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(54) Title: IMAGE CAPTURING SYSTEM AND QUALITY INSPECTION SYSTEM WITH IMAGE CAPTURING SYSTEM

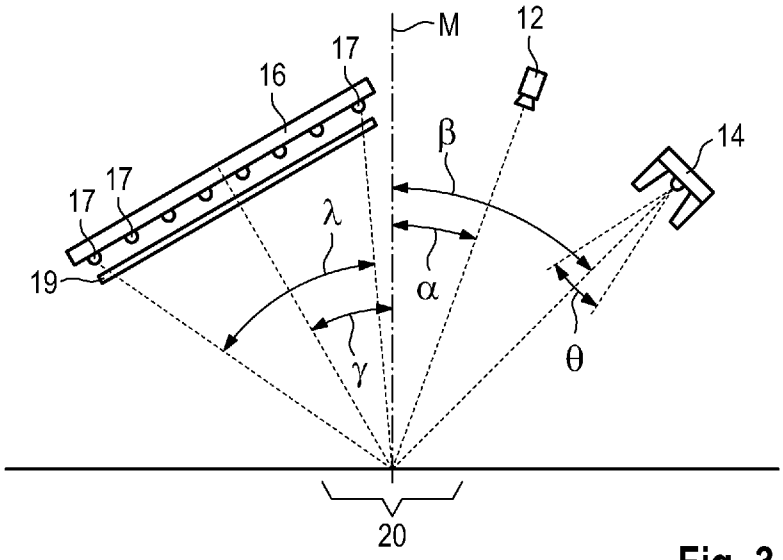

Fig. 3

(57) Abstract: An image capturing system comprising a line camera (12) adapted for capturing a linear viewing area (20), a dark-field illuminator (14) and a bright-field illuminator (16) illuminating the viewing area (20), wherein the components are arranged such that with respect to a reference plane (M) which is perpendicular to the surface of the sheet elements (4) passing through the viewing area (20) where images are being captured, the optical plane of the line camera (12) being arranged with an angle (a) of approx. 10° to 30°, preferably 20°, with respect to a reference plane (M), the optical plane of the dark-field illuminator (14) being arranged at an angle (β) of approx. 30° to 60°, preferably 45°, with respect to the reference plane (M), and the optical plane of the bright-field illuminator (16) being arranged at an angle (γ) of approx. 20° to 40°, preferably 30°, with respect to the reference plane (M), the bright-field illuminator (16) having an opening angle between 50° and 1 10°, preferably between 80° and 90°.

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Image capturing system and quality inspection system with image capturing system

The invention relates to an image capturing system and to a quality inspection station adapted for inspecting sheet elements in a sheet element processing machine.

The term “sheet element processing machine” is here intended to comprise any machine which is being used for processing sheet elements such as paper, cardboard, plastic foil or similar materials, in particular printing machines, coating machines, laminating machines and converting machines (for example cutting, stamping, folding and/or gluing machines).

It is generally known to inspect the surface of the sheet element moved through the quality inspection station with a camera and to analyze the captured images in various respects. To this end, quite elaborate cameras and associated illumination units are being used which are fitted into the sheet element processing machine at the quality inspection station.

The object of the invention is to allow inspecting the surface of sheet elements to be inspected in different respects.

In order to achieve this object, the invention provides an image capturing system comprising a line camera capturing a linear viewing area, a dark-field illuminator and a bright-field illuminator illuminating the viewing area, wherein the components are arranged such that with respect to a reference plane which is perpendicular to the surface of the inspected sheet element passing through the linear viewing area, the optical plane of the camera being arranged with an angle of approx. 10° to 30°, preferably 20°, with respect to the reference plane, the optical plane of the dark-field illuminator being arranged at an angle of approx. 30° to 60°, preferably 45°, with respect to the reference plane, and the optical plane of the bright-field illuminator being arranged at an angle of approx. 20° to 40°, preferably 30°, with respect to the reference plane, the bright-field illuminator (16) having an opening angle between 50° and 110°, preferably between 80° and 90°. It has been found that this arrangement of the components allows inspecting the surface of sheet elements simultaneously in many respects, for example regarding the

position of embossed structures, the position of reflective surface portions or the identification of scratches in the surface.

The distance of the camera is 600 mm ±200mm depending on the width to cover.

It is possible to use more than one line camera together with the same illumination system, in particular two or three cameras.

In order to obtain a more compact design, a mirror can be used to fold the path of the light towards the camera.

The dimension of the viewing area, measured perpendicular to the direction of movement of the sheet elements, can be 400 mm to 1500 mm and sometimes even up to 3200 mm in length, with the dimension parallel to the direction of movement of the sheet elements being very low, for example only a few millimeters in width.

Preferably, the camera and the dark-field illuminator are arranged on the same side of a reference plane, and the bright-field illuminator is arranged, with respect to the same reference plane, on a side which is opposite the side at which the camera is arranged.

According to a preferred embodiment of the invention, the dark-field illuminator generates light with an intensity at a field of view of the camera which does not significantly change over a height in the order of 10 mm to 12 mm. This on the one hand makes the image capturing system insensitive regarding mounting tolerances. On the other hand, it allows illuminating a viewing area of the camera with an intensity which does not change even if the thickness of the sheet elements being inspected changes considerably.

In accordance with a preferred embodiment, the bright-field illuminator comprises a plurality of adjacent rows of light sources. This allows illuminating the viewing area of the camera under different illumination angles.

According to an embodiment of the invention, the camera and the illuminators combined to a self-contained unit. Further, the invention provides a quality inspection station comprising this image capturing system, the quality inspection station being adapted for inspecting sheet elements in a sheet element processing

machine. The idea underlying the invention is to have a comparatively small unit which can be installed in a machine at a suitable space without requiring too much effort for distributing the elements of the image capturing system within the machine. The unit is compact enough for being placed at a point where the camera can capture the necessary images in a viewing area.

Preferably, the camera and the illuminators are arranged in a common housing so that they can be installed in a pre-aligned manner. Further, the components of the image capturing system are protected against dust.

In one possible embodiment, the housing has a width which is below 30 cm which allows using the image capturing system in the confined space available in a sheet element processing machine. Generally speaking, the housing here has the size of a shoe box.

The image capturing system can in particular be used for inspecting the margin of the sheet elements being moved through the quality inspection station as a very compact unit with a small viewing area is sufficient for this task.

The invention will now be described with reference to a preferred embodiment which is shown in the enclosed drawings. In the drawings,

- Figure 1 schematically shows in a side view a surface inspection system according to the invention employed in a quality control station of a sheet element processing machine;
- Figure 2 schematically shows the surface inspection system of Figure 1 in a top view;
- Figure 3 schematically shows the surface inspection system of Figure 1 in greater detail; and
- Figure 4 schematically shows a surface inspection system in an alternative embodiment in a top view.

In Figure 1, a quality control station 2 is schematically shown, which is employed in a sheet element processing machine of which conveyor tables 3 are depicted. The sheet element processing machine can process sheet elements 4 which are being transported in the direction of arrow A. The sheet elements 4 can

be sheets of paper, cardboard, plastic foil or a similar material, or they can be in the form of a longer web. The sheet element processing machine can be a printing machine, a stamping machine, a laminating machine, a folding machine, a gluing machine, etc.

The quality control station 2 is used for controlling the quality of the sheet elements 4. To this end, a plurality of parameters can be checked, e.g. the position of certain element with respect to other elements such as the position of a hologram with respect to print, or the presence of embossed portions at the correct position.

Within quality control station 2, an image capturing system 10 is being used which is here adapted for capturing images of a viewing area 20. Viewing area 20 is arranged so the full width of a sheet element 4 (i.e. at 90 degrees to the direction A of travel of the sheet elements 4 through the machine) is covered. The images captured by the image capturing system 10 are being evaluated by an image evaluation unit (not shown) in order to verify if that surface features of the sheet conform to requirements. For example, this may entail any one or more of the following: determining that surface elements (including printed, embossed, stamped (including with foil or holograms) or varnished elements are correctly positioned in the x direction, the y direction and regarding their orientation around the z axis, that the surface elements cover the required area, that surface elements are without omission, that surface elements do not extend beyond a predefined area, that the color reproduction is according to specification, and/or that the any three dimensional profile has been correctly reproduced.

The image capturing system 10 here comprises a camera 12, a dark-field illuminator 14, and a bright-field illuminator 16.

Camera 12 is adapted for capturing an image of a viewing area (a line of interest) 20 which is an elongate zone which extending perpendicularly to the direction A across the width of the sheet processing machine (and thus can be up to 3200 mm wide).

Camera 12 is arranged at an angle α of approx. 20° with respect to a median plane M which is perpendicular to the surface of the sheet elements 4 within viewing area 20 and which forms a reference plane.

Camera 12 is a line camera able to capture images of viewing area 20 at a rate of 20,000 to 40,000 images per second or even more.

The resolution of the camera 12 is such that elements of the order of 0.05 to 0.3 mm on the surface of the sheet elements 4 can be resolved, preferably of 0.1 mm.

Dark-field illuminator 14 is adapted for illuminating the viewing area 20. The optical plane of the dark-field illuminator 14 is arranged at an angle β of approx. 45° with respect to median plane M. The opening angle θ of the dark-field illuminator 14 is in the range of 10° to 25°.

Dark-field illuminator 14 can generally be of any type. In a particular embodiment, it comprises a row of LEDs arranged adjacent each other, and two reflectors arranged opposite each other along the row of LEDs. The reflectors have a contour such that the light directed onto viewing area 20 has an intensity which does (at least not considerably) change with changes of the height of the viewing area 20. Thus, thin sheet elements 4 (e.g. paper) are being illuminated in the viewing area with the same intensity as thick sheet elements 4 (e.g. thick cardboard).

By appropriately choosing the geometry of the reflectors and by directing part of the light of the LEDs directly onto the viewing area, the intensity changes less than 3%/mm in a vertical direction and less than 5% between the lowest and the highest level at which the surface of different sheet elements 4 can be (with this difference being in the order of 10 mm max.).

The distance between viewing area 20 and dark-field illuminator 14 is in the range of 30 mm to 100 mm.

Bright-field illuminator 16 is adapted for also illuminating the viewing area 20. The optical plane of the dark-field illuminator 16 is arranged at an angle γ of approx. 30° with respect to the median plane.

Bright-field illuminator 16 can generally be of any type. In a particular embodiment, it comprises several parallel rows of LEDs arranged adjacent each other, with each row being adapted for illuminating viewing area 20. This type of

illuminator can be used in different applications for directing light in different directions to viewing area 20.

In the embodiment of Figures 1 to 3, eight rows of LEDs 17 are shown. A different number of rows can be used, preferably in the range of three to twelve rows and more preferably in the range of 5 to eight rows.

Between the LEDs 17 and viewing area 20, a diffuser 19 is arranged. The distance between diffuser 19 and the LEDs should be in the range of 30 to 100 mm.

In view of the fact that illuminator 14 is being used as a dark-field illuminator, it is arranged on the same side of median plane M as camera 12. Illuminator 16 however is, since it is being used as a bright-field illuminator, arranged on the opposite side of median plane M.

As can be seen in Figure 3, some of the rows of LEDs of the bright-field illuminator 16 are arranged at a smaller inclination with respect to median plane M, and some of the rows of LEDs of the bright-field illuminator 16 are arranged at a larger inclination with respect to median plane M. Thus, it is possible to establish specular reflection conditions with respect to camera 12 over a large variety of inclination of the surface of the sheet elements 4 in viewing area 20.

Viewed from the viewing area, the “opening angle” (designated with λ) of bright-field illuminator 16 (the angle between the row of LEDs being closest to median plane M and the row of LEDs being furthest from median plane M) is in the order of 80° to 90°.

The LEDs of each row is oriented towards the viewing area. In view of the fact that the rows are arranged equally spaced from each other, they are arranged relative to each other at substantially uniform angular offsets. In other words: the opening angle of bright-field illuminator 16 is divided in equal intervals by the rows of LEDs.

In Figure 4, an alternative embodiment is shown. The difference over the embodiment shown in Figures 1 to 3 is that the image capturing system 10 is being used for capturing images of a viewing area 20which is arranged so as to cover the margin of the sheet elements 4. The images captured by the image capturing

system 10 are being evaluated by an image evaluation unit (not shown) in order to verify if test marks (shown schematically with reference numeral 22) have correctly been printed onto the sheet elements 4. These test marks can consist of geometrical patterns, color samples, etc., which allow an operator to check if the sheet element processing machine is correctly set up.

An important feature of the image capturing system 10 is that it is a self-contained unit. Camera 12 and the illuminators 14, 16 are integrated into a common housing 24.

The advantage of integrating the components into a common housing is that it is only housing 24 which has to be mounted to the sheet element processing machine. The camera 12 and the illuminators 14, 16 can be precision-mounted and calibrated at the end of the manufacturing process so that only one element, namely housing 24, has to be properly aligned later.

Further, housing 24 protects the camera 12 and the illuminators 14, 16 from dust.

Regarding the angular orientation of the components of the image capturing system, reference is made to the details of the embodiment of Figures 1 to 3.

Claims

1. An image capturing system comprising a line camera (12) adapted for capturing a linear viewing area (20), a dark-field illuminator (14) and a bright-field illuminator (16) illuminating the viewing area (20), wherein the components are arranged such that with respect to a reference plane (M) which is perpendicular to the surface of the sheet elements (4) passing through the viewing area (20) where images are being captured, the optical plane of the line camera (12) being arranged with an angle (α) of approx. 10° to 30°, preferably 20°, with respect to a reference plane (M), the optical plane of the dark-field illuminator (14) being arranged at an angle (β) of approx. 30° to 60°, preferably 45°, with respect to the reference plane (M), and the optical plane of the bright-field illuminator (16) being arranged at an angle (γ) of approx. 20° to 40°, preferably 30°, with respect to the reference plane (M), the bright-field illuminator (16) having an opening angle between 50° and 110°, preferably between 80° and 90°.

2. The image capturing system of claim 1 wherein the camera (12) and the dark-field illuminator (14) are arranged on the same side of a reference plane (M).

3. The image capturing system of any of the preceding claims wherein the bright-field illuminator (16) is arranged, with respect to a reference plane (M), on a side which is opposite the side at which the camera (12) is arranged.

4. The image capturing system of any of the preceding claims wherein the dark-field illuminator (14) generates light with an intensity at a field of view of the camera (12) which does not significantly change over a height in the order of 10 mm to 12 mm.

5. The image capturing system of any of the preceding claims wherein the distance between the dark-field illuminator (14) and the viewing area (20) is between 60 mm and 150 mm.

6. The image capturing system of any of the preceding claims wherein the opening angle of the dark-field illuminator (14) is between 10° and 25°.

7. The image capturing system of any of the preceding claims wherein the bright-field illuminator (16) comprises a plurality of adjacent rows of light sources (17).

8. The image capturing system of claim 7 wherein the light sources (17) can be adjusted.

9. The image capturing system of claim 7 or claim 8 wherein the bright-field illuminator (16) comprises between three and twelve rows of light sources (17), preferably between five and eight.

10. The image capturing system of any of claims 7 to 9 wherein the rows of light sources (17) are arranged relative to each other at substantially uniform angular offsets.

11. The image capturing system of any of claim 7 to 10 wherein a diffuser (19) is arranged between the light sources (17) and the viewing area (20).

12. The image capturing system of claim 11 wherein the distance between the diffuser and the light sources (17) of the bright-field illuminator (16) is between 30 mm and 100 mm.

13. The image capturing system of any of the preceding claims wherein each light source of the bright-field illuminator consists of a plurality of adjacent LEDs (17).

14. The image capturing system of any of the preceding claims wherein the width of the viewing area (20) is at least 1000 mm.

15. The image capturing system of any of claims 1 to 13 wherein the housing (24) has a width which is below 30 cm.

16. The image capturing system of claim 15 wherein the camera (12) and the illuminators (14, 16) are combined to a self-contained unit.

17. The image capturing system of claim 16 wherein the camera (12) and the illuminators (14, 16) are arranged in a common housing (24).

18. A quality inspection station (2) comprising the image capturing system (10) as defined in any of the preceding claims, the quality inspection station (2) being adapted for inspecting sheet elements (4) in a sheet element processing machine.

19. The quality inspection station as defined in claim 18 wherein the image capturing system (10) is arranged for inspecting the margin of the sheet elements (4) being moved through the quality inspection station.

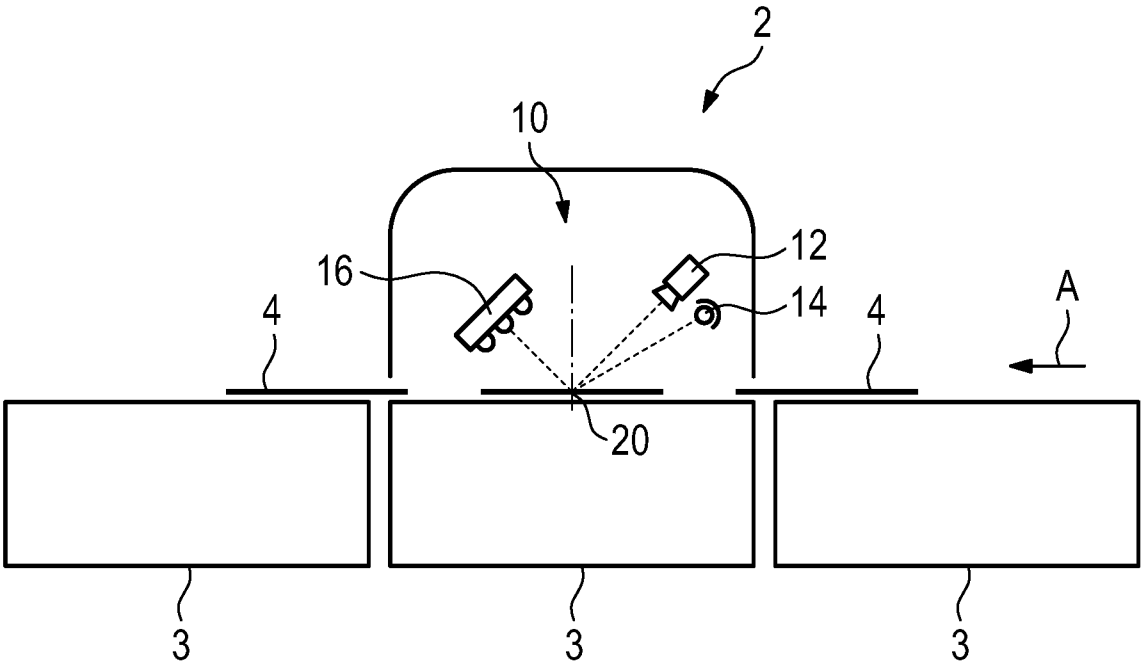

Fig. 1

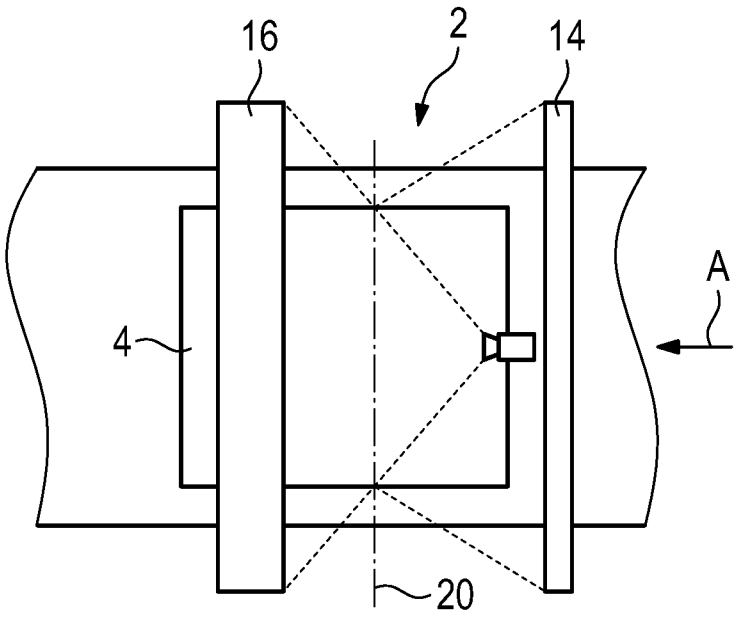

Fig. 2

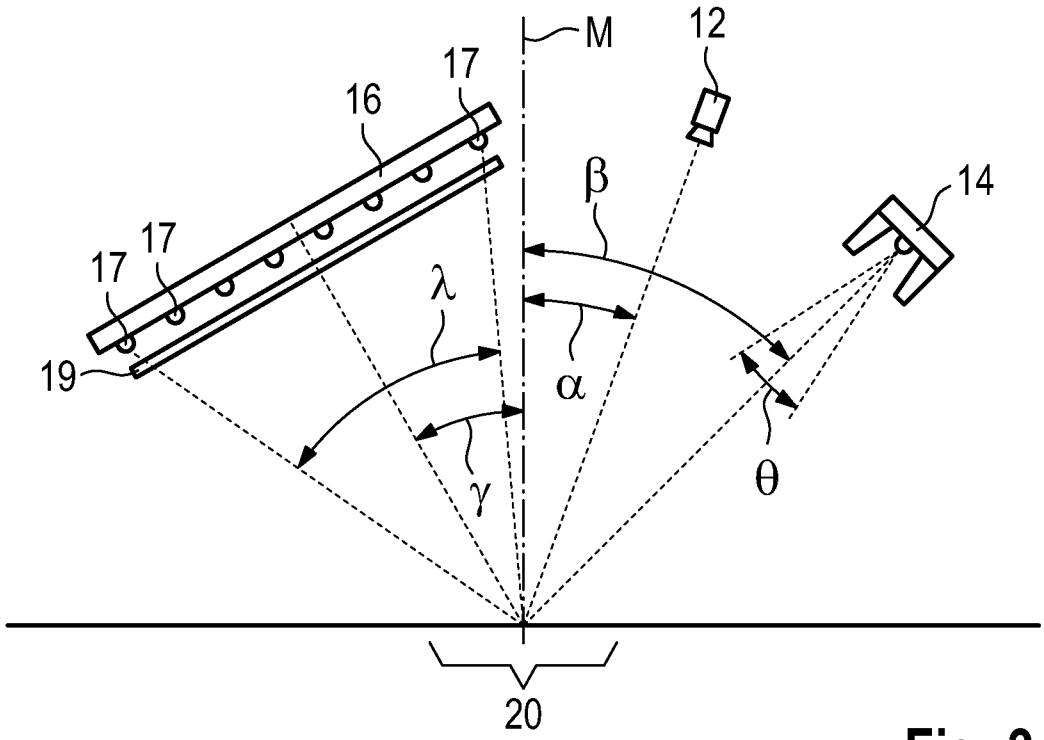

Fig. 3

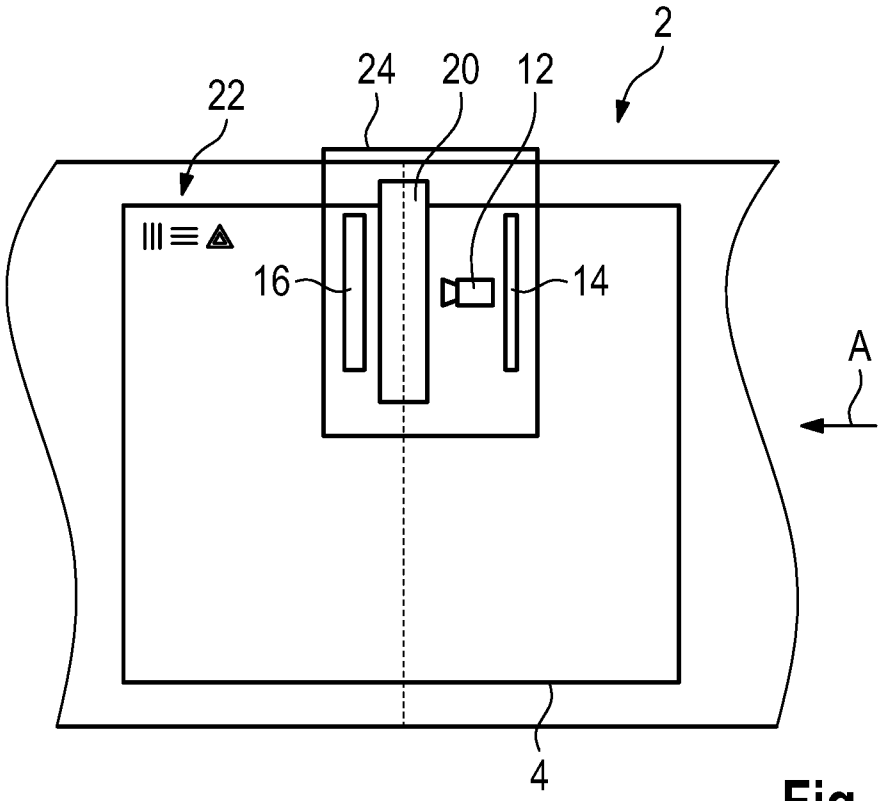

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N21/88 G01N21/89 G01N21/896 G01B11/00
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)
G01N G01B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2002/136009 A1 (YONEDA KENJI [JP]) 26 September 2002 (2002-09-26) abstract; figure 3 paragraphs [0026], [0031] -----	1-19
A	US 6 327 374 B1 (PIIRONEN TIMO H [FI] ET AL) 4 December 2001 (2001-12-04) abstract; figure 1 column 1 -----	1-19

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[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
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INTERNATIONAL SEARCH REPORT

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/168729 A1 (JUNG PAUL [DE] ET AL) 4 August 2005 (2005-08-04) abstract; figure 1	1-19
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Information on patent family members

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