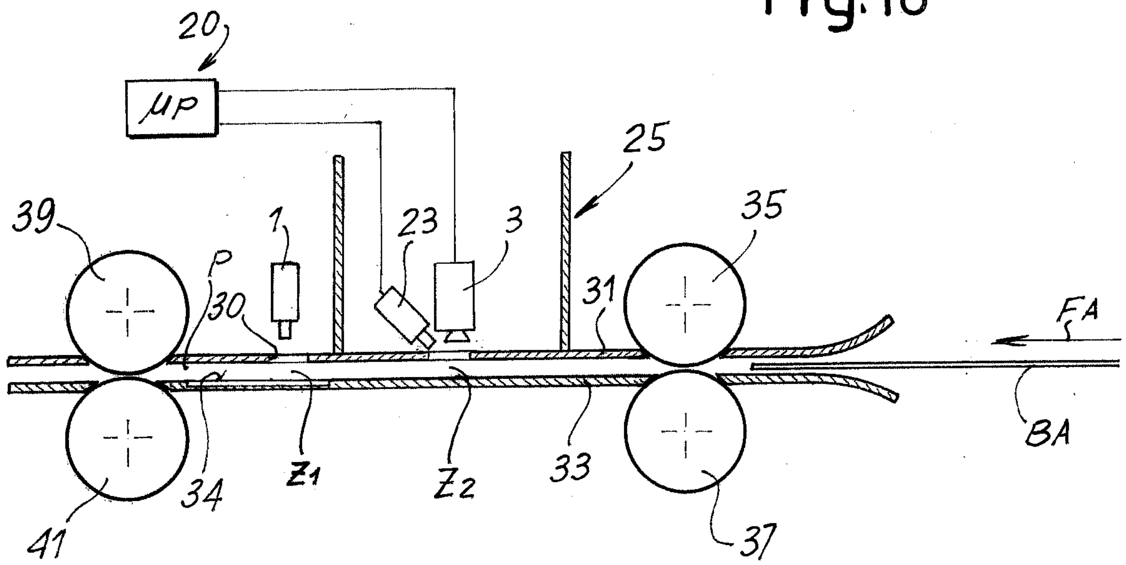



Fig.16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FA
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34
Z1
Z2
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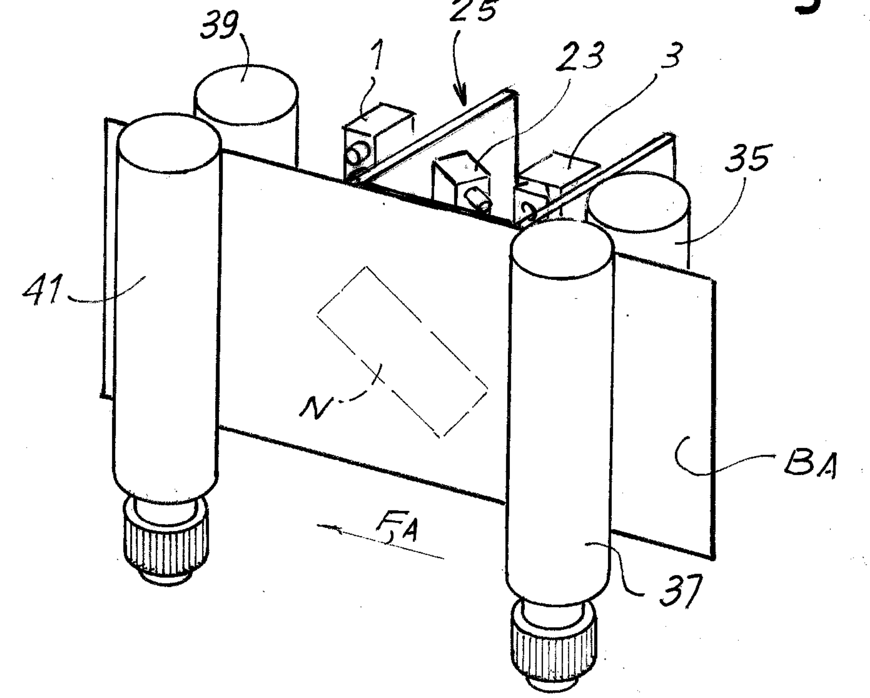
41
37

Fig. 17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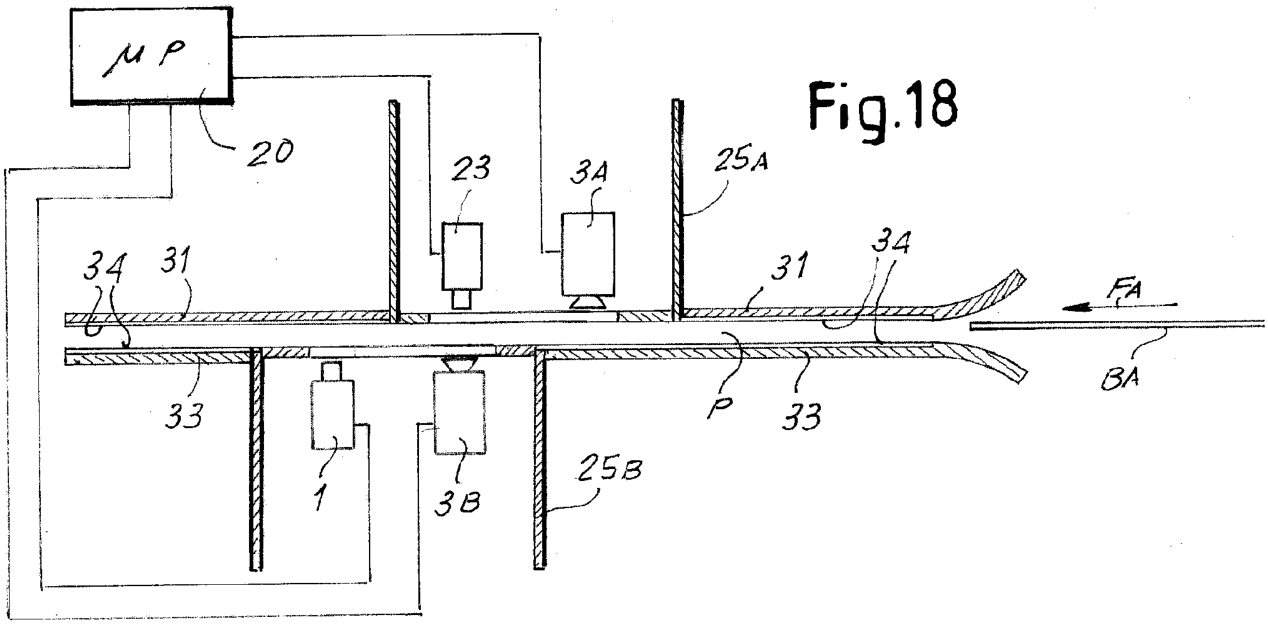
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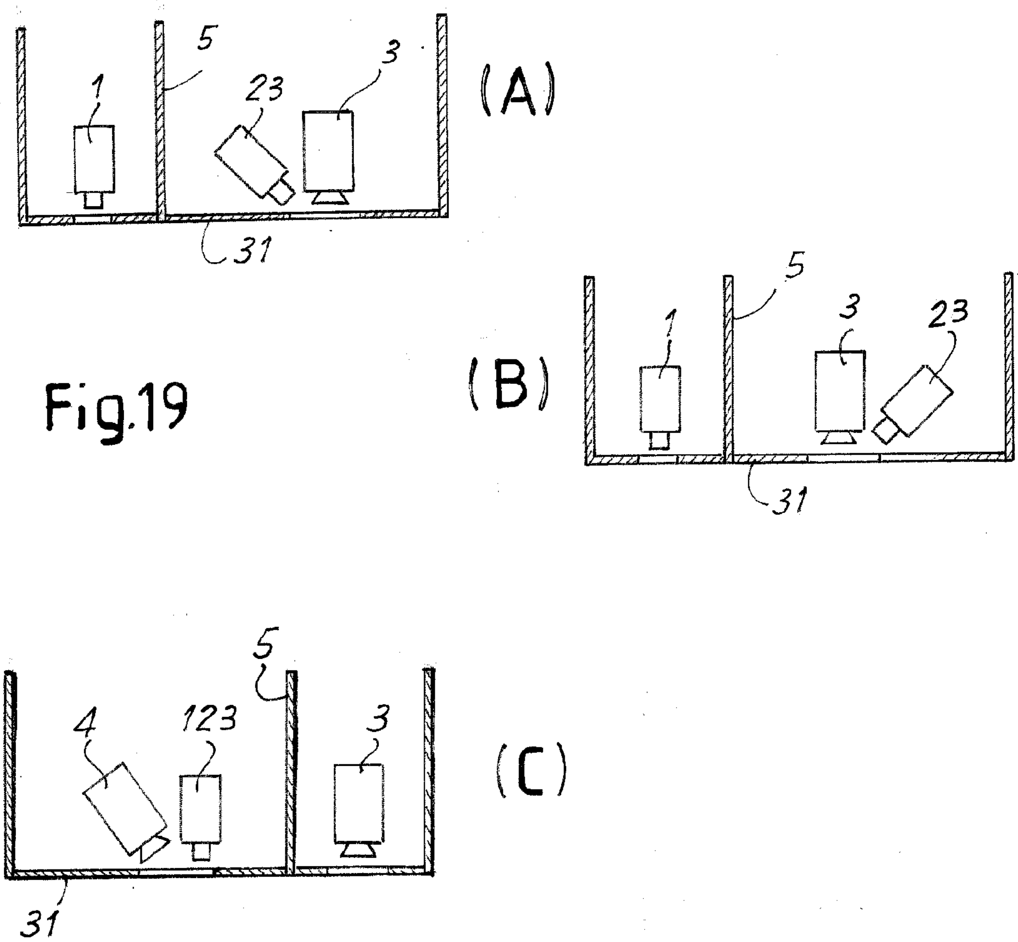
Fig.18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(B)
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4
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31
(C)

Fig.19

Fig. 20

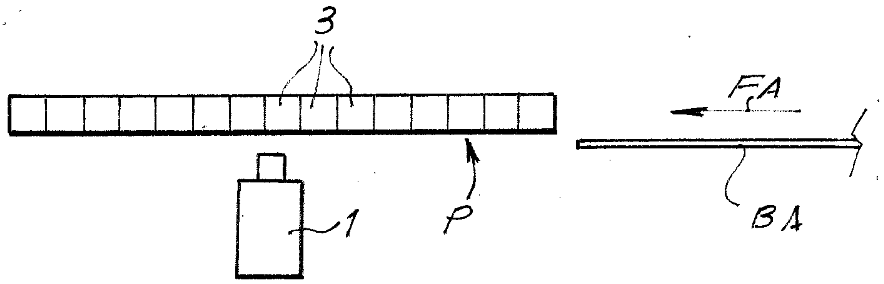
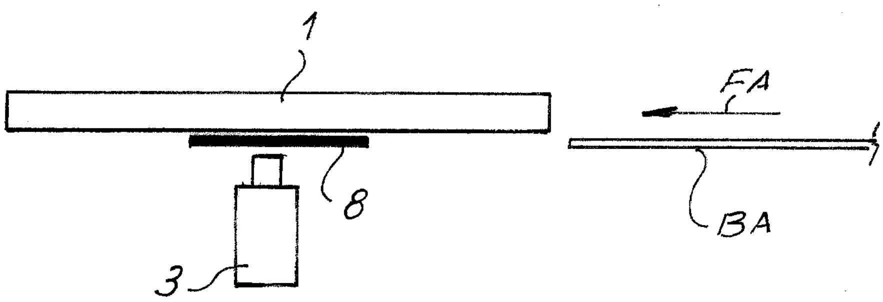



Fig. 21



# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/055280

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G07D7/12
ADD.

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
G07D

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

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

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 87/06041 A1 (ESSELTE VAERDETRYCK AB [SE]) 8 October 1987 (1987-10-08) | 1,7,8, 12-14, 16-26 |
| Y | page 4, line 15 - line 39 | 2-6,9-11 |
| A | page 5, line 10 - line 19; figures 2, 3<br>page 7, last paragraph<br>page 8, line 21 - line 26<br>page 8, line 31 - page 9, line 19; figure 7<br>----- | 15 |
| X | WO 2011/072405 A1 (ORELL FUESSLI SICHERHEITSDRUCK [CH]; EICHENBERGER MARTIN [CH]) 23 June 2011 (2011-06-23) | 1,6, 12-14, 16-24,26 |
| Y | page 5, line 12 - page 6, line 35 | 2,3 |
| A | page 9, line 33 - page 10, line 4; figure 6<br>-----<br>-/-- | 4,5, 7-11,15, 25 |

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

[X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 29 January 2013 | 05/02/2013 |

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

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International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br><br>Y<br>A | US 2003/234362 A1 (THIERAUF KLAUS [DE] ET AL) 25 December 2003 (2003-12-25)<br>paragraphs [0022], [0026], [0029] - [0034]; figure 1 | 12-14, 16-26<br>4-6,9-11<br>1-3,7,8, 15 |
| X<br><br>A | EP 2 290 622 A2 (TOSHIBA KK [JP])<br>2 March 2011 (2011-03-02)<br>paragraphs [0059] - [0061], [0063] - [0065], [0111], [0116]; figures 4, 5, 9, 10 | 12-14, 16-26<br>1-11,15 |

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/055280

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| WO 8706041 | A1 | 08-10-1987 | EP | 0263099 | A1 | 13-04-1988 |
| | | | SE | 447516 | B | 17-11-1986 |
| | | | SE | 8501458 | A | 26-09-1986 |
| | | | WO | 8706041 | A1 | 08-10-1987 |
| WO 2011072405 | A1 | 23-06-2011 | AU | 2009356927 | A1 | 12-07-2012 |
| | | | CA | 2784619 | A1 | 23-06-2011 |
| | | | CN | 102781629 | A | 14-11-2012 |
| | | | EP | 2512742 | A1 | 24-10-2012 |
| | | | KR | 20120123050 | A | 07-11-2012 |
| | | | SG | 181783 | A1 | 30-07-2012 |
| | | | US | 2012299287 | A1 | 29-11-2012 |
| | | | WO | 2011072405 | A1 | 23-06-2011 |
| US 2003234362 | A1 | 25-12-2003 | DE | 10217586 | A1 | 20-11-2003 |
| | | | GB | 2390898 | A | 21-01-2004 |
| | | | US | 2003234362 | A1 | 25-12-2003 |
| EP 2290622 | A2 | 02-03-2011 | CN | 102005076 | A | 06-04-2011 |
| | | | EP | 2290622 | A2 | 02-03-2011 |
| | | | JP | 2011048677 | A | 10-03-2011 |
| | | | US | 2011052085 | A1 | 03-03-2011 |