(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 216 614 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.09.2017 Bulletin 2017/37

(21) Application number: **17159874.1**

(22) Date of filing: **08.03.2017**

(51) Int Cl.:
B41J 2/21 *(2006.01)*
B41J 11/00 *(2006.01)*
B41J 15/04 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **11.03.2016 JP 2016048248**
03.02.2017 JP 2017018113

(71) Applicant: **Ricoh Company, Ltd.**
Tokyo 143-8555 (JP)

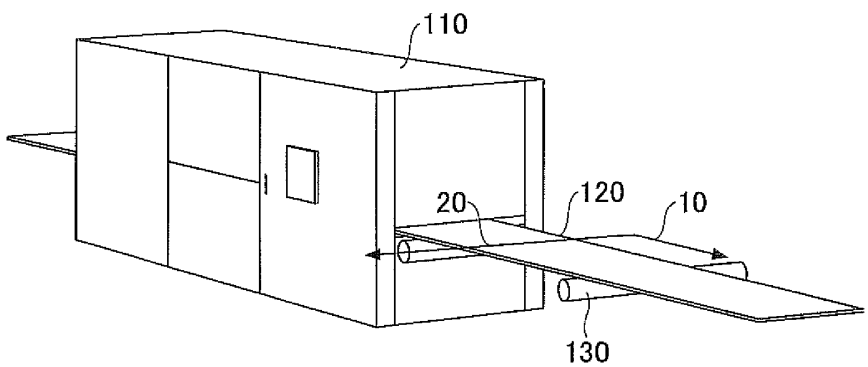
(72) Inventors:
- **HAYASHI, Tomoaki**
Tokyo, 143-8555 (JP)
- **KUDO, Koichi**
Tokyo, 143-8555 (JP)
- **NAGASU, Tsuyoshi**
Tokyo, 143-8555 (JP)
- **SUNAOSHI, Masayuki**
Tokyo, 143-8555 (JP)
- **MIZUNO, Masahiro**
Tokyo, 143-8555 (JP)

(74) Representative: **Schwabe - Sandmair - Marx**
Patentanwälte Rechtsanwalt
Partnerschaft mbB
Joseph-Wild-Straße 20
81829 München (DE)

(54) LIQUID EJECTION DEVICE, LIQUID EJECTION SYSTEM, AND LIQUID EJECTION METHOD

(57) A liquid ejection device includes a plurality of liquid ejection head units to eject liquid to a print medium at different positions on a transport path respectively, a conveying roller to transport the print medium on the transport path, a detection unit, disposed at a distance of an integral multiple of a peripheral length of the conveying roller away from an impact position where the liquid ejected from each of the plurality of liquid ejection head units reaches the print medium, to output a detection result indicating a lateral position of the print medium in a direction orthogonal to a transport direction in which the print medium is transported, and a movement unit to move the corresponding one of the plurality of liquid ejection head units based on the detection result from the detection unit.

FIG.1



EP 3 216 614 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present disclosure relates to a liquid ejection device, a liquid ejection system, and a liquid ejection method.

2. Description of the Related Art

[0002] Conventionally, an inkjet image formation method is known which carries out image formation with ink ejected from a print head. Approaches for increasing the printing quality of an image printed on a print medium by this image forming method are also known.

[0003] For example, a method for adjusting a position of a print head in order to increase the printing quality of a printed image is known as one of the approaches. Specifically, in this method, a positional change of a lateral direction of a web of print medium passing through a continuous-form printing system is first detected by a sensor, and the position of the print head in the lateral direction is adjusted to compensate for the positional change detected by the sensor. For details of this method, see Japanese Laid-Open Patent Publication No. 2015-013476.

[0004] However, in order to further increase the image quality of a printed image, it is required to increase the level of accuracy of an impact position of ejected liquid on the print medium in a direction (which direction will be referred to as "orthogonal direction") orthogonal to a direction in which the print medium is transported. In this respect, it was difficult for the related art to increase the level of accuracy of the impact position of ejected liquid on the print medium in the orthogonal direction.

SUMMARY OF THE INVENTION

[0005] In one aspect, the present disclosure provides a liquid ejection device which provides an increased level of accuracy of the impact position of ejected liquid on the print medium in the orthogonal direction.

[0006] In one embodiment, the present disclosure provides a liquid ejection device including: a plurality of liquid ejection head units configured to eject liquid to a print medium at different positions on a transport path respectively; a conveying roller configured to transport the print medium on the transport path; a detection unit disposed at a distance of an integral multiple of a peripheral length of the conveying roller away from an impact position where the liquid ejected from each of the plurality of liquid ejection head units reaches the print medium, the detection unit being configured to output a detection result indicating a lateral position of the print medium in a direction orthogonal to a transport direction in which the print medium is transported; and a movement unit configured to move the corresponding one of the plurality of liquid ejection head units based on the detection result from the detection unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a diagram illustrating a liquid ejection device according to an embodiment.

FIG. 2 is a diagram illustrating an overall configuration of the liquid ejection device according to the embodiment.

FIGS. 3A and 3B are diagrams illustrating an outer configuration of a liquid ejection head unit according to an embodiment.

FIG. 4 is a block diagram illustrating a hardware configuration to implement a detection unit according to an embodiment.

FIG. 5 is a diagram illustrating an outer configuration of a detection device according to an embodiment.

FIG. 6 is a block diagram illustrating a functional configuration of the detection unit according to the embodiment.

FIGS. 7A and 7B are diagrams illustrating an example in which a lateral position of a print medium in an orthogonal direction is changed.

FIG. 8 is a diagram for explaining the cause of color shift on the print medium.

FIG. 9 is a block diagram illustrating a hardware configuration of a control unit according to an embodiment.

FIG. 10 is a block diagram illustrating a hardware configuration of a data management unit included in the control unit according to the embodiment.

FIG. 11 is a block diagram illustrating a hardware configuration of an image outputting device included in the control unit according to the embodiment.

FIG. 12 is a flowchart for explaining overall processing performed by the liquid ejection device according to the embodiment.

FIG. 13 is a block diagram illustrating a hardware configuration for moving the liquid ejection head unit included in the liquid ejection device according to the embodiment.

FIG. 14 is a diagram illustrating a movement mechanism for moving the liquid ejection head unit included in the liquid ejection device according to the embodiment.

FIG. 15 is a timing chart for explaining a method of computing a change of the position of the print medium by the liquid ejection device according to the embodiment.

FIG. 16 is a diagram illustrating a test pattern which is used by the liquid ejection device according to the embodiment.

FIGS. 17A and 17B are diagrams illustrating a processing result of overall processing by the liquid ejection device according to the embodiment.

FIG. 18 is a diagram illustrating a position where a sensor is disposed in the liquid ejection device according to the embodiment.

FIG. 19 is a diagram illustrating a hardware configuration of a first comparative example.

FIG. 20 is a diagram illustrating a processing result of overall processing performed by a liquid ejection device according to the first comparative example.

FIG. 21 is a diagram illustrating a processing result of overall processing performed by a liquid ejection device according to a second comparative example.

FIG. 22 is a diagram illustrating a position where a sensor is disposed in a liquid ejection device according to a comparative example.

FIG. 23 is a diagram for explaining a correlation computation method according to an embodiment.

FIG. 24 is a diagram for explaining a method of determining a peak position in the correlation computation according to the embodiment.

FIG. 25 is a diagram illustrating an example of computation results of the correlation computation according to the embodiment.

FIG. 26 is a block diagram illustrating a functional configuration of the liquid ejection device according to the embodiment.

FIG. 27 is a diagram illustrating a first modification of the hardware configuration to implement the detection unit according to the embodiment.

FIG. 28 is a diagram illustrating a second modification of the hardware configuration to implement the detection unit according to the embodiment.

FIGS. 29A and 29B are diagrams illustrating a third modification of the hardware configuration to implement the detection unit according to the embodiment.

FIG. 30 is a diagram illustrating a lens array including a plurality of imaging lenses for use in the detection unit according to the embodiment.

FIG. 31 is a diagram illustrating a modification of the liquid ejection device according to the embodiment.

FIG. 32 is a timing chart for explaining a modification of the method of computing an amount of change of a lateral position of a print medium in the liquid ejection device according to the embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] Some embodiments of the present disclosure are now described, by way of examples only, and with reference to the accompanying drawings. The same reference number or character represents the same element or the same type of element on all the drawings, and redundant overlapping description will be omitted.

<Overall Configuration>

[0009] FIG. 1 is a diagram illustrating a liquid ejection device according to an embodiment. For example, the liquid ejection device is an image forming apparatus 110 as illustrated in FIG. 1. In this image forming apparatus 110, liquid being ejected is a marking liquid, such as aqueous inks or oil-based paints. In the following, the image forming apparatus 110 which is an example of the liquid ejection device according to the embodiment will be described.

[0010] For example, a medium being transported in the image forming apparatus 110 is a web 120 of continuous-form print medium. As illustrated in FIG. 1, the web 120 is transported by rollers 130, and the image forming apparatus 110 ejects liquid to the web 120 to perform image formation on the web 120. The web 120 may be a continuous-form print medium or the like. Namely, the web 120 may be a rolled-form sheet of paper and such a sheet can be rolled. The image forming apparatus 110 may be a production printer.

In this example, the web 120 is transported in a direction indicated by the arrow 10 in FIG. 1 and the rollers 130 position and tension the web 120 as the web 120 travels through the image forming apparatus 110. The direction 10 will be referred to as "transport direction". Further, in this example, a direction indicated by the arrow 20 in FIG. 1, which is orthogonal to the transport direction 10, will be referred to as "orthogonal direction". Moreover, in this example, the image forming apparatus 110 may comprise an inkjet printer which ejects color inks, such as yellow (Y), magenta (M), cyan (C), and black (K) inks, so that an image is formed at a predetermined position on the web 120.

[0011] FIG. 2 is a diagram illustrating an overall configuration of the liquid ejection device according to the embodiment. As illustrated in FIG. 2, the image forming apparatus 110 includes four liquid ejection head units 210Y, 210M, 210C, 210K which are configured to eject four color inks, respectively.

[0012] Each of the four liquid ejection head units is configured to eject a corresponding one of the color inks to the web 120 which is transported in the transport direction 10. Specifically, the web 120 is transported by using two pairs of nip rollers NR1, NR2, and a roller 230. In the following, one of the two nip roller pairs disposed upstream of the four liquid ejection head units will be referred to as "first nip rollers NR1", and the other nip roller pair disposed downstream of the first nip rollers NR1 and the four liquid ejection head units will be referred to as "second nip rollers NR2". Note that each nip roller pair pinches the print medium such as the web 120 between the nip rollers so that the print medium is rotated in the transport direction as illustrated in FIG. 2. In this way, the nip roller pairs and the roller 230 constitute a mechanism configured to transport the web 120 in the transport direction.

[0013] It is preferable that the print medium of the web

120 is a continuous-form sheet extending longitudinally in the transport direction. Specifically, it is preferable that a length of the print medium is greater than a distance between the first nip rollers NR1 and the second nip rollers NR2. Furthermore, the print medium is not limited to the web. Namely, the print medium may be fanfold paper (e.g., z-fold paper).

[0014] In the configuration illustrated in FIG. 2, the four liquid ejection head units are disposed in order of black (K), cyan (C), magenta (M), and yellow (Y) in the direction from the upstream side to the downstream side. Specifically, the liquid ejection head unit disposed on the most upstream side is the black liquid ejection head unit 210K. The liquid ejection head unit disposed on the second most upstream side is the cyan liquid ejection head unit 210C. The liquid ejection head unit disposed on the second most downstream side is the magenta liquid ejection head 210M. The liquid ejection head unit disposed on the most downstream side is the yellow liquid ejection head unit 210Y.

[0015] Each of the four liquid ejection head units is configured to eject the corresponding one of the color inks to a predetermined position on the web 120 in accordance with image data. This position where the liquid ejected from each liquid ejection head unit reaches the print medium of the web 120 (which position will be referred to as "impact position") is located immediately under the liquid ejection head unit concerned. In this example, the black ink is ejected to an impact position of the black liquid ejection head unit 210K ("black impact position PK"), the cyan ink is ejected to an impact position of the cyan liquid ejection head unit 210C ("cyan impact position PC"), the magenta ink is ejected to an impact position of the magenta liquid ejection head unit 210M ("magenta impact position PM"), and the yellow ink is ejected to an impact position of the yellow liquid ejection head unit 210Y ("yellow impact position PY"). Note that the timing when each liquid ejection head unit ejects the ink is controlled by a controller 520 connected to the liquid ejection head unit.

[0016] It is preferable that, in the image forming apparatus 110, a plurality of rollers are provided for each of the four liquid ejection head units. Specifically, it is preferable that, as illustrated in FIG. 2, the plurality of rollers are disposed at both positions upstream and downstream of each liquid ejection head unit. In the illustrated example, a roller ("first roller") is disposed in each liquid ejection head unit upstream of the liquid ejection head unit to transport the web 120 to the impact position, and a roller ("second roller") is disposed downstream of each liquid ejection head unit to transport the web 120 from the impact position to a downstream position. In this way, by disposing the first rollers and the second rollers, it is possible to prevent rattling of the web 120 at each impact position during the rotation of the web 120. Note that the first rollers and the second rollers are used to transport the print medium, and these rollers may be driven rollers. Alternatively, the first rollers and the second rollers may be rollers rotated by a motor.

[0017] However, it is not necessary that the first rollers which implement the first support member and the second rollers which implement the second support member are rollers, such as driven rollers. Namely, the first rollers and the second rollers may be support members configured to support the print medium. For example, the first support member and the second support member may be implemented by pipes or shafts having a round cross section. Otherwise, the first support member and the second support member may be implemented by curved plates having a circular portion which comes in contact with the print medium. An example in which the first support member and the second support member are disposed is explained. Specifically, an example in which the first support member is implemented by the first rollers and the second support member is implemented by the second rollers is explained.

[0018] In the illustrated example, a black first roller CR1K for transporting the web 120 to the black impact position PK is disposed in order to eject the black ink to the predetermined position on the web 120. A black second roller CR2K for transporting the web 120 from the black impact position PK to the downstream position is disposed. Similarly, a cyan first roller CR1C and a cyan second roller CR2C are disposed with respect to the cyan liquid ejection head unit 210C. Furthermore, a magenta first roller CR1M and a magenta second roller CR2M are disposed with respect to the magenta liquid ejection head unit 210M. Moreover, a yellow first roller CR1Y and a yellow second roller CR2Y are disposed with respect to the yellow liquid ejection head unit 210Y.

[0019] FIGS. 3A and 3B are diagrams illustrating an outer configuration of a liquid ejection head unit according to an embodiment. FIG. 3A is a plan view illustrating an example of the four liquid ejection head units 210K to 210Y of the image forming apparatus 110 according to the embodiment.

[0020] As illustrated in FIG. 3A, each liquid ejection head unit 210 is a line-type liquid ejection head unit. Namely, in the image forming apparatus 110, the four liquid ejection head units 210K, 210C, 210M, and 210Y corresponding to black (K), cyan (C), magenta (M), and yellow (Y) are disposed from the upstream side in the transport direction 10 of the print medium.

[0021] For instance, in the black liquid ejection head unit 210K, four black heads 210K-1, 210K-2, 210K-3, and 210K-4 are disposed in a zig-zag pattern in the direction orthogonal to the transport direction 10 of the web 120. Thereby, the image forming apparatus 110 is able to form an image that covers an overall width direction of an image formation area (printing area) of the web 120 (which direction corresponds to the orthogonal direction which is orthogonal to the transport direction). Note that the configurations of other liquid ejection head units 210C, 210M, and 210Y are the same as the configuration of the black liquid ejection head unit 210K, and a description thereof will be omitted.

[0022] Although the example of the liquid ejection head unit including the four heads has been illustrated, a liquid ejection head unit including a single head may be utilized instead of the above example.

<Example of Detection Unit>

[0023] A sensor configured to detect a lateral position of the print medium in the orthogonal direction (which is an example of a detection unit) is disposed for each of the liquid ejection head units. Examples of this sensor include an optical sensor utilizing light, such as infrared light, a laser sensor, an air pressure sensor, an optoelectronic sensor, a supersonic wave sensor, etc. For example, the optical sensor may be implemented by a charge-coupled-device (CCD) camera. The sensor to implement the detection unit may be a sensor configured to detect an edge of the print medium. For instance, the detection unit may be implemented by the following hardware configuration.

[0024] FIG. 4 is a block diagram illustrating a hardware configuration to implement a detection unit according to an embodiment. For instance, the detection unit may be implemented by the hardware configuration illustrated in FIG. 4, which includes a detection device 50, a control device 52, a memory device 53, and a computation device 54.

[0025] Next, the detection device 50 is explained. FIG. 5 is a diagram illustrating an outer configuration of a detection device according to an embodiment.

[0026] When a position of a target, such as the web, is detected by the detection device illustrated in FIG. 5, light from a light source is emitted to the web of print medium and a speckle pattern image generated by the reflected light is captured by an imaging sensor. Specifically, the detection device includes a semiconductor laser light source (LD) and a collimator lens (CL). The detection device further includes a CMOS (complementary metal oxide semiconductor) image sensor configured to capture a speckle pattern image, and a telecentric imaging optical system (OL) configured to focus the speckle pattern image onto the CMOS image sensor.

[0027] In the configuration illustrated in FIG. 5, the CMOS image sensor captures a speckle pattern image at each of multiple times including time T1 and time T2. The computation device, such as an FPGA (field-programmable gate array) circuit, is configured to perform correlation computation based on the speckle pattern image captured at time T1 and the speckle pattern image captured at time T2. Based on the movement of the position of the correlation peak obtained from the computation result from the computation device, the CMOS image sensor outputs an amount of movement of the print medium in a period from time T1 to time T2. Note that, in the illustrated example, the dimensions (width W x depth D x height H) of the detection device are 15 x 60 x 32 mm. The details of the correlation computation will be described later.

[0028] Note that the CMOS image sensor is an example of the imaging unit and the FPGA circuit is an example of the computation device.

[0029] As illustrated in FIG. 4, the control device 52 is configured to control the detection device 50. Specifically, the control device 52 outputs a trigger signal to the detection device 50 and controls the timing at which the shutter of the CMOS image sensor is caused to fire. The control device 52 is configured to control the detection device 50 and receive a two-dimensional image from the detection device 50. Further, the control device 52 is configured to send the two-dimensional image generated by the detection device 50 to the memory device 53.

[0030] The memory device 53 is implemented by a memory. Note that it is desirable that the control device 52 is configured to divide the two-dimensional image received from the detection device 50 into image portions and store the image portions in different storage areas.

[0031] The computation device 54 is implemented by a microcomputer. Namely, the computation device 54 is configured to perform computation using the image data stored in the memory device 53 in order to carry out various processes.

[0032] For example, the control device 52 and the computation device 54 are implemented by a CPU (central processing unit) or electronic circuitry. Note that the control device 52, the memory device 53, and the computation device 54 may not be separate devices. For example, the control device 52 and the computation device 54 may be implemented by a single CPU.

<Functional Configuration of Detection Unit>

[0033] FIG. 6 is a block diagram illustrating a functional configuration of a detection unit according to an embodiment. As illustrated in FIG. 6, the detection unit includes an imaging unit 110F1, an imaging control unit 110F2, a memory unit 110F3, and a velocity computation unit 110F4.

[0034] In the following, a case in which an image of the web 120 transported in the transport direction 10 is captured by the imaging unit 110F1 twice (namely, two images are generated by the imaging unit 110F1) is explained. A position where the first one of the images is captured by the imaging unit 110F1 is referred to as position A, and a position where the second one of the images is captured by the imaging unit 110F1 is referred to as position B. Suppose that, when the second image is captured, the first image captured at position A is already moved to position B by the transport of the web in the transport direction 10.

[0035] As illustrated in FIG. 6, the imaging unit 110F1 is configured to capture an image of the web 120 transported in the transport direction 10. For example, the imaging unit 110F1 is implemented by the detection unit 50 (FIG. 4).

[0036] The imaging control unit 110F2 includes an image acquisition unit 110F21 and a shutter control unit

110F22. For example, the imaging control unit 110F2 is implemented by the control device 52 (FIG. 4).

[0037] The image acquisition unit 110F21 is configured to acquire the image captured by the imaging unit 110F1. The shutter control unit 110F22 is configured to control the timing at which the image is captured by the imaging unit 110F1.

[0038] The memory unit 110F3 includes a first storage area 110F31, a second storage area 110F32, and an image division unit 110F33. For example, the memory unit 110F3 is implemented by the memory device 53 (FIG. 4).

[0039] The image division unit 110F33 is configured to divide the image captured by the imaging unit 110F1 into an image portion indicating position A and an image portion indicating position B. Subsequently, the divided image portions are stored in the first storage area 110F31 and in the second storage area 110F32, respectively.

[0040] The velocity computation unit 110F4 is configured to compute each of a position of the pattern on the web 120, a moving velocity at which the web 120 is transported, and a movement by which the web 120 is transported, based on the image portions stored in the first storage area 110F31 and the second storage area 110F32. Moreover, the velocity computation unit 110F4 is configured to output data of a difference Δt, which indicates a shutter timing, to the shutter control unit 110F22. Namely, the velocity computation unit 110F4 outputs a trigger signal to the shutter control unit 110F22, so that the image portion indicating position A and the image portion indicating position B may be captured with the difference Δt. The velocity computation unit 110F4 may be configured to control the motor which transports the web 120 at a velocity consistent with the computed moving velocity. For example, the velocity computation unit 110F4 is implemented by the computation unit 54 (FIG. 4).

[0041] The web 120 is implemented by a member having scattering characteristic on an external surface or an internal surface of the member. When a laser beam is emitted to the web 120, diffused reflection occurs with the reflected laser beam. A pattern is formed on the web 120 by this diffused reflection. This pattern is a speckle pattern including spots or speckles. Hence, when the image of the web 120 is captured, a speckle pattern image indicating the speckle pattern is captured. Because the position where a speckle pattern is present is known from this speckle pattern image, the detection unit is configured to detect where the predetermined position of the web 120 is. Note that the laser beam which is emitted to the web 120 is interfered with by projections and depressions formed on the external or internal surface of the web 120, and this pattern is generated by the interference of the laser beam.

[0042] The light source is not limited to a device to emit a laser beam. For example, the light source may be implemented by a LED (light emitting diode) or an organic EL (electro-luminescence). The pattern may not be a speckle pattern depending on the type of the light source. In the following, a case in which the pattern is a speckle pattern is explained.

[0043] When the web 120 is transported, the speckle pattern on the web 120 is also transported together with the web 120. Hence, a movement of the pattern on the web 120 may be computed by detecting the same speckle pattern at different times. After the same speckle pattern is detected and the movement of the pattern is computed, the velocity computation unit 110F4 is able to compute the movement of the web 120. Further, if the computed movement is converted into a movement per unit time, the velocity computation unit 110F4 is able to compute the moving velocity at which the web 120 is transported.

[0044] As described above, the imaging of the web 120 is performed multiple times at the positions including position A and position B as illustrated. The same speckle pattern is included in each captured image. The position, the movement, and the moving velocity of the web are computed based on the speckle pattern of each captured image. In this way, based on the speckle pattern, the image forming apparatus 110 is able to determine the detection result indicating the position of the web 120 in the orthogonal direction.

[0045] Note that the detection unit may detect a position of the print medium in the transport direction. Namely, the detection unit may be used in common to detect a position of the print medium in the transport direction and in the orthogonal direction. This will reduce the cost for installing the detection device with respect to each of the transport direction and the orthogonal direction. Further, the number of detection devices may be reduced, which will allow saving of the installation space.

[0046] Referring back to FIG. 2, in the following, the sensor disposed on the black liquid ejection head unit 210K will be referred to as "black sensor SENK". Similarly, the sensor disposed on the cyan liquid ejection head unit 210C will be referred to as "cyan sensor SENK". Similarly, the sensor disposed on the magenta liquid ejection head unit 210M will be referred to as "magenta sensor SENK". Furthermore, the sensor disposed on the yellow liquid ejection head unit 210Y will be referred to as "yellow sensor SENY". In the following, the black sensor SENK, the cyan sensor SENK, the magenta sensor SENK, and the yellow sensor SENY will collectively be called "sensor".

[0047] Moreover, in the following, the position where the sensor is disposed is the same as the position where the detection is performed. Hence, it is not necessary that all the devices including the detection device be disposed at the positions where the sensors are disposed, and devices other than the sensors which are connected together by a cable or the like may be disposed at other positions. Note that the black sensor SENK, the cyan sensor SENK, the magenta sensor SENK, and the yellow sensor SENY, illustrated in FIG. 2, represent an example of the positions where the sensors are disposed.

[0048] It is preferable that the position where the sensor is disposed is a position in a vicinity of each impact position. If the sensor is disposed in a vicinity of each impact position, the distance between each impact position and the sensor becomes small. If the distance between each impact position and the sensor becomes small, it is possible to reduce the error in the detection result. Hence, the image forming apparatus 110 is able to detect the position of the print medium in the orthogonal direction by using the sensor with a good level of accuracy.

[0049] Specifically, the position in a vicinity of each impact position is a position between the first roller and the second roller. In the illustrated example, it is preferable that the position where the black sensor SENK is disposed is in a range INTK1 between the black first and second rollers CR1K and CR2K. Similarly, it is preferable that the position where the cyan sensor SENK is disposed is in a range INTC1 between the cyan first and second rollers CR1C and CR2C. Similarly, it is preferable that the position where the magenta sensor SENK is disposed is in a range INTM1 between the magenta first and second rollers CR1M and CR2M. Furthermore, it is preferable that the position where the yellow sensor SENY is disposed is in a range INTY1 between the yellow first and second rollers CR1Y and CR2Y.

[0050] If the sensors are disposed between the first and second rollers, the sensors are able to detect the position of the print medium in the vicinity of each impact position. Moreover, in many cases, the moving velocity of the print medium between the rollers is comparatively stable. Hence, the image forming apparatus 110 is able to detect the position of the print medium in the orthogonal direction with a good level of accuracy.

[0051] It is preferable that the position where the sensor is disposed is an intermediate position between the first and second rollers, the intermediate position being nearer to the first roller than the impact position. Namely, it is preferable that the sensor is disposed at a position upstream of the impact position.

[0052] Specifically, it is preferable that the position where the black sensor SENK is disposed is in a section (which is called "black upstream section INTK2") between the black impact position PK and the position where the black first roller CR1K is disposed. Similarly, it is preferable that the position where the cyan sensor SENK is disposed is in a section (which is called "cyan upstream section INTC2") between the cyan impact position PC and the position where the cyan first roller CR1C is disposed. Similarly, it is preferable that the position where the magenta sensor SENK is disposed is in a section (which is called "magenta upstream section INTM2") between the magenta impact position PM and the position where the magenta first roller CR1M is disposed. Further, it is preferable that the position where the yellow sensor SENY is disposed is in a section (which is called "yellow upstream section INTY2") between the yellow impact position PY and the position where the yellow first roller CR1Y is disposed.

[0053] If the above sensors are disposed in the black upstream section INTK2, the cyan upstream section INTC2, the magenta upstream section INTM2, and the yellow upstream section INTY2, respectively, the image forming apparatus 110 is able to detect the position of the print medium in the orthogonal direction with a good level of accuracy.

[0054] Furthermore, if the above sensors are disposed in this way, the position where each sensor is disposed is located upstream of each impact position. Hence, the image forming apparatus 110 is able to detect the position of the print medium in the orthogonal direction with a good level of accuracy by using the upstream-side sensors, and also able to compute the timing for controlling each liquid ejection head unit to eject the ink. Namely, if the web 12 is transported to the downstream position during the period when the computation is performed, each liquid ejection head unit can be controlled to eject the ink to the web 12 according to the computed timing.

[0055] If each sensor is disposed at a position immediately under the corresponding liquid ejection head unit, a color shift may arise due to the delay of the control action. Hence, if each sensor is disposed upstream of the corresponding impact position in order to prevent the color shift, the image forming apparatus 110 is able to provide increased image quality. If each sensor is disposed in a vicinity of the corresponding impact position, the restriction of the installation space for the sensor may arise. Hence, it is preferable that the position where each sensor is disposed is in a section between the corresponding impact position and the corresponding first roller.

[0056] FIGS. 7A and 7B are diagrams illustrating an example in which a lateral position of the print medium in the orthogonal direction is changed. In the this example, suppose that the web 120 (the print medium) is transported in the transport direction 10 as illustrated in FIG. 7A. When the web 120 is transported by the conveying roller, there may be a case in which the position of the web 120 in the orthogonal direction perpendicular to the transport direction 10 is changed as illustrated in FIG. 7B. Namely, the web 120 in this example is snaking along the transport path as illustrated in FIG. 7B.

[0057] For example, the change of the position of the web 120 in the orthogonal direction (or snaking movement) may arise due to eccentricity or misalignment of the conveying roller or cutting of the web 120 by the blade. Moreover, when the web 120 has a too small width in the orthogonal direction, thermal expansion of the conveying roller or the like may affect the change of the position of the web 120 in the orthogonal direction.

[0058] FIG. 8 is a diagram for explaining the cause of color shift on the print medium. When the position of the web 120 (the print medium) in the orthogonal direction is changed (or when the snaking movement arises) as illustrated in FIG. 7B, color shift is likely to arise on the web 120 due to the cause illustrated in FIG. 8.

[0059] Specifically, when an image is formed on the print medium using multiple color inks (or when a color image is formed), in the image forming apparatus, the color inks ejected from the liquid ejection head units are overlapped to form a color image on the web 120 as illustrated in FIG. 8.

[0060] There may be the case in which the change of the position of the web 120 (or the snaking movement) illustrated in FIG. 7B arises with respect to a reference line 320 indicated in FIG. 8. In this case, the position of the web 120 in the orthogonal direction is changed due to the snaking movement of the web 120 relative to the liquid ejection head units, and if each liquid ejection head unit ejects the ink to the web 120 at the same lateral position, the color shift arises on the web 120 as indicated by lines 330 in FIG. 8. Namely, the positions of the lines formed on the web 120 with the inks ejected from the liquid ejection head units shift in the orthogonal direction, and the color shift 330 is caused. If the color shift 330 arises, the image quality of the image formed on the web 120 will deteriorate.

<Control Unit>

[0061] A hardware configuration of a controller 520 illustrated in FIG. 2 which is an example of a control unit according to an embodiment will be described.

[0062] FIG. 9 is a block diagram illustrating a hardware configuration of the control unit (the controller 520). As illustrated in FIG. 9, the controller 520 includes a host device 71 which is an information processing apparatus, and a printer 72. In this embodiment, the controller 520 is configured to control the printer 72 to perform image formation to form an image on the print medium based on image data and control data received from the host device 71.

[0063] For example, the host device 71 is implemented by a personal computer (PC). The printer 72 includes a printer controller 72C and a printer engine 72E.

[0064] The printer controller 72C is configured to control operation of the printer engine 72E. Initially, the printer controller 72C transmits a print request to the host device 71 and receives control data from the host device 71 via a control line 70LC. Further, the printer controller 72C transmits and receives the control data to and from the printer engine 72E via control lines 72LC. Various printing conditions indicated by the control data are input to the printer controller 72C through the communication of the control data with the printer engine 72E, and the printing conditions are stored in registers of the printer controller 72C. Subsequently, the printer controller 72C controls the printer engine 72E based on the control data, and performs image formation according to the control data (i.e., print job data).

[0065] The printer controller 72C includes a CPU 72Cp, a print control device 72Cc, and a memory device 72Cm. Note that the CPU 72Cp and the print control device 72Cc are interconnected by a bus 72Cb to communicate with each other. The bus 72Cb is connected to the control line 70LC via a communication interface (IF).

[0066] The CPU 72Cp is configured to control the overall operation of the printer 72 by executing a control program stored in the memory device 72Cm. Namely, the CPU 72Cp is provided to implement the computation device and the control device (FIG. 4).

[0067] The print control device 72Cc is configured to transmit and receive commands and status data to and from the printer engine 72E based on the control data received from the host device 71. Thereby, the print control device 72Cc controls the printer engine 72E. The memory unit 110F3 of FIG. 6 may be implemented by the memory device 72Cm. The velocity computation unit 110F4 of FIG. 6 may be implemented by the CPU 72Cp. Note that the functions of the memory unit 110F3 and the velocity computation unit 110F4 may be implemented by another computation unit and another memory unit.

[0068] The host device 71 and the printer engine 72E are interconnected by four data lines 70LD-C, 70LD-M, 70LD-Y, and 70LD-K (or a plurality of data lines). The printer engine 72E receives image data from the host device 71 via these data lines. Subsequently, the printer engine 72E performs image formation of each color on the print medium under the control of the printer controller 72C.

[0069] The printer engine 72E includes four data management devices 72EC, 72EM, 72EY, and 72EK (or a plurality of data management devices), an image output device 72Ei, and a transport control device 72Ec, which will be described below.

[0070] FIG. 10 is a block diagram illustrating a hardware configuration of the data management device included in the control unit according to the embodiment. For example, each of the plurality of data management devices has the same configuration. Since these data management units in this example have the same configuration, a description will be given of the configuration of the data management device 72EC as a typical one, and a description of other data management units is omitted.

[0071] As illustrated in FIG. 10, the data management device 72EC includes a logic circuit 72EC1 and a memory device 72ECm. The logic circuit 72EC1 is connected to the host device 71 via the data line 70LD-C. Further, the logic circuit 72EC1 is connected to the print control device 72Cc via the control line 72LC. Note that the logic circuit 72EC1 may be implemented by an ASIC (application specific integrated circuit) or a PLD (programmable logic device).

[0072] The logic circuit 72EC1 is configured to store the image data received from the host device 71 into the memory device 72ECm based on the control signal received from the printer controller 72C (FIG. 9).

[0073] The logic circuit 72EC1 is configured to read the cyan image data Ic from the memory device 72ECm based on the control signal received from the printer controller 72C. Subsequently, the logic circuit 72EC1 is configured to send the read cyan image data Ic to the image output device 72Ei.

[0074] It is preferable that the memory device 72ECm has a storage capacity to store image data amounting to 3 pages. With the storage capacity of 3-page image data, the memory device 72ECm can store simultaneously image data received from the host device 71, image data for forming an image in the current cycle, and image data for forming an image in the following cycle.

[0075] FIG. 11 is a block diagram illustrating a hardware configuration of the image output device included in the control unit according to the embodiment. As illustrated in FIG. 11, the image output device 72Ei includes an output control device 72Eic, and includes the cyan liquid ejection head unit 210C, the magenta liquid ejection head unit 210M, the yellow liquid ejection head unit 210Y, and the black liquid ejection head unit 210K, which are the plurality of liquid ejection head units of the color inks connected to the output control device 72Eic.

[0076] The output control device 72Eic is configured to output the image data of each of the color inks to the corresponding one of the liquid ejection head units of the color inks. Namely, the output control device 72Eic is configured to control the corresponding one of the liquid ejection head units of the color inks based on the received image data.

[0077] The output control device 72Eic is configured to control simultaneously or individually the plurality of liquid ejection head units. Namely, the output control device 72Eic receives an input timing signal and performs control for changing the timings to cause the liquid ejection head units to eject the respective inks in response to receiving the input timing signal. Note that the output control device 72Eic may be configured to control any one of the liquid ejection head units in response to receiving a control signal from the printer controller 72C (FIG. 9). Alternatively, the output control device 72Eic may be configured to control any one of the liquid ejection head units in response to receiving instructions from the user.

[0078] Note that, in the example of the printer 72 illustrated in FIG. 9, the path for inputting image data from the host device 71 and the path for communication between the host device 71 and the printer 72 based on the control data are separate from each other.

[0079] Alternatively, the printer 72 may be configured to perform monochrome image formation with black ink only. For example, in order to increase the image formation speed in the case of the monochrome image formation, the printer 72 may be modified to include one data management unit and four black liquid ejection head units. In such a case, each of the black liquid ejection head units is configured to eject the black ink to the print medium. Hence, the image formation speed of the configuration of the four black liquid ejection head units may be increased from that of the configuration including only one black liquid ejection head unit.

[0080] The transport control device 72Ec (FIG. 9) is implemented by a combination of an actuator, a mechanism, and a driver device which are configured to transport the web 120 in the transport direction. For instance, the transport control device 72Ec is configured to control the motors engaged with the rollers to transport the web 120 in the transport direction.

<Overall Processing>

[0081] FIG. 12 is a flowchart for explaining overall processing by the liquid ejection device according to the embodiment. For example, suppose that image data indicating an image to be formed on the web 120 (FIG. 1) is initially input to the image forming apparatus 110. Subsequently, the image forming apparatus 110 performs the overall processing illustrated in FIG. 12 based on the image data, so that an image indicated by the image data is formed on the web 120.

[0082] Note that the processing of FIG. 12 is provided for one liquid ejection head unit. Namely, FIG. 12 illustrates the processing related to the black liquid ejection head unit 210K (FIG. 2). The processing related to other liquid ejection head units may be performed separately in parallel with, prior to or subsequent to the processing of FIG. 12.

[0083] As illustrated in FIG. 12, in step S01, the image forming apparatus 110 detects a lateral position of the print medium in the orthogonal direction. Namely, in step S01, the image forming apparatus 110 detects the lateral position of the web 120 in the orthogonal direction by using the sensor SENK.

[0084] In step S02, the image forming apparatus 110 moves the liquid ejection head unit 210K in the orthogonal direction (perpendicular to the transport direction of the web 120) based on the detection result obtained at step S01. In this step S02, the liquid ejection head unit 210K is moved to compensate for the change of the position of the web 120 indicated by the detection result obtained at step S01. For instance, in step S02, the image forming apparatus 110 moves the liquid ejection head unit 210K in the orthogonal direction and compensates for the change of the orthogonal-direction position of the web 120 detected at step S01.

[0085] FIG. 13 is a block diagram illustrating a hardware configuration for moving the liquid ejection head unit included in the liquid ejection device according to the embodiment. For example, the image forming apparatus 110 includes the sensor (SENK, SENC, SENM, SENY), a time shifting device 81, a computation device 82, an LPF (low pass filter) 83, and an actuator controller 84.

[0086] The time shifting device 81 is configured to store the detection result from the sensor and store data indicating a one-cycle preceding position of the print medium. Namely, the time shifting device 81 is implemented by a memory device.

[0087] The computation device 82 is configured to subtract, from the current position of the print medium detected by the sensor, the one-cycle preceding position of the print medium stored in the time shifting device 81 to compute the change of the position of the print medium. Namely, the computation device 82 computes an amount of snaking movement. The computation device 82 is implemented by a processor (CPU) or an electronic circuit.

[0088] The LPF 83 is configured to perform a filtering process on the amount of snaking movement computed by the computation device 82. Hence, the LPF 83 reduces steep changes of the amount of snaking movement. A range of the frequency of snaking movement may be determined to some extent depending on the moving velocity of the print medium. Hence, the LPF 83 is configured to attenuate high frequency values (i.e., steep changes) based on a predetermined frequency of snaking movement. In many cases, the steep changes arise due to noise or erroneous detection. If the steep changes of the amount of snaking movement are reduced by the LPF 83, the image forming apparatus 110 is able to reduce malfunction of the actuator.

[0089] The actuator controller 84 is configured to control the actuator for moving the liquid ejection head unit. A configuration of the actuator (movement mechanism) controlled by the actuator controller 84 will be described below.

[0090] FIG. 14 is a diagram illustrating a movement mechanism for moving the liquid ejection head unit included in the liquid ejection device according to the embodiment. For instance, the actuator controller 84 of FIG. 13 corresponds to the actuator controller CTL of FIG. 14, and the actuator controller CTL is configured to control the actuator ACT (movement mechanism) for moving the cyan liquid ejection head unit 210C as illustrated in FIG. 14.

[0091] In the example illustrated in FIG. 14, the actuator ACT may be implemented by a linear actuator or a motor, and this actuator ACT is disposed on and configured to move the cyan liquid ejection head unit 210C in the orthogonal direction 20. The actuator controller CTL is connected to the actuator ACT and configured to control operation of the actuator ACT

[0092] The actuator ACT may include a control circuit, a power supply circuit, and mechanical parts.

[0093] The actuator controller CTL may be implemented by a driver circuit. The actuator controller CTL is configured to control the position of the cyan liquid ejection head unit 210C.

[0094] The detection result obtained at the step S01 of FIG. 12 is input to the actuator controller CTL. In the step S02 of FIG. 12, the actuator controller CTL controls the actuator ACT to move the liquid ejection head unit 210C in the orthogonal direction 20 and compensates for the change of the orthogonal-direction position of the web 120 detected at step S01.

[0095] In the example illustrated in FIG. 14, the detection result corresponds to the difference Δt described above. Hence, in this example, the actuator controller CTL controls the actuator ACT to move the liquid ejection head unit 210C in the orthogonal direction 20 and compensates for the difference Δt.

[0096] Note that the hardware of the controller 520 illustrated in FIG. 2 and the hardware of the mechanism for moving the liquid ejection head unit illustrated in FIGS. 13 and 14 may be constructed as a single piece or as separate pieces.

[0097] FIG. 15 is a timing chart for explaining a method of computing a change of the position of the print medium by the liquid ejection device according to the embodiment. As illustrated in FIG. 15, the image forming apparatus 110 is configured to compute a change of the position of the print medium by subtracting the one-cycle preceding position of the print medium from the current position of the print medium.

[0098] In the following, an example in which the current detection cycle is the "0"-th cycle is explained. In this example, the image forming apparatus 110 is configured to compute a change "X(0) - X(-1)" of the position of the print medium by subtracting the one-cycle preceding position "X(-1)" of the print medium from the current position "X(0)" of the print medium.

[0099] Note that, in this example, the one-cycle preceding position of the print medium was detected by the sensor at the "-1"-th cycle and the detected data was stored in the time shifting device 81 (FIG. 16). Then, the image forming apparatus 110 computes the change of the position of the print medium by subtracting "X(-1)" stored in the time shifting device 81 from "X(0)" detected by the sensor at the "0"-th cycle.

[0100] In this way, after the liquid ejection head unit is moved and the liquid is ejected to the print medium, an image is formed on the print medium.

<Processing Result>

[0101] FIG. 16 is a diagram illustrating a test pattern which is used by the liquid ejection device according to the embodiment. Initially, the image forming apparatus 110 performs test printing with the black ink which is the first color ink, so that a straight line along the transport direction 10 is formed. A distance Lk from the web edge in the orthogonal direction is obtained based on the result of the test printing. In this way, after the distance Lk from the web edge in the orthogonal direction is adjusted manually or by using the device, a position (reference position) where the black ink as the first color ink is ejected is determined. Note that the method of determining a position where the black ink is ejected is not limited to this exemplary method.

[0102] FIGS. 17A and 17B are diagrams illustrating a processing result of the overall processing by the liquid ejection device according to the embodiment. As illustrated in an upper portion of FIG. 17A, suppose that the liquid ejection device performs image formation in order of black, cyan, magenta, and yellow. A lower portion of FIG. 17A is a plan view of the liquid ejection device when viewed from the top surface of the liquid ejection device.

[0103] In the following, an example of the roller 230 having an eccentricity EC as illustrated in FIG. 17B is explained. When the roller 230 has the eccentricity EC, oscillations OS occur on the roller 230 during the transport of the web 120. The occurrence of the oscillations OS causes a change of a lateral position POS of the web 120. Namely, the "snaking movement" arises due to the oscillations OS.

[0104] For instance, in order to configured the image forming apparatus 110 to reduce the color shift with respect to black, the one-cycle preceding position of the print medium is subtracted from the current position of the print medium detected by the sensor as illustrated in the lower portion of FIG. 17A, so that a change of the position of the print medium is computed. Specifically, a difference between the position of the web 120 detected by the black sensor SENK and the position of the web 120 immediately under the black liquid ejection head unit 210K is set to "Pk". Similarly, a difference between the position of the web 120 detected by the cyan sensor SENC and the position of the web 120 immediately under the cyan liquid ejection head unit 210C is set to "Pc". Similarly, a difference between the position of the web 120 detected by the magenta sensor SENM and the position of the web 120 immediately under the magenta liquid ejection head unit 210M is set to "Pm". Further, a difference between the position of the web 120 detected by the yellow sensor SENY and the position of the web 120 immediately under the yellow liquid ejection head unit 210Y is set to "Py".

[0105] Then, a distance between the position where the liquid from each liquid ejection head unit reaches the web 120 and the edge of the web 120 is set to "Lk3", "Lc3", "Lm3", and "Ly3" for the respective colors. In this case, the position of the web 120 is detected by each sensor, and the equations "Pk=0", "Pc=0", "Pm=0", and "Py=0" are held. Hence, the following formulas (1) can be obtained:

$$Lc3 = Lk3 - Pc = Lk3,$$
$$Lm3 = Lk3,$$
$$Ly3 = Lk3 - Py = Lk3 \qquad (1)$$

From the formulas (1) above, the equations "Lk3 = Lm3 - Lc3 = Ly3" are obtained. Thus, the image forming apparatus 110 is able to provide an increased level of accuracy of the impact position of the ejected liquid by moving each liquid ejection head unit in the orthogonal direction to compensate for the change of the position of the web 120. Further, the liquid of each color reaches the web with a good level of accuracy when performing image formation, and the color shift can be reduced and increased image quality of the image formed can be provided.

[0106] The position where each sensor is disposed is a position which indicated by an integral multiple of a peripheral length d of the conveying roller away from the impact position. In the following, an example of the black sensor SENK for explaining the position where the sensor is disposed is explained. For example, if the integral multiple of the peripheral length d is "d x 0", the black sensor SENK is disposed in a close vicinity of the impact position. If the integral multiple of the peripheral length d is "d x 1 ", the black sensor SENK is disposed at a distance ("first distance d1") from the impact position, which distance is equal to the peripheral length d of the conveying roller. In the case of "d x 1", the black sensor SENK is disposed at a position of the first distance d1 from the impact position as illustrated in FIG. 17A.

[0107] Similarly, if the integral multiple of the peripheral length d is "d x 2", the black sensor SENK is disposed at a distance ("second distance d2") from the impact position, which distance is obtained by doubling the peripheral length d of the conveying roller. In the case of "d x 2", the black sensor SENK is disposed at a position of the second distance d2 from the impact position as illustrated in FIG. 17A. Note that the integral multiple may be 3 or greater.

[0108] Note that a sensor installation error, an impact position error, or a combination of these errors may be added to the distance, such as the first distance d1 and the second distance d2. The sensors of other colors may be disposed similarly.

[0109] It is preferable that the position where each sensor is disposed is an intermediate position between the first and second rollers, the intermediate position being nearer to the first roller than the impact position.

[0110] FIG. 18 is a diagram illustrating a position where a sensor is disposed in the liquid ejection device according to the embodiment. In the following, an example of the black sensor is explained. As illustrated in FIG. 18, the black sensor SENK is disposed at an intermediate position between the black first roller CR1K and the black second roller CR2K, and the intermediate position is nearer to the black first roller CR1K than the black impact position PK.

[0111] Note that the distance of the sensor which is put closer to the black first roller CR1K from the black impact position PK may be determined based on the time needed for the control action. For instance, in this example, the distance of the sensor put closer to the black first roller CR1K is set to 20 mm. In this case, the position where the black sensor SENK is disposed is at a distance of 20 mm upstream of the black impact position PK.

[0112] If the position where the sensor is disposed is near the impact position, the detection error E1 becomes small. If the detection error E1 is small, the image forming apparatus 110 is able to eject the liquid of each color to the web with a good level of accuracy. Hence, when performing image formation, the image forming apparatus 110 is able to eject the liquid of each color to the web with a good level of accuracy, the color shift can be reduced and increased image quality of the formed image can be provided.

[0113] Further, in such a configuration, no restriction that the distance between the liquid ejection head units must be set to the integral multiple of the peripheral length d of the roller (FIG. 17A) is needed, and the position where each liquid ejection head unit is disposed may be freely determined. Namely, the image forming apparatus 110 is able to eject the liquid of each color to the web with a good level of accuracy even when the distance between the liquid ejection head units is not consistent with the integral multiple of the peripheral length d of the roller.

<Comparative Examples>

[0114] FIG. 19 is a diagram illustrating a hardware configuration of a first comparative example. As illustrated in FIG. 19, in the first comparative example, the position of the web 120 is detected, before each liquid ejection head unit reaches the position where the liquid is ejected. For instance, in this comparative example, the position where the sensor is disposed is 200 mm upstream from the position immediately under the liquid ejection head unit. In this case, the image forming apparatus of the first comparative example moves the liquid ejection head unit based on the detection result to compensate for the change of the position of the print medium.

[0115] FIG. 20 is a diagram illustrating a processing result of overall processing performed by the liquid ejection device according to the first comparative example. In this comparative example, the liquid ejection head units are disposed so that the distance between the liquid ejection head units is consistent with the integral multiple of the peripheral length d of the roller. A difference between the position of the web detected by each sensor and the position of the web immediately under the liquid ejection head unit is set to 0. In this comparative example, a distance between the impact position of the liquid of each color and the edge of the web is set to "Lk1", "Lk1", "Lm1", and "Ly1" for the respective colors, and the equations "Lk1 = Lc1 = Lm1 =Ly1" are held. In this way, the position shift is compensated for.

[0116] FIG. 21 is a diagram illustrating a processing result of overall processing performed by a liquid ejection device according to a second comparative example. Note that the second comparative example has a hardware configuration which is the same as that of the first comparative example. The second comparative example differs from the first comparative example in that each of the distance between the liquid ejection head units of black and cyan and the distance between the liquid ejection head units of magenta and yellow is set to 1.75d. Namely, in the second comparative example, the distance between the liquid ejection head units of black and cyan and the distance between the liquid ejection head units of magenta and yellow are not consistent with the integral multiple of the peripheral length d of the roller.

[0117] Similar to FIG. 17A, in this second comparative example, a difference between the position of the web detected by the black sensor SENK and the position of the web immediately under the black liquid ejection head unit 210K is set to "Pk". Similarly, a difference between the position of the web detected by the cyan sensor SENK and the position of the web immediately under the cyan liquid ejection head unit 210C is set to "Pc". Similarly, a difference between the position of the web detected by the magenta sensor SENK and the position of the web 120 immediately under the magenta liquid ejection head unit 210M is set to "Pm". Further, a difference between the position of the web detected by the yellow sensor SENY and the position of the web 120 immediately under the yellow liquid ejection head unit 210Y is set to "Py". Moreover, in the second comparative example, if a distance between the impact position of the liquid of the ink of each color and the edge of the web is set to "Lk2", "Lc2", "Lm2", and "Ly2", the following formulas (2) can be obtained:

$$Lc2 = Lk2 - Pc,$$

$$Lm2 = Lk2,$$

$$Ly2 = Lk2 - Py \qquad (2)$$

For the formulas (2) above, the equations "Lk2 = Lm2≠ Lc2 = Ly2" are obtained. In this comparative example, if the distance between the liquid ejection head units is not consistent with the integral multiple of the peripheral length d of the roller, the position of the web immediately under the cyan liquid ejection head unit 210C shifts by "Pc" and the position of the web immediately under the magenta liquid ejection head unit 210M shifts by "Py", which are different from the first comparative example described above. Hence, the change of the position of the web is not compensated for and the color shift is likely to arise.

<Example of Correlation Computation>

[0118] FIG. 23 is a block diagram illustrating a correlation computation method according to an embodiment. For instance, a detection unit having the configuration illustrated is configured to perform correlation computation so that a relative position of the web to the position of the sensor, a movement, a moving velocity, and a combination of these items are computed.

[0119] Specifically, the detection unit illustrated in FIG. 23 includes a first two-dimensional (2D) Fourier transform unit FT1, a second two-dimensional (2D) Fourier transform unit FT2, a correlation image data generation unit DMK, a peak position search unit SR, a computation unit CAL, and a transform result storage unit MEM.

[0120] The first 2D Fourier transform unit FT1 is configured to transform first image data D1. Specifically, the first 2D Fourier transform unit FT1 has a configuration including a Fourier transform unit FT1a for the orthogonal direction and a Fourier transform unit FT1b for the transport direction.

[0121] The Fourier transform unit FT1a for the orthogonal direction is configured to perform a one-dimensional Fourier transform of the first image data D1 in the orthogonal direction. The Fourier transform unit FT1b for the transport directions is configured to perform a one-dimensional Fourier transform of the first image data D1 in the transport direction based on the transform result obtained by the Fourier transform unit FT1a for the orthogonal direction. In this way, the Fourier transform unit FT1a for the orthogonal direction and the Fourier transform unit FT1b for the transport direction perform the one-dimensional Fourier transforms in the orthogonal direction and in the transport direction, respectively. In this way, the first 2D Fourier transform unit FT1 outputs the obtained transform results to the correlation image data generation unit DMK.

[0122] Similarly, the second 2D Fourier transform unit FT2 is configured to transform second image data D2. Specifically, the second 2D Fourier transform unit FT2 has a configuration including a Fourier transform unit FT2a for the orthogonal direction, a Fourier transform unit FT2b for the transport direction, and a complex conjugate unit FT2c.

[0123] The Fourier transform unit FT2a for the orthogonal direction is configured to perform a one-dimensional Fourier transform of the second image data D2 in the orthogonal direction. The Fourier transform unit FT2b for the transport direction is configured to perform a one-dimensional Fourier transform of the second image data D2 in the transport direction based on the transform result obtained by the Fourier transform unit FT2a for the orthogonal direction. In this way, the Fourier transform unit FT2a for the orthogonal direction and the Fourier transform unit FT2b for the transport direction perform the one-dimensional Fourier transforms in the orthogonal direction and the transport direction, respectively.

[0124] The complex conjugate unit FT2c is configured to compute a complex conjugate of the transform results by the Fourier transform unit FT2a for the orthogonal direction and the Fourier transform unit FT2b for the transport direction. The second 2D Fourier transform unit FT2 is configured to output the complex conjugate computed by the complex conjugate unit FT2c to the correlation image data generation unit DMK.

[0125] The correlation image data generation unit DMK is configured to generate correlation image data based on the transform results of the first image data D1 output from the first 2D Fourier transform unit FT1 and the transform results of the second image data D2 output from the second 2D Fourier transform unit FT2.

[0126] The correlation image data generation unit DMK has a configuration including an integral unit DMKa and a 2D inverse Fourier transform unit DMKb.

[0127] The integral unit DMKa is configured to compute an integral of the transform results of the first image data D1 and the transform results of the second image data D2. The integral unit DMKa is configured to output the computed integral to the 2D inverse Fourier transform unit DMKb.

[0128] The 2D inverse Fourier transform unit DMKb is configured to perform a 2D inverse Fourier transform of the integral from the integral unit DMKa. After the 2D inverse Fourier transform is performed in this way, correlation image data is generated. The 2D inverse Fourier transform unit DMKb is configured to output the correlation image data to the peak position search unit SR.

[0129] The peak position search unit SR is configured to determine a peak position where the luminance becomes the peak (peak value) in the correlation image data. The correlation image data input to the peak position search unit SR includes optical intensity values (i.e., values indicating the magnitudes of luminance). The values indicating the magnitudes of luminance are input in a matrix form.

[0130] Note that, in the correlation image data, luminance values are arrayed at intervals of a pixel pitch (pixel size) of the area sensor. Hence, it is preferable to perform the peak position search after sub-pixel processing is performed.

[0131] After the sub-pixel processing is performed, the peak position can be determined with a good level of accuracy. Hence, the detection unit is able to output the relative position, the movement, and the moving velocity with a good level of accuracy.

[0132] For instance, the peak position search unit SR is configured to determine the peak position as follows.

[0133] FIG. 24 is a diagram for explaining a method of determining a peak position in the correlation computation according to the embodiment. In FIG. 24, the horizontal axis indicates a position in the transport direction of the image indicated by the correlation image data, and the vertical axis indicates a luminance of the image indicated by the correlation image data.

[0134] In the following, an example of three data values, including a first data value q1, a second data value q2, and a third data value q3, among the luminance values indicated by the correlation image data is explained. In this example, the peak position search unit SR (FIG. 23) determines a peak position P in a curve k connecting the first data value q1, the second data value q2, and the third data value q3.

[0135] Initially, the peak position search unit SR computes a difference between two of the luminance values of the image indicated by the correlation image data. The peak position search unit SR extracts a combination of the data values with which the difference is the greatest among the obtained differences. Subsequently, the peak position search unit SR extracts a combination of the data values with which the difference is the second greatest among the obtained differences. In this way, the peak position search unit SR is able to extract three data values such as the first data value q1 and the second data value q2, and the third data value q3 as illustrated in FIG. 24. After the curve k is computed by connecting the extracted data values, the peak position search unit SR is able to determine the peak position P in the curve k. In this way, the peak position search unit SR is able to reduce the computation load of the sub pixel processing and determine the peak position P quickly. Note that the position of the combination of data values where the difference is the greatest corresponds to the steepest portion. Moreover, another sub pixel processing different from the above-described processing may be performed.

[0136] For instance, after the peak position is determined by the peak position search unit SR in the above manner, the following computation results may be obtained.

[0137] FIG. 25 is a diagram illustrating an example of computation results of the correlation computation according to the embodiment. A correlation intensity distribution of a correlation function is illustrated in FIG. 25. In FIG. 25, the X-axis and the Y-axis indicate the pixel serial numbers. A peak position such as a "correlation peak" as indicated in FIG. 25 is determined by the peak position search unit SR (FIG. 23).

[0138] Referring back to FIG. 23, the computation unit CAL is configured to compute a relative position, a movement, and a moving velocity of the web. For instance, the computation unit CAL is configured to compute a relative position and a movement of the web by computing a difference between the median position of the correlation image data and the peak position obtained by the peak position search unit SR.

[0139] For instance, the computation unit CAL is configured to compute a moving velocity of the web by dividing a movement of the web by a time needed for the movement.

[0140] As described above, the detection unit is able to determine the relative position, the movement, and the moving velocity by performing the correlation computation. Note that the method of determining the relative position, the movement, and the moving velocity is not limited to the above example. For instance, the detection unit may be configured to determine the relative position, the movement, and the moving velocity as follows.

[0141] The above-described detection unit generates binary values of luminance values of each of a first image data and a second image data. Namely, when a luminance value is less than a predetermined threshold, the detection unit converts the luminance value into "0", and when a luminance value is greater than the threshold, the detection unit converts the luminance value into "1". In this way, the binary values of the first image data and the second image data are compared with each other, and the detection unit is able to determine the relative position.

[0142] Moreover, the detection unit may be configured to determine the relative position, the movement, and the moving velocity by using another detection method other than described above. For instance, the detection unit may be configured to determine the relative position based on patterns derived from the respective image data by performing a pattern matching process.

<Functional Configuration>

[0143] FIG. 26 is a block diagram illustrating a functional configuration of the liquid ejection device according to the embodiment. As illustrated in FIG. 26, the image forming apparatus 110 includes a detection unit 11F10 for each of the plurality of liquid ejection head units. The image forming apparatus 110 further includes a movement unit 110F20.

[0144] As illustrated in FIG. 26, the detection units 110F10 are provided for the liquid ejection head units, respectively. Specifically, in the example of FIG. 26, the four detection units 110F10 are provided. Each detection unit 110F10 is configured to detect a lateral position of the print medium of the web 120 in the orthogonal direction. Note that each detection unit 110F10 is implemented by the configuration illustrated in FIG. 4.

[0145] The movement unit 110F20 is configured to move the liquid ejection head unit based on the detection result by the detection units 110F10. Note that the movement unit 110F20 is implemented by the configuration illustrated in FIG. 14.

[0146] The image forming apparatus 110 further includes the conveying roller. For instance, the conveying roller is the conveying roller 230 illustrated in FIG. 26. The conveying roller 230 is configured to transport the print medium of the web 120 in the transport direction as illustrated in FIG. 26.

[0147] For instance, the black detection unit 110F10 is disposed at a distance of an integral multiple (d x N, where N = 0, 1, 2, 3 ...) of the peripheral length d of the conveying roller 230 from the black impact position PK. Namely, the detection by the black detection unit 110F10 is performed at a distance of the integral multiple "d x N" of the peripheral length d of the conveying roller 230 from the black impact position PK. Note that if the detection unit 110F10 is distant from the impact position by "d x N", the detection unit 110F10 may be disposed downstream of the impact position.

[0148] For instance, when the distance between the liquid ejection head units (print heads) is not consistent with the integral multiple of the peripheral length d of the conveying roller, the color shift may arise. However, when the distance between the liquid ejection head units (print heads) is not consistent with the integral multiple of the peripheral length d of the conveying roller, flexibility of the design of the print head installation is increased. In the present embodiment, each sensor is disposed at a distance of the integral multiple of the peripheral length d from the impact position, the change of the position of the print medium can be compensated for, and an increased level of accuracy of the impact position of the ejected liquid can be provided. Hence, the image forming apparatus 110 is able to correct the color shift.

[0149] In the present embodiment, the movement unit 110F20 is configured to move the liquid ejection head units based on the detection results obtained by the detection units 110F10, and the image forming apparatus 110 is able to provide an increased level of accuracy of the impact position of the ejected liquid in the orthogonal direction.

[0150] Further, it is preferable that the position where the detection is performed by the detection unit 110F10 (i.e., the position where the sensor is disposed) is the intermediate position between the rollers upstream of the impact position, such as in the black upstream section INTK2. Namely, if the detection is performed in the black upstream section INTK2, the image forming apparatus 110 is able to detect the position of the print medium in the orthogonal direction with a good level of accuracy.

[0151] Further, it is preferable that the image forming apparatus 110 includes the measurement unit 110F30 illustrated in FIG. 26.

[0152] If the measurement unit 110F30 is used, the image forming apparatus 110 is able to detect a position of the print medium more reliably. For instance, suppose that a measurement device, such as an encoder, is disposed on the rotary shaft of the roller 230. The measurement unit 110F30 is configured to measure an amount of movement of the print medium by using the encoder. After the measurement result measured by the measurement unit 110F30 is further input, the image forming apparatus 110 is able to detect a position of the print medium in the transport direction more reliably.

<Conclusion>

[0153] In one embodiment, the liquid ejection device is configured to detect a lateral position of the print medium in the orthogonal direction for each of the plurality of liquid ejection head units in a vicinity of the corresponding liquid ejection head unit. Subsequently, the liquid ejection device is configured to move the liquid ejection head unit based on the detection result. Hence, the liquid ejection device of this embodiment is able to compensate for the change of the impact position of the liquid in the orthogonal direction with a better level of accuracy than that in the cases of with the first comparative example and the second comparative example illustrated in FIG. 20 and FIG. 21, respectively.

[0154] In one embodiment, the detection unit included in the liquid ejection device is disposed at a distance of an integral multiple of the peripheral length d of the conveying roller away from the impact position. Hence, the liquid ejection device of this embodiment is able to compensate for the change of the impact position of the liquid in the orthogonal direction.

[0155] In one embodiment, the liquid ejection device is not required to dispose each liquid ejection head unit at the distance of the integral multiple of the peripheral length of the conveying roller as in the first comparative example, and it is possible to reduce the restriction of the installation of each liquid ejection head unit. Moreover, even if the ejected liquid is the first one of the color inks, it is possible for the liquid ejection device of this embodiment to provide an increased level of accuracy of the impact position of the ejected liquid in the orthogonal direction.

[0156] In one embodiment, the liquid ejection device provides an increased level of accuracy of the impact position of the ejected liquid of each color and eliminates the color shift, and it is possible to increase the quality of the image when the image is formed on the print medium by the ejected liquid.

<Modifications>

[0157] In one embodiment, the detection device 50 illustrated in FIG. 4 may be implemented by the following hardware.

[0158] FIG. 27 is a diagram illustrating a first modification of the hardware configuration to implement the detection unit according to the embodiment. In the following, a description of the elements which are designated by the same reference numerals and the same as corresponding elements in the above-described embodiment will be omitted.

[0159] The detection device 50 of the first modification differs from that in the previously described hardware configuration in that the detection device 50 of the first modification includes a plurality of optical systems. The hardware configuration of the first modification corresponds to a compound eye system and the previously described hardware configuration corresponds to a monocular system.

[0160] As illustrated in FIG. 27, each of the first light source 51A and the second light source 51B emits a laser beam to the web 120 as a detection target. Note that the position to which the laser beam is emitted by the first light source 51A is referred to as "position A", and the position to which the laser beam is emitted by the second light source 51B is referred to as "position B".

[0161] Each of the first light source 51A and the second light source 51B includes a light emitting device to emit a laser beam, and a collimator lens to convert the laser beam emitted from the light emitting device into a collimated laser beam. Each of the first light source 51A and the second light source 51B is disposed in the position where the light source emits a laser beam in a slanting direction to the surface of the web 120.

[0162] The detection device 50 includes an area sensor 11, a first imaging lens 12A disposed at a position which counters the "position A", and a second imaging lens 12B disposed at a position which counters the "position B".

[0163] The area sensor 11 may be a sensor constructed by forming an image sensor 112 on a silicon substrate 111. The image sensor 112 includes an area-A 11A and an area-B 11B, and each of the two areas of the image sensor 112 is configured to capture a 2D image. For instance, the area sensor 11 may be implemented by any of a CCD sensor, a CMOS sensor, and a photodiode array. The area sensor 112 is mounted in a housing 13. Further, the first imaging lens 12A and the second imaging lens 12B are retained in a first lens mirror pipe 13A and a second lens mirror pipe 13B, respectively.

[0164] In this example, as illustrated in FIG. 27, the optical axis of the first imaging lens 12A is consistent with the center of the area-A 11A. Similarly, the optical axis of the second imaging lens 12B is consistent with the center of the area-B 11B. The first imaging lens 12A focuses the incoming light on the area-A 11A and the second imaging lens 12B focuses the incoming light on the area-B 11B so that a 2D image is generated.

[0165] Alternatively, the detection device 50 illustrated in FIG. 4 may be implemented by another hardware configuration. FIG. 28 is a diagram illustrating a second modification of the hardware configuration to implement the detection unit according to the embodiment. In the following, differences between the hardware configuration of the detection device 50 illustrated in FIG. 28 and the configuration illustrated in FIG. 27 will be described.

[0166] The detection device 50 illustrated in FIG. 28 differs from the detection device 50 illustrated in FIG. 27 in that the first imaging lens 12A and the second imaging lens 12B are united into an imaging lens array 12C. The area sensor 11 and other elements in the detection device 50 illustrated in FIG. 28 are essentially the same as the corresponding elements in the detection device 50 illustrated in FIG. 27.

[0167] Further, in this example, it is desirable to use an aperture 121 such that an image of the first imaging lens 12A and an image of the second imaging lens 12B may not interfere with each other. When the aperture 121 is used, the focusing area of the image of the first imaging lens 12A and the focusing area of the image of the second imaging lens 12B may be restricted. Hence, it is possible to prevent the interference of the focusing images and the detection device 50 is able to generate the image for each of the position A and the position B.

[0168] FIGS. 29A and 29B are diagrams illustrating a third modification of the hardware configuration to implement the detection unit according to the embodiment. The detection device 50 illustrated in FIG. 29A differs from the detection device 50 illustrated in FIG. 28 in that the area sensor 11 is replaced by a second area sensor 11'. The first imaging lens 12A and the second imaging lens 12B in the detection device 50 illustrated in FIG. 29A are the same as the corresponding elements illustrated in FIG. 28.

[0169] For instance, the second area sensor 11' has a configuration as illustrated in FIG. 29B. As illustrated in FIG. 29B, a plurality of image sensors "b" are fabricated on a wafer "a". Subsequently, such image sensors are cut away from the wafer. The first image sensor 112A and the second image sensor 112B are formed on the silicon substrate 111 by using the image sensors. On the other hand, the first imaging lens 12A and the second imaging lens 12B are disposed at positions consistent with the positions of the first image sensor 112A and the second image sensor 112B.

[0170] Generally, image sensors are manufactured for imaging purposes. Hence, in many cases, an aspect ratio of an image sensor (i.e., the ratio of the X-axis and the Y-axis direction size of the image sensor) is set to be consistent with an imaging format, such as 1:1, 4:3, or 16:9. In this embodiment, an image is captured for each of two or more points which are spaced at predetermined intervals. Specifically, in this embodiment, an image is captured for each of the points spaced at the predetermined intervals in the X-axis direction which is the transport direction 10 (FIG. 2). The image sensor has the aspect ratio consistent with the imaging format. Hence, when capturing an image for each of the points spaced at the predetermined intervals in the X-axis direction, there may be a case in which no image sensor is used for capturing an image for each of points spaced in the Y-axis direction. Further, when it is desired to increase the pixel density, an image sensor with an increased pixel density capability has to be disposed for capturing an image with respect to either the X-axis direction or the Y-axis direction, which may raise the cost.

[0171] If the configuration as illustrated in FIG. 29A is used, the first image sensor 112A and the second image sensor 112B, spaced at a predetermined distance, may be formed on the silicon substrate 111. The use of the image sensor disposed for capturing an image with respect to the Y-axis direction may become unnecessary. Hence, the use of the unnecessary image sensor is avoided. Furthermore, the first image sensor 112A and the second image sensor 112B are formed with a good level of accuracy by the semiconductor fabrication process, and it is possible to increase the level of accuracy of the distance between the first image sensor 112A and the second image sensor 112B.

[0172] FIG. 30 is a diagram illustrating a lens array including a plurality of imaging lenses for use in the detection unit according to the embodiment. The lens array illustrated in FIG. 30 may be used to implement the detection unit according to the embodiment.

[0173] The lens array illustrated in FIG. 30 may have a structure in which the imaging lenses are integrated. Specifically, the lens array illustrated in FIG. 30 includes a total of nine imaging lenses A1 to C3 in which the imaging lenses are arrayed in three rows in a longitudinal direction and three columns in a lateral direction. If this lens array is used, an image may be captured for each of nine points spaced in the X-axis and Y-axis directions. In this case, the area sensor including imaging areas of nine points is used.

[0174] In this example, the computations for two imaging areas may easily be performed simultaneously or by parallel execution. Subsequently, if the computation results are averaged or the error elimination is performed, the detection device is able to provide an increased level of stability of the computations or accuracy of the computation results when compared with the case in which one computation result is used. Moreover, there is a case in which computation is executed based on the application program in which the computation speed is varied. Even in such a case, the areas to which the correlation computation is applied may be increased and the velocity computation results with an increased level of accuracy may be obtained.

[0175] FIG. 31 is a diagram illustrating a modification of the liquid ejection device according to the embodiment. In the modification illustrated in FIG. 31, the arrangement of the first support member and the second support member differs from that in the previously described embodiment of FIG. 2.

As illustrated, the first support member and the second support member may be implemented by a first member RL1, a second member RL2, a third member RL3, a fourth member RL4, and a fifth member RL5. Namely, the second support member disposed upstream of each liquid ejection head unit and the first support member disposed downstream of each liquid ejection head unit may be implemented by the common members. Note that the first support member and the second support member may be implemented by a number of rollers or a number of curved boards.

[0176] FIG. 32 is a timing chart for explaining a modification of the method of computing an amount of change of a print medium in the liquid ejection device according to the embodiment. The amount of change may be computed by the method as illustrated in FIG. 32. As described in the foregoing, the image forming apparatus of this modification is configured to compute the amount of change based on plural detection results. Specifically, the control device CTRL is configured to output a computation result indicating the amount of change based on a first detection result S1 and a second detection result S2. Initially, the first detection result S1 and the second detection result S2 are detection results indicated by the sensor data output from any two sensors of the plurality of sensors.

[0177] The amount of change is computed for each of the plurality of liquid ejection head units. An exemplary method of computing the amount of change using the cyan liquid ejection head unit 210C (FIG. 2) will be described. In this example, the amount of change is computed based on both the detection result output from the cyan sensor SENC (FIG. 2), and the detection result output from the black sensor SENK (FIG. 2) disposed upstream of the cyan sensor SENC. On the other hand, in the example of FIG. 17, the first detection result S1 is the detection result output from the black sensor SENK, and the second detection result S2 is the detection result output from the cyan sensor SENC.

[0178] Suppose that L2 denotes a distance between the black sensor SENK and the cyan sensor SENC (i.e., a distance between sensors) and V denotes a moving velocity detected by the velocity detection circuit SCR. Further, suppose that T2 denotes a moving time required for the print medium to be transported from the position of the black sensor SENK to the position of the cyan sensor SENC. In this case, the moving time T2 is computed by the formula "$T2 = L2/V$".

[0179] Moreover, suppose that "A" denotes a sampling period of each sensor, and "n" denotes a sampling frequency between the black sensor SENK and the cyan sensor SENC. In this case, the sampling frequency n is computed by the formula "$n = T2/A$".

[0180] Suppose that ΔX denotes the amount of change which is the computation result. For example, in the example of FIG. 32, when the detection cycle is "0", the amount of change is computed by comparing the first detection result S1 obtained the moving time "T2" before with the second detection result S2 obtained at the detection cycle "0". Specifically, the amount of change is computed by the formula "$\Delta X = X2(0) - X1(n)$". When the position of the sensor is a position nearer to the first roller than the impact position, the image forming apparatus is configured to compute an amount of change of the position of the print medium when the print medium is moved to the position of the sensor, and drive the actuator based on the computation result.

[0181] Subsequently, the image forming apparatus controls the actuator and moves the cyan liquid ejection head unit 210C (FIG. 14) in the orthogonal direction to compensate for the amount of change "ΔX". In this way, even when the lateral position of the print medium fluctuates, the image forming apparatus is able to perform image formation with an increased level of accuracy of a printed image on the print medium. Moreover, by computing the amount of change based on the two detection results (i.e., the detection results output from the two sensors) as illustrated, the amount of change can be computed without accumulating the position information of the sensors. In this way, it is possible to attenuate the accumulation of detection errors of the sensors.

[0182] Note that the computation of the amount of change may be performed by using other liquid ejection head units likewise. For example, the amount of change for the cyan liquid ejection head unit 210C (FIG. 2) is computed based on the first detection result S1 output from the black sensor SENK (FIG. 2) and the second detection result S2 output from the cyan sensor SENC (FIG. 2). Similarly, the amount of change for the magenta liquid ejection head unit 210M (FIG. 2) is computed based on the first detection result S1 output from the cyan sensor SENC and the second detection result S2 output from the magenta sensor SENM. Further, the amount of change for the yellow liquid ejection head unit 210Y (FIG. 2) is computed based on the first detection result S1 output from the magenta sensor SENM and the second detection result S2 output from the yellow sensor SENY. Furthermore, the amount of change for the black liquid ejection head unit 210K (FIG. 2) may be computed based on the second detection result S2 output from the black sensor SENK (FIG. 2).

[0183] The detection result used for the first detection result S1 is not limited to the detection result output from the sensor disposed upstream of and adjacent to the liquid ejection head unit being moved. Namely, the first detection result S1 may be a detection result output from any sensor disposed upstream of the liquid ejection head unit being moved. For example, the amount of change for the yellow liquid ejection head units 210Y may be computed based on the first detection result S1 which is a detection result output from any one of the second sensor SEN2, the black sensor SENK, and the cyan sensor SENC.

[0184] On the other hand, it is desirable that the second detection result S2 is a detection result output from the sensor disposed at a position nearest to the liquid ejection head unit being moved.

[0185] Alternatively, the amount of change may be computed based on three or more detection results.

[0186] In the image forming apparatus of this modification, the amount of change is computed based on the plural detection results, the liquid ejection head unit is moved based on the computed amount of change, and when the liquid is ejected to the web, an image is formed on the print medium.

[0187] Note that the liquid ejection device of the present disclosure may be implemented by a liquid ejection system including one or more liquid ejection devices. For example, the liquid ejection device of the present disclosure may be implemented by a liquid ejection system including a first device having a black liquid ejection head unit 210K and a cyan liquid ejection head unit 210C mounted on a housing of the first device, and a second device having a magenta liquid ejection head unit 210M and a yellow liquid ejection head unit 210Y mounted on a housing of the second device.

[0188] Further, in the liquid ejection device and the liquid ejection system of the present disclosure, the liquid is not limited to ink but may be a recording liquid of any other kind or a fixing process liquid. Namely, the liquid ejection device and the liquid ejection system of the present disclosure may be applied to a liquid ejection device for a recording liquid of another kind different from ink.

[0189] Hence, the liquid ejection device and the liquid ejection system of the present disclosure are not limited to image forming apparatuses. For example, an object to be formed by the liquid ejection device and the liquid ejection system of the present disclosure may be a three-dimensional fabrication object.

[0190] Further, the medium to be transported therein is not limited to a print medium or recording medium, such as paper. The medium to be transported may be provided of a material with liquid adherence. For example, the material with liquid adherence may be any material to which liquid adheres temporarily or permanently, such as paper, thread, fibers, cloth, leather, metal, plastics, glass, wood, ceramics, or a combination thereof.

[0191] Furthermore, in one embodiment, all or a part of the steps of the liquid ejection method may be implemented by causing a computer incorporated in an image forming apparatus, an information processing apparatus or a combination thereof to execute a program for performing the liquid ejection method.

[0192] As described in the foregoing, according to the liquid ejection device of the present disclosure, it is possible to provide an increased level of accuracy of an impact position of ejected liquid in a direction orthogonal to a direction in which a print medium is transported.

[0193] The foregoing description and the drawings illustrate specific exemplary embodiments of the present disclosure. It will thus be appreciated that those of ordinary skill in the art will be above to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the present disclosure and are included within the scope of the present disclosure. Further, any examples described herein are intended to aid in understanding the principles of the present disclosure, and are to be construed as being without limitation to such specifically recited examples and conditions. As a result, the present disclosure is not limited to the specific embodiments or examples described above, but by the claims and their equivalents.

[0194] The present application is based on and claims the benefit of priority of Japanese Patent Application No. 2016-048248, filed on March 11, 2016, and Japanese Patent Application No. 2017-018113, filed on February 3, 2017, the contents of which are incorporated herein by reference in their entirety.

Claims

1. A liquid ejection device comprising:

a plurality of liquid ejection head units configured to eject liquid to a print medium at different positions on a transport path respectively;
a conveying roller configured to transport the print medium on the transport path;
a detection unit disposed at a distance of an integral multiple of a peripheral length of the conveying roller away from an impact position where the liquid ejected from each of the plurality of liquid ejection head units reaches the print medium, the detection unit being configured to output a detection result indicating a lateral position of the print medium in a direction orthogonal to a transport direction in which the print medium is transported; and
a movement unit configured to move the corresponding one of the plurality of liquid ejection head units based on the detection result from the detection unit.

2. The liquid ejection device according to claim 1, further comprising:

a first support member disposed on each liquid ejection head unit at a position upstream of the

impact position to support the print medium; and a second support member disposed on each liquid ejection head unit at a position downstream of the impact position to support the print medium;
wherein the detection unit is disposed at a position between the first support member and the second support component.

3. The liquid ejection device according to claim 2, wherein the position of the detection unit is between the impact position and the first support member.

4. The liquid ejection device according to any one of claims 1 to 3, wherein the movement unit is configured to move each liquid ejection head unit in the direction orthogonal to the transport direction in which the print medium is transported.

5. The liquid ejection device according to any one of claims 1 to 4, wherein the detection unit comprises an optical sensor.

6. The liquid ejection device according to claim 5, wherein the detection unit is configured to determine the detection result based on a pattern on the print medium.

7. The liquid ejection device according to claim 6, wherein the detection unit is configured to detect a lateral position of the print medium for each of the plurality of liquid ejection head units based on the detection result obtained by detecting the pattern on the print medium at two or more different times.

8. The liquid ejection device according to claim 6 or 7, wherein the pattern is generated by interference of light which is emitted to projections and depressions formed on the print medium, and
the detection unit is configured to determine the detection result based on a captured image of the pattern.

9. The liquid ejection device according to any one of claims 1 to 8, further comprising:

a measurement unit configured to measure an amount of movement of the print medium in the transport direction in which the print medium is transported,
wherein the liquid ejection device is configured to eject the liquid based on the detection result from the detection unit and the amount of movement from the measurement unit.

10. The liquid ejection device according to any one of claims 1 to 9, wherein the print medium is a continuous-form sheet extending longitudinally in the transport direction.

11. The liquid ejection device according to any one of claims 1 to 10, wherein an image is formed on the print medium when the plurality of liquid ejection head units eject the liquid to the print medium.

12. The liquid ejection device according to any one of claims 1 to 11, wherein a distance between two of the plurality of liquid ejection head units is not consistent with an integral multiple of the peripheral length of the conveying roller.

13. A liquid ejection system comprising:

the liquid ejection device according to claim 1.

14. A liquid ejection method performed by a liquid ejection device, comprising:

providing, in the liquid ejection device, a plurality of liquid ejection head units configured to eject liquid to a print medium at different positions on a transport path respectively;
providing, in the liquid ejection device, a conveying roller configured to transport the print medium on the transport path;
disposing, in the liquid ejection device, a detection unit at a distance of an integral multiple of a peripheral length of the conveying roller away from an impact position where the liquid ejected from each of the plurality of liquid ejection head units reaches the print medium;
outputting, by the detection unit, a detection result indicating a lateral position of the print medium in a direction orthogonal to a transport direction in which the print medium is transported; and
moving, by a movement unit, the corresponding one of the plurality of liquid ejection head units based on the detection result from the detection unit.

FIG.1

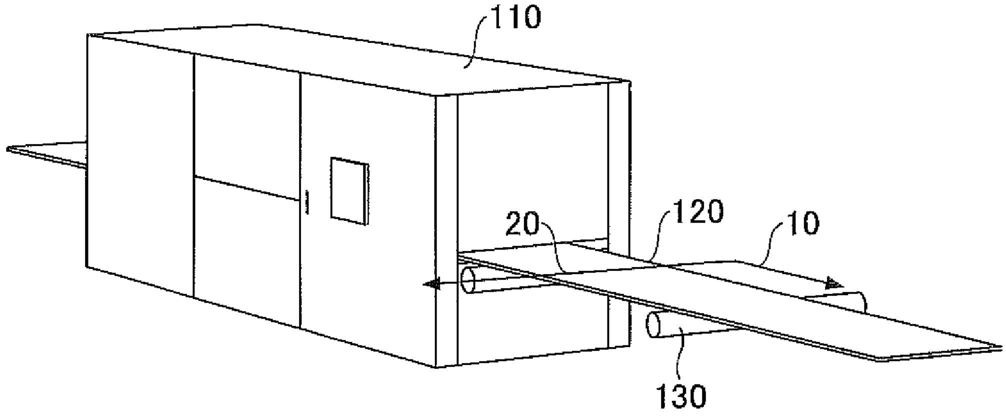


FIG.2

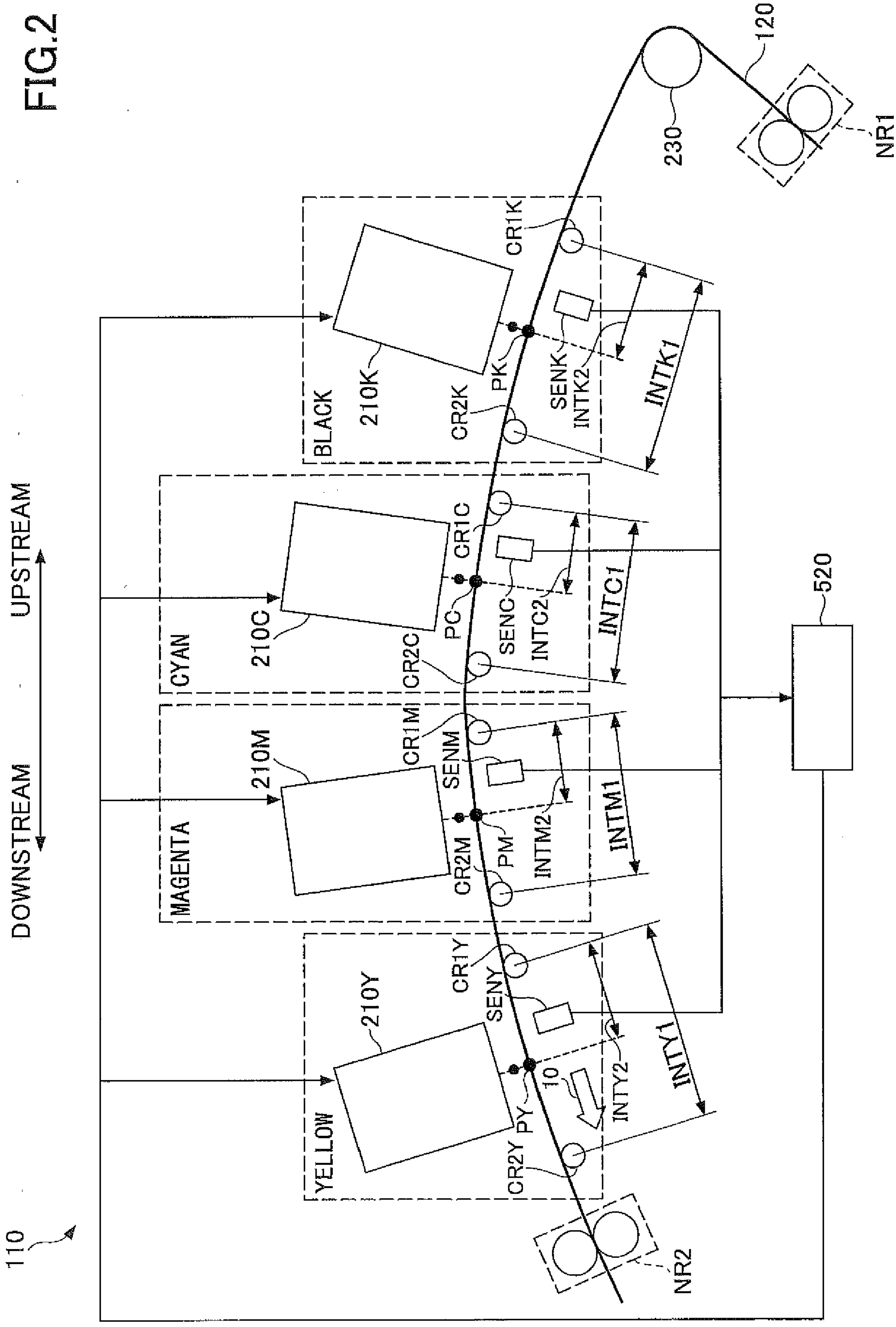

UPSTREAM
DOWNSTREAM
110
BLACK
210K
CR2K
PK
SENK
INTK2
INTK1
CR1K
CYAN
210C
CR2C
PC
SENC
INTC2
INTC1
CR1C
MAGENTA
210M
CR2M
PM
SENM
INTM2
INTM1
CR1M
YELLOW
210Y
CR2Y
PY
SENY
INTY2
INTY1
CR1Y
10
230
120
NR1
NR2
520

FIG.3A

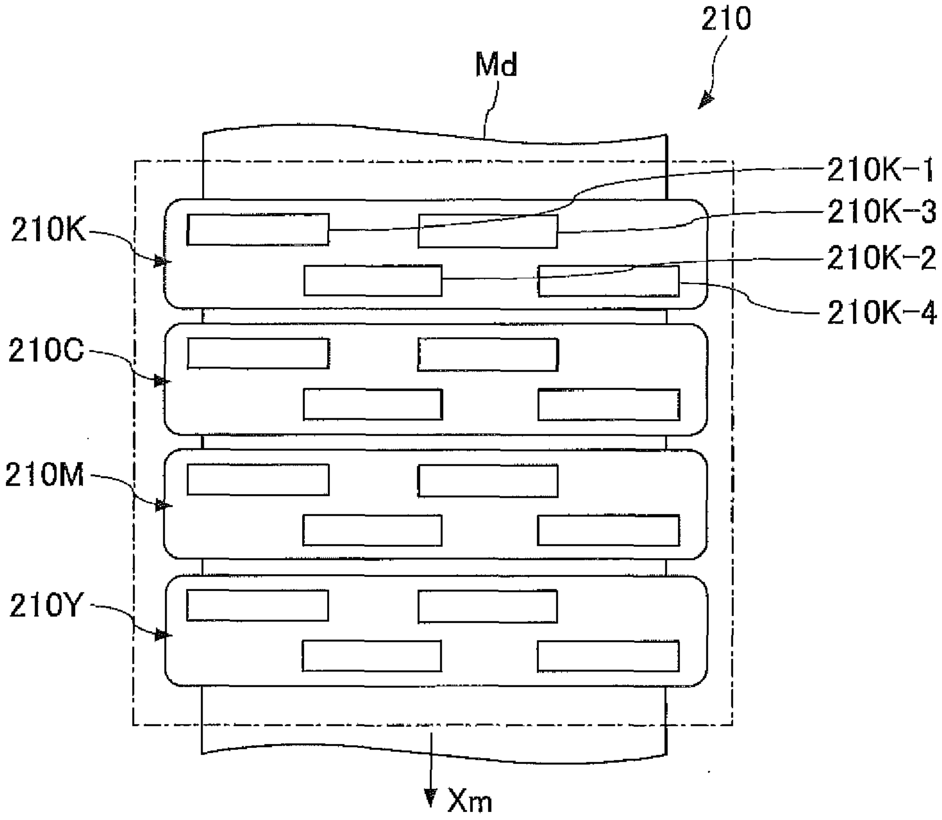


FIG.3B

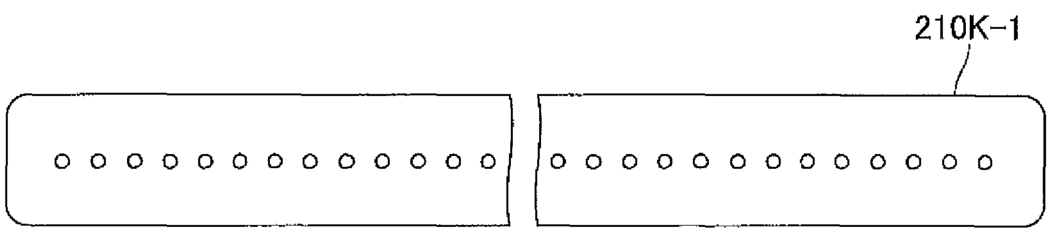


FIG.4

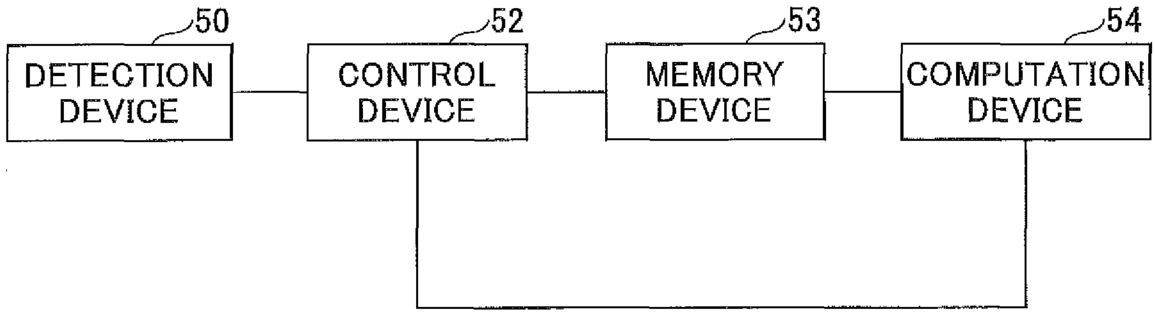

50
DETECTION DEVICE
52
CONTROL DEVICE
53
MEMORY DEVICE
54
COMPUTATION DEVICE

FIG.5

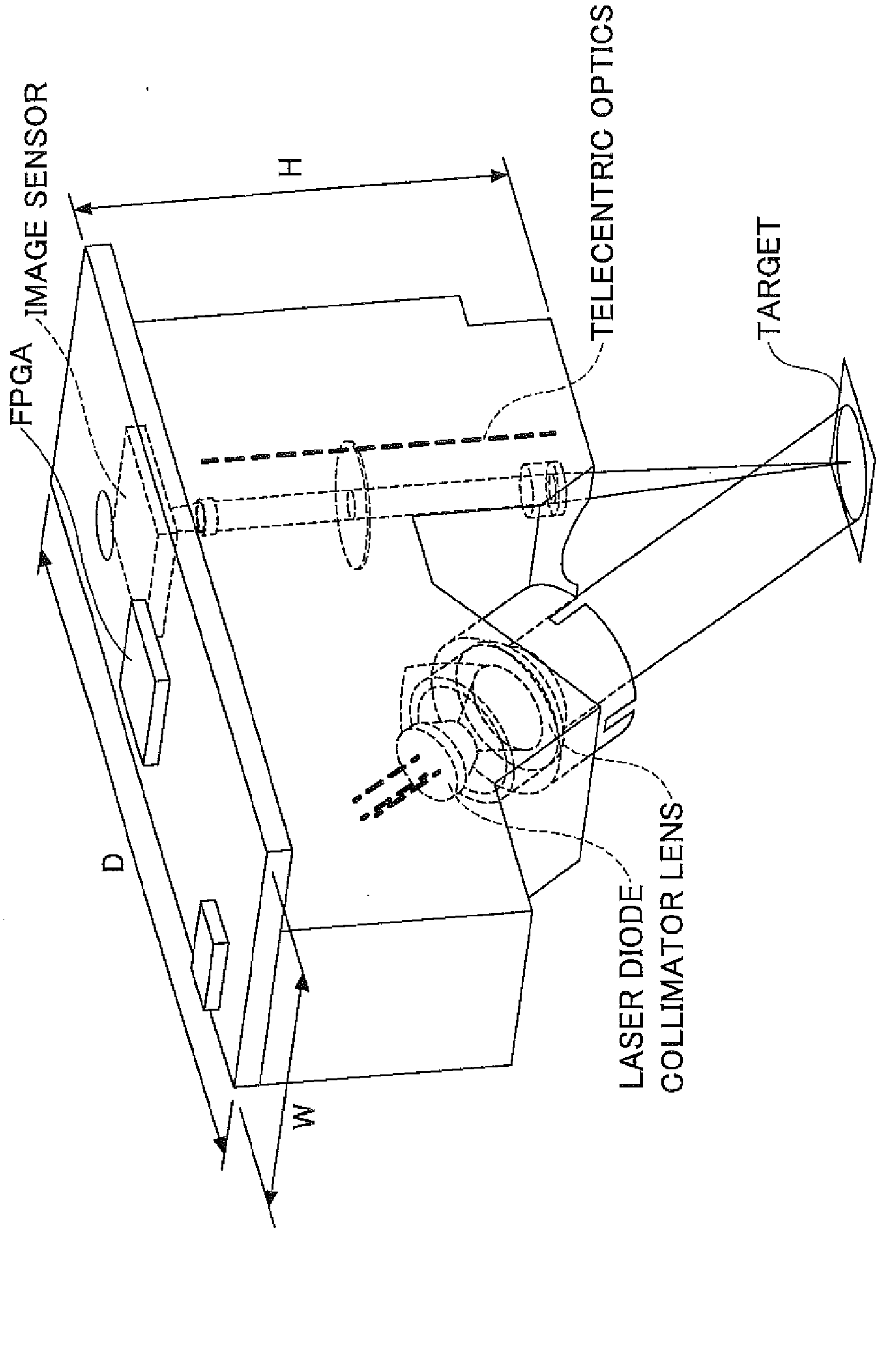


IMAGE SENSOR
FPGA
H
D
W
TELECENTRIC OPTICS
TARGET
LASER DIODE
COLLIMATOR LENS

FIG.6

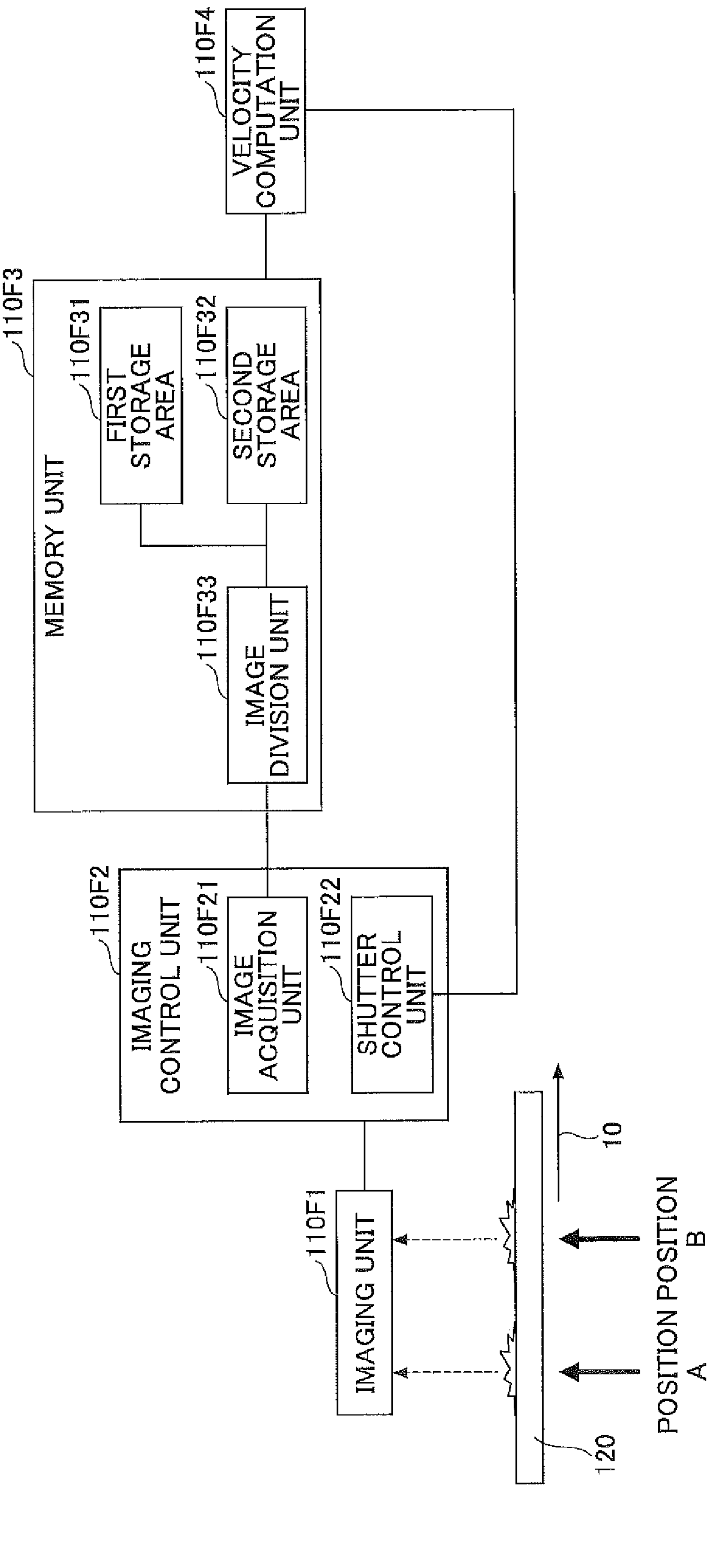

110F4
VELOCITY COMPUTATION UNIT
110F3
MEMORY UNIT
110F31
FIRST STORAGE AREA
110F32
SECOND STORAGE AREA
110F33
IMAGE DIVISION UNIT
110F2
IMAGING CONTROL UNIT
110F21
IMAGE ACQUISITION UNIT
110F22
SHUTTER CONTROL UNIT
110F1
IMAGING UNIT
10
120
POSITION A
POSITION B

FIG.7A

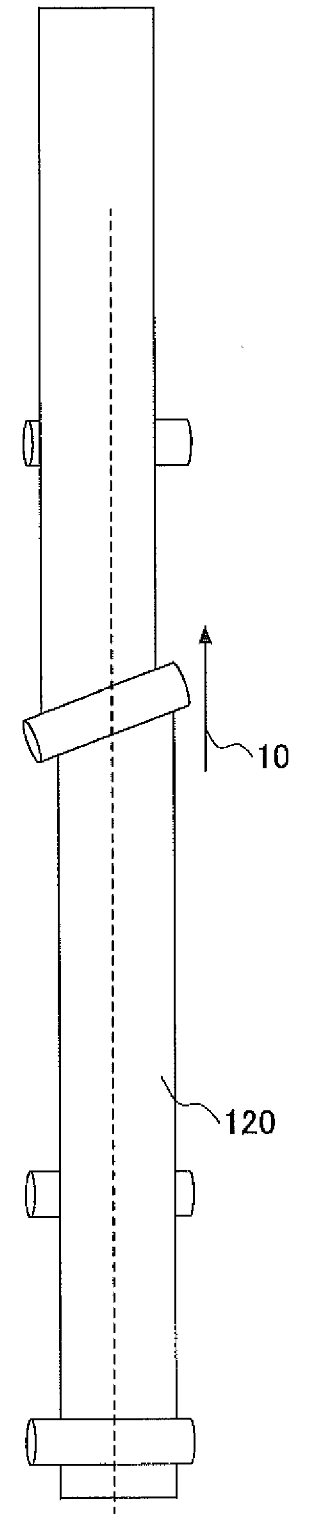


FIG.7B

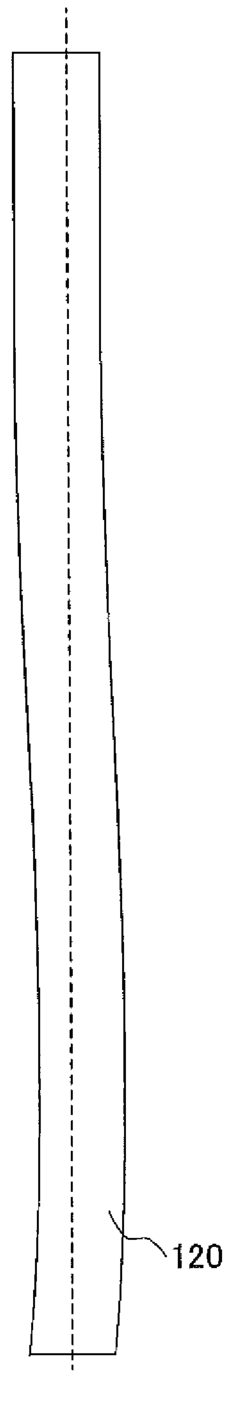


FIG.8

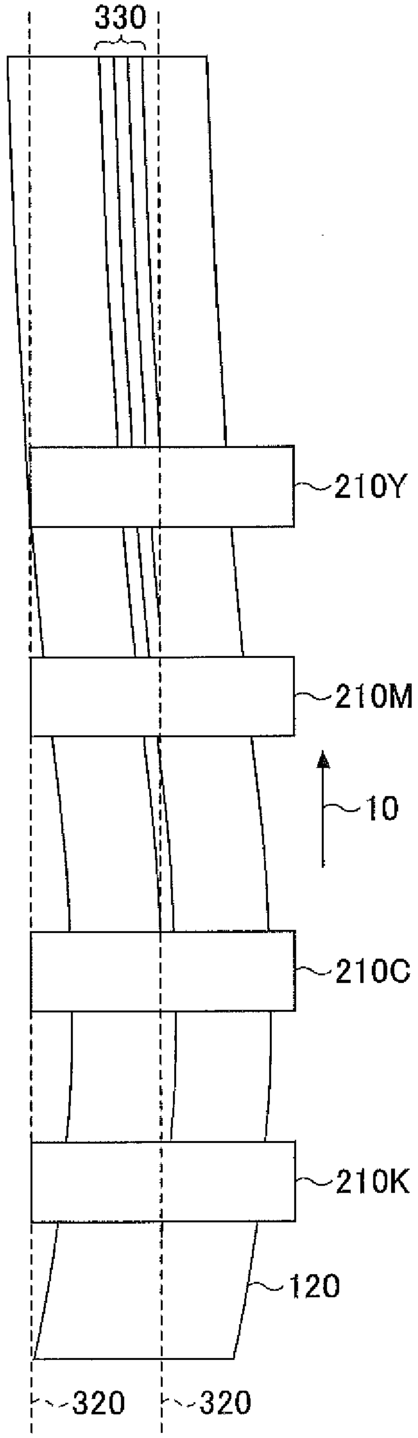


FIG.9

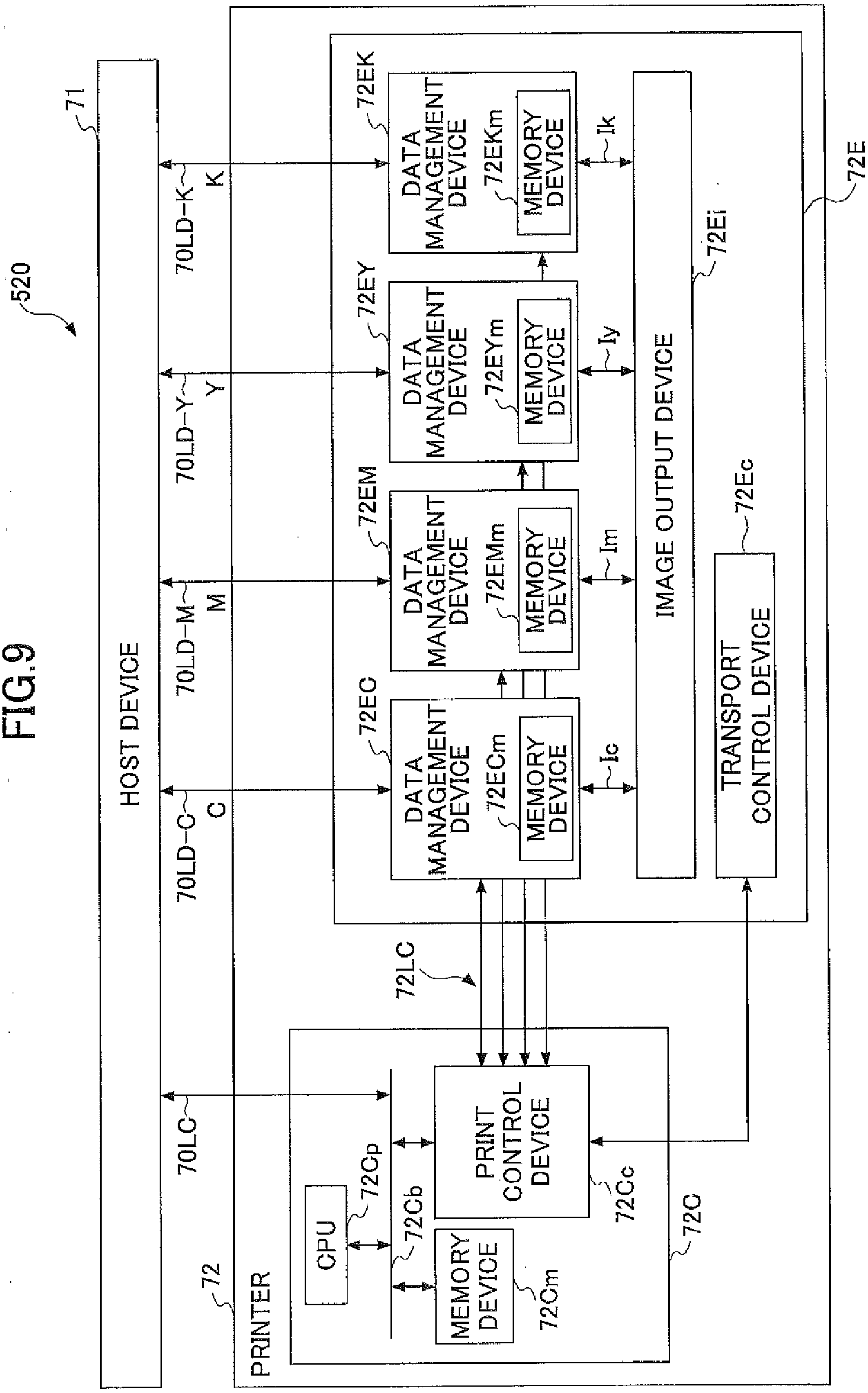

520
71
HOST DEVICE
70LD-C
C
70LD-M
M
70LD-Y
Y
70LD-K
K
70LC
72
PRINTER
72E
72Ei
72EC
DATA MANAGEMENT DEVICE
72ECm
MEMORY DEVICE
Ic
72EM
DATA MANAGEMENT DEVICE
72EMm
MEMORY DEVICE
Im
72EY
DATA MANAGEMENT DEVICE
72EYm
MEMORY DEVICE
Iy
72EK
DATA MANAGEMENT DEVICE
72EKm
MEMORY DEVICE
Ik
IMAGE OUTPUT DEVICE
72Ec
TRANSPORT CONTROL DEVICE
72LC
72C
CPU
72Cp
72Cb
MEMORY DEVICE
72Cm
PRINT CONTROL DEVICE
72Cc

FIG.10

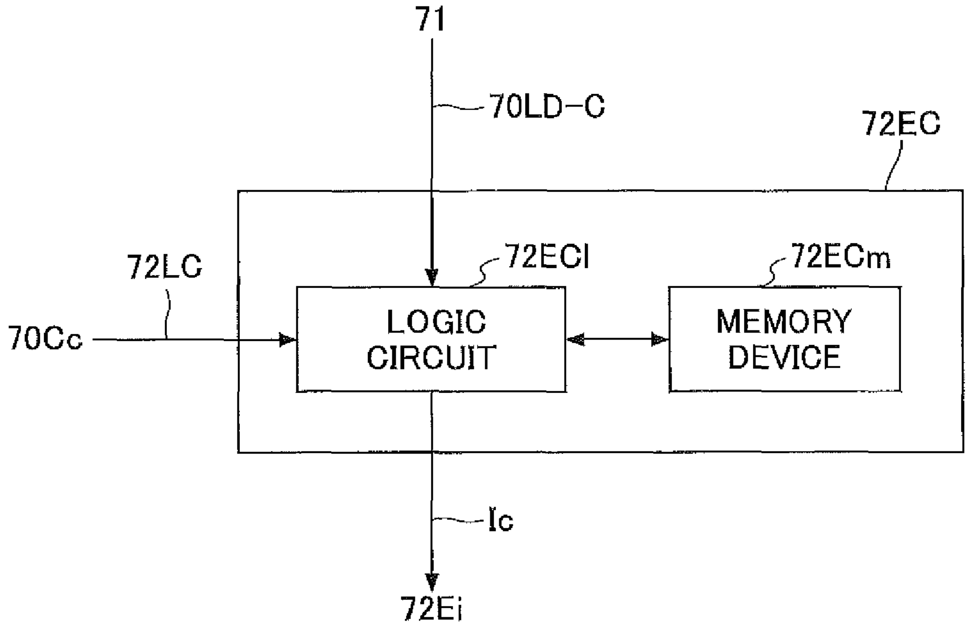

71
70LD-C
72EC
72ECl
72ECm
72LC
70Cc
LOGIC CIRCUIT
MEMORY DEVICE
Ic
72Ei

FIG.11

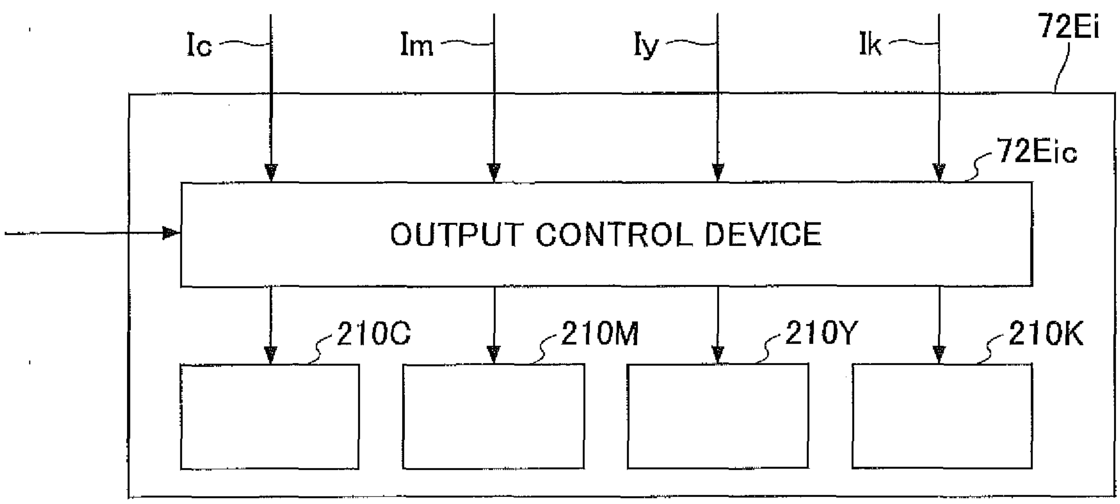

Ic
Im
Iy
Ik
72Ei
72Eic
OUTPUT CONTROL DEVICE
210C
210M
210Y
210K

FIG.12

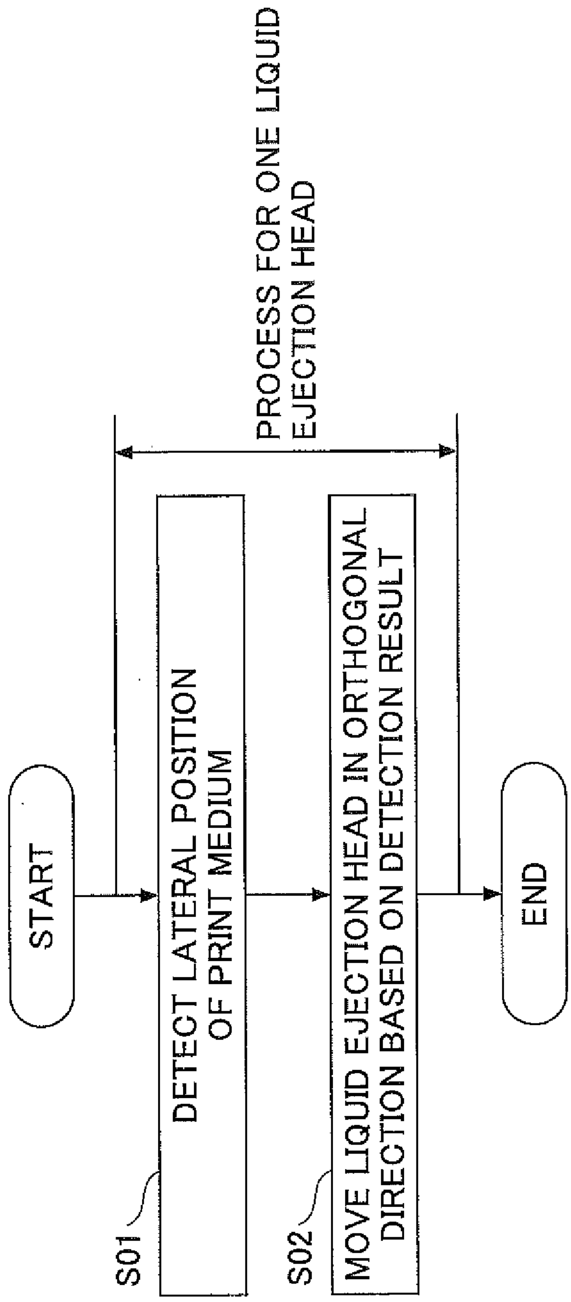

START
S01
DETECT LATERAL POSITION OF PRINT MEDIUM
S02
MOVE LIQUID EJECTION HEAD IN ORTHOGONAL DIRECTION BASED ON DETECTION RESULT
END
PROCESS FOR ONE LIQUID EJECTION HEAD

FIG.13

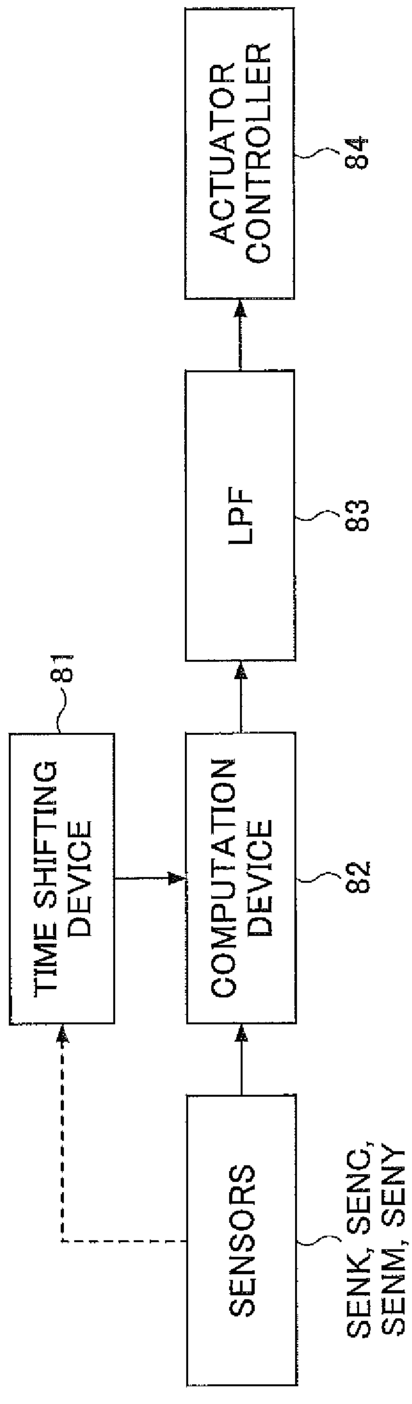

ACTUATOR CONTROLLER
84
LPF
83
TIME SHIFTING DEVICE
81
COMPUTATION DEVICE
82
SENSORS
SENK, SENC, SENM, SENY

FIG.14

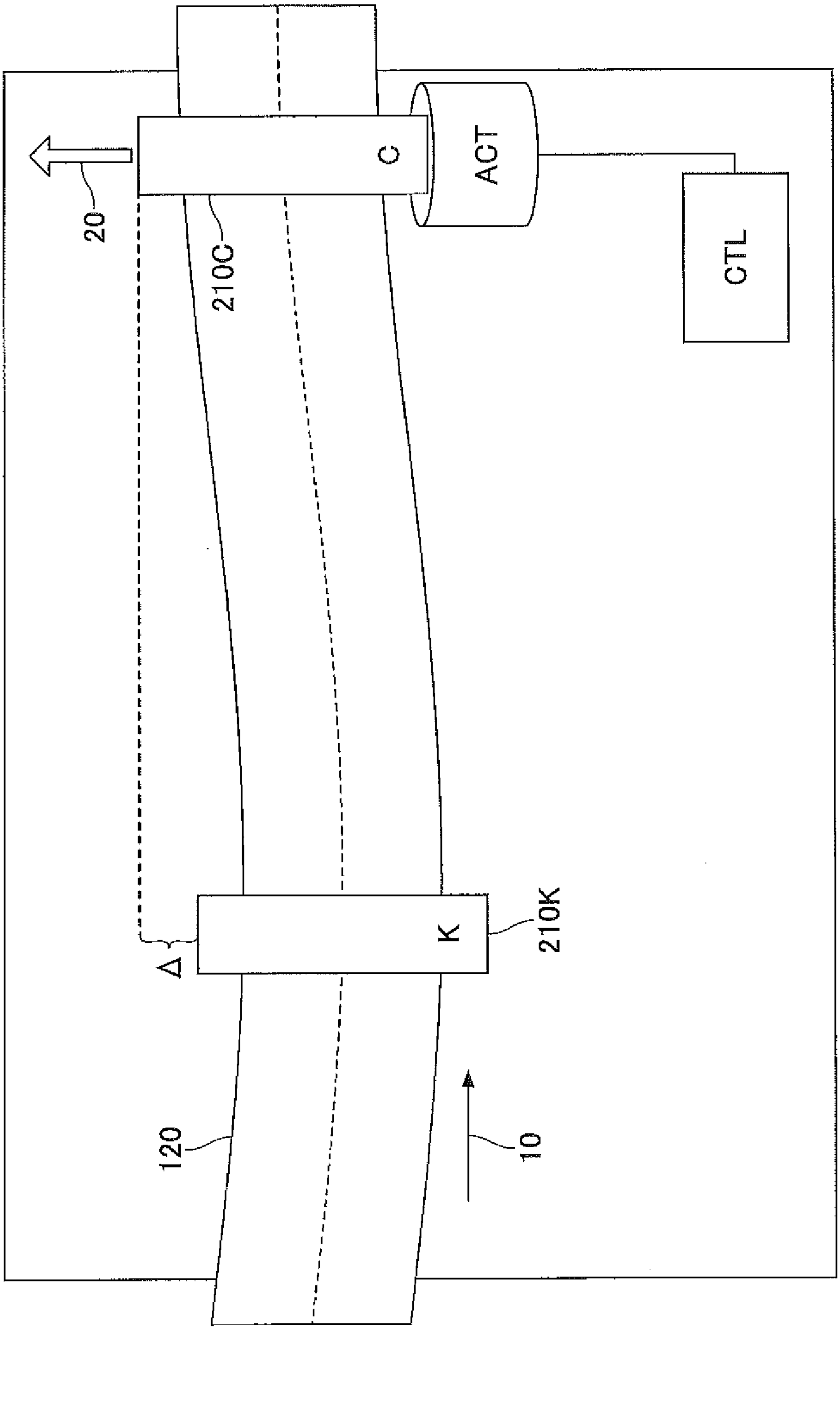


FIG.15

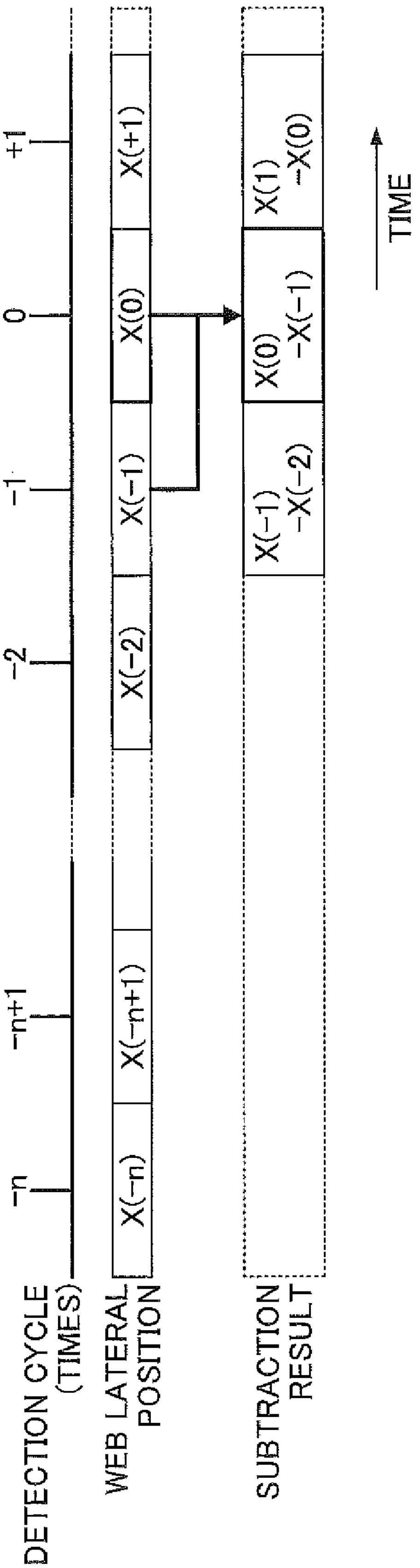

DETECTION CYCLE (TIMES)
−n
−n+1
−2
−1
0
+1
WEB LATERAL POSITION
X(−n)
X(−n+1)
X(−2)
X(−1)
X(0)
X(+1)
SUBTRACTION RESULT
X(−1) −X(−2)
X(0) −X(−1)
X(1) −X(0)
TIME

FIG.16

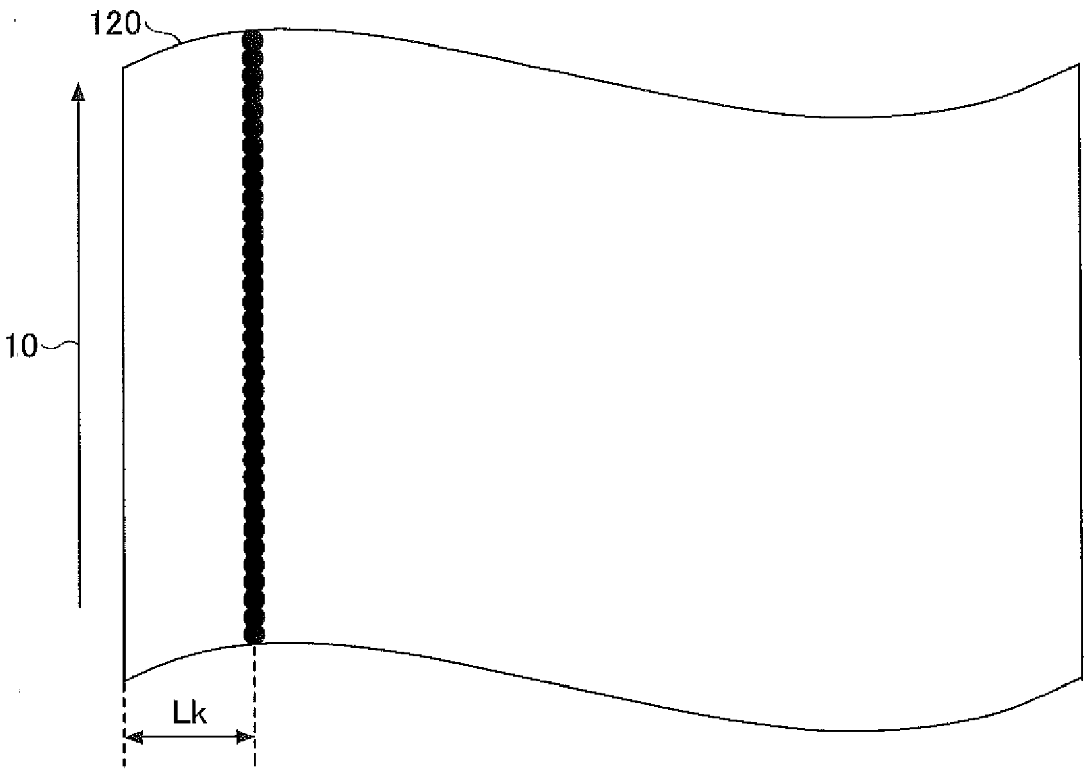


FIG.17A

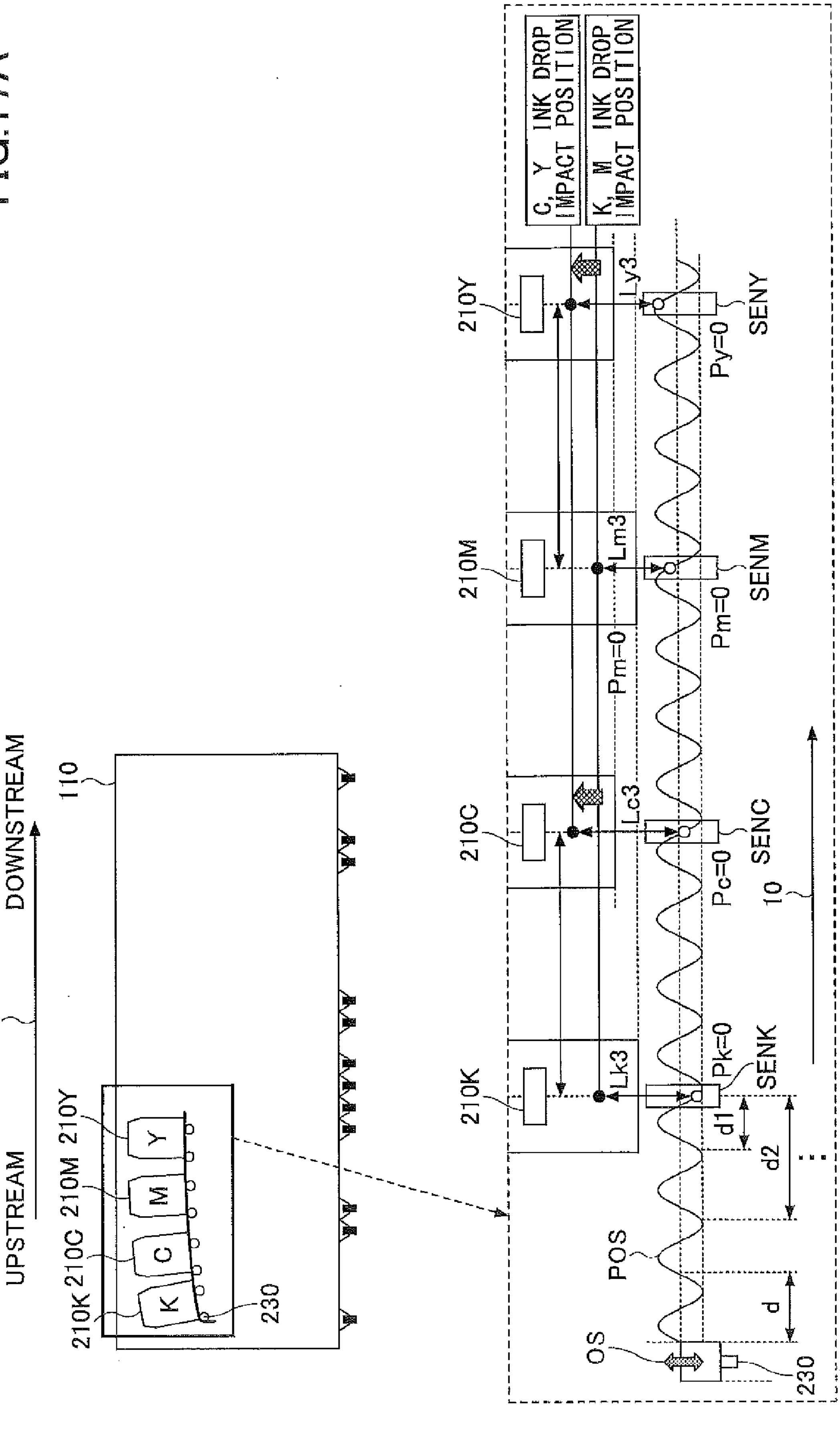

UPSTREAM
DOWNSTREAM
10
110
210K
210C
210M
210Y
K
C
M
Y
230
C, Y INK DROP IMPACT POSITION
K, M INK DROP IMPACT POSITION
Ly3
Lm3
Lc3
Lk3
Pm=0
Py=0
Pc=0
Pk=0
SENY
SENM
SENC
SENK
d1
d2
d
POS
OS

FIG.17B

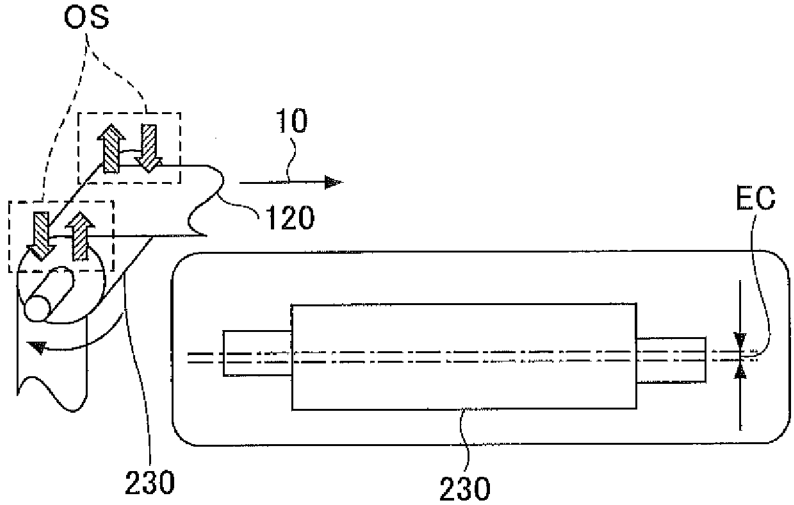


FIG.18

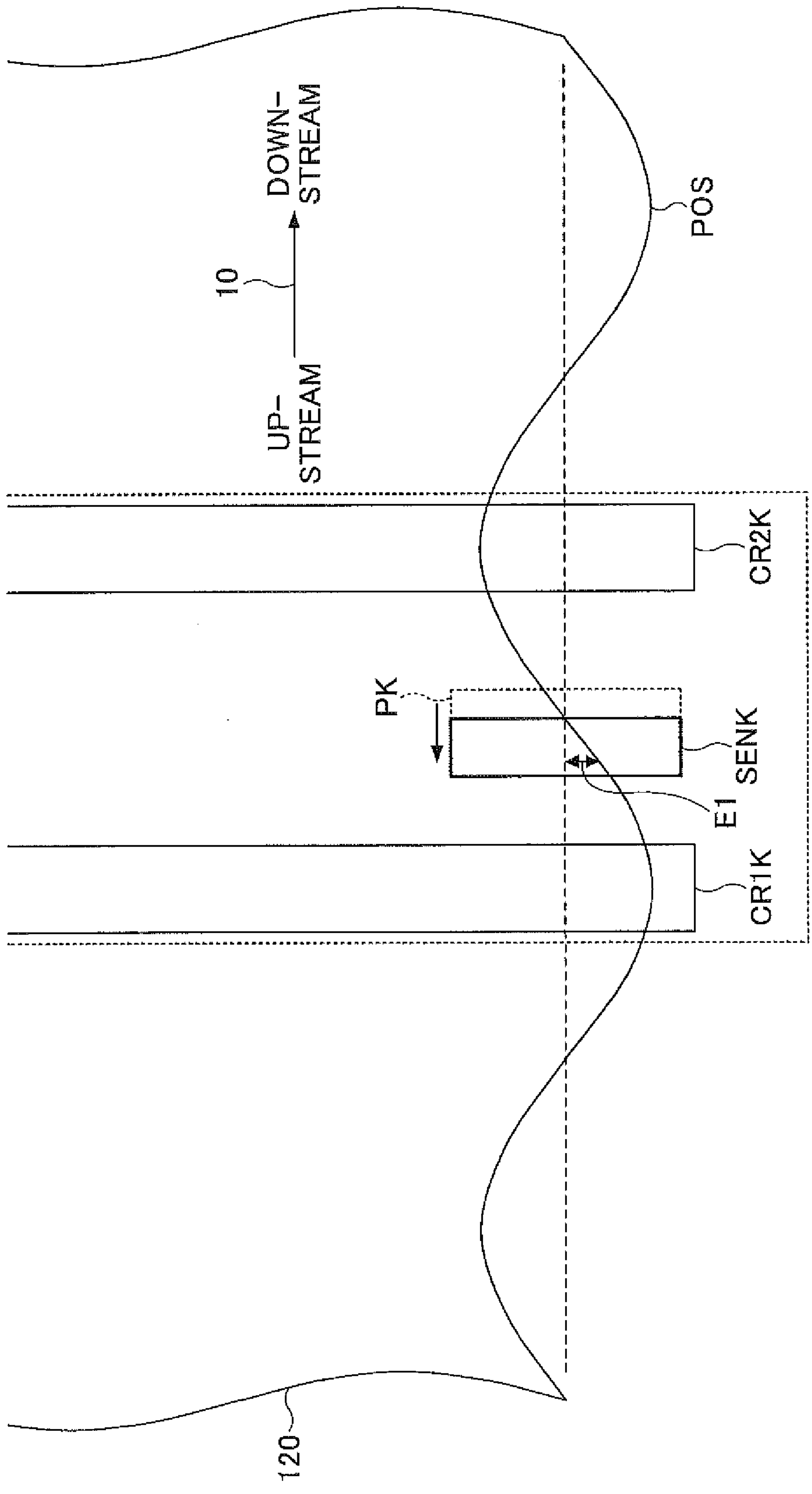


FIG.19

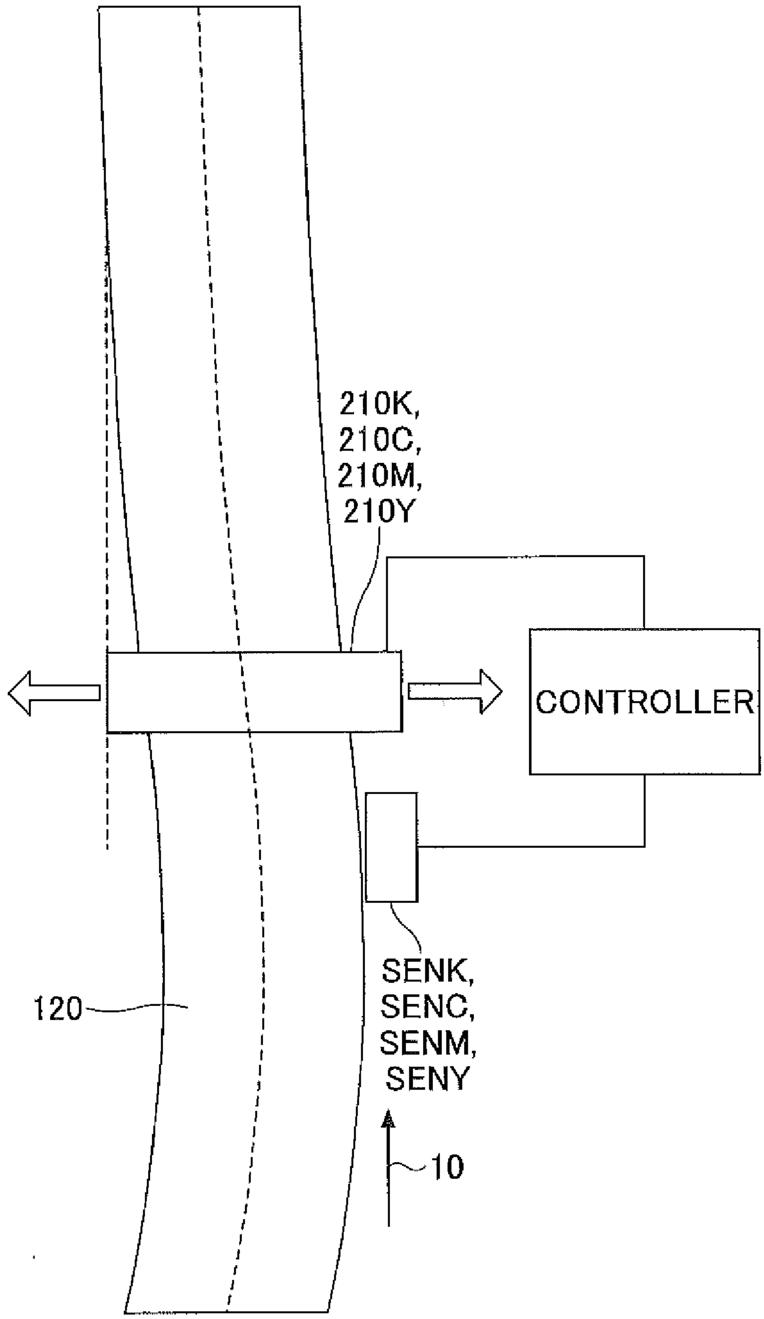


FIG.20

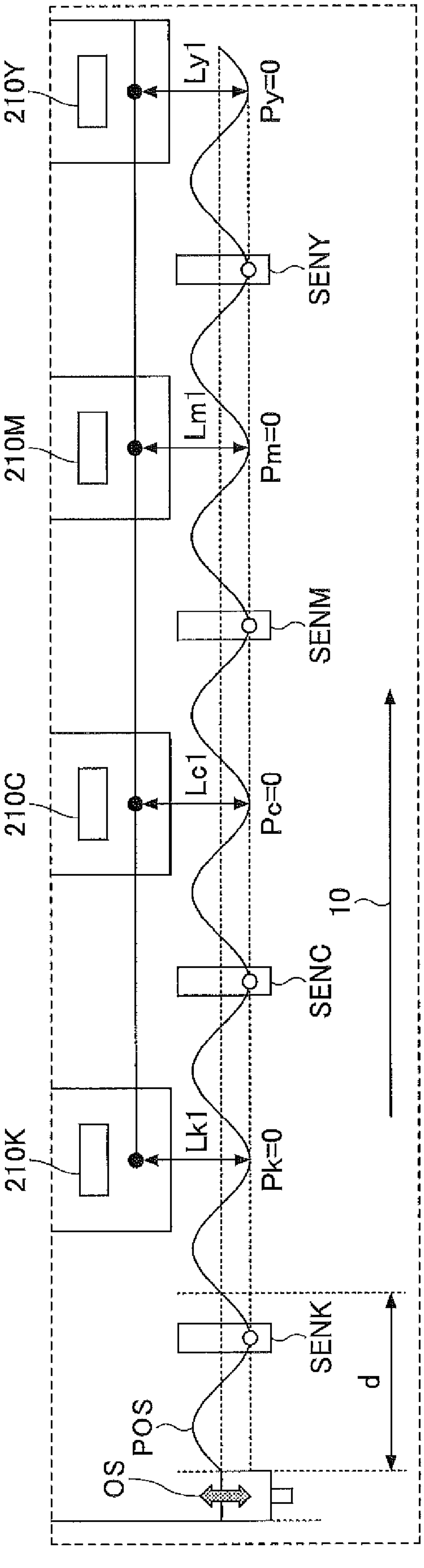

210Y
Ly1
Py=0
SENY
210M
Lm1
Pm=0
SENM
210C
Lc1
Pc=0
SENC
10
210K
Lk1
Pk=0
SENK
d
POS
OS

FIG.21

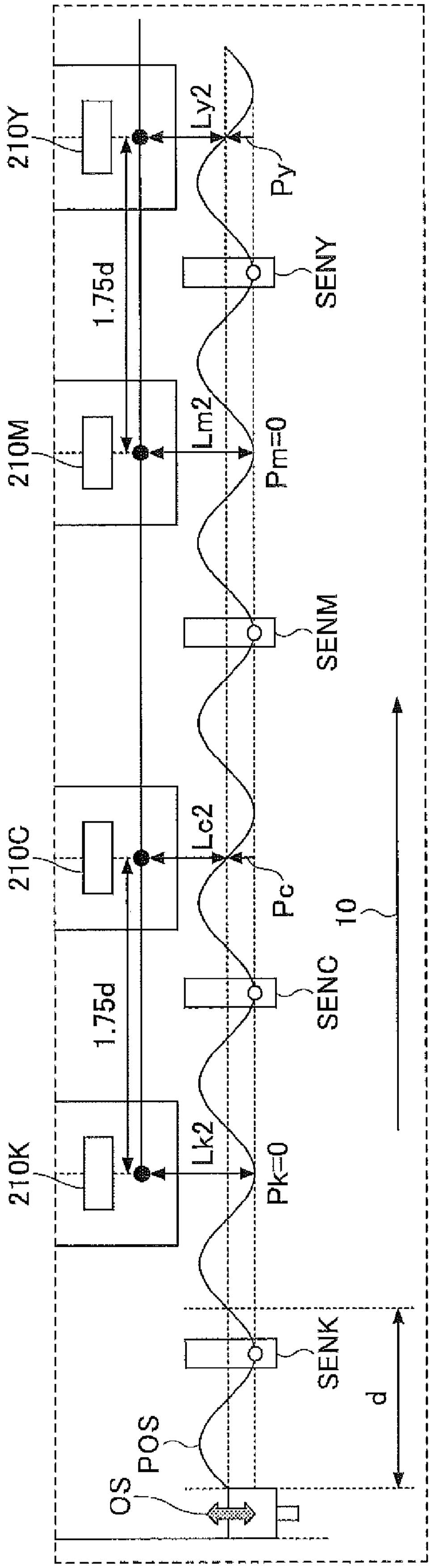
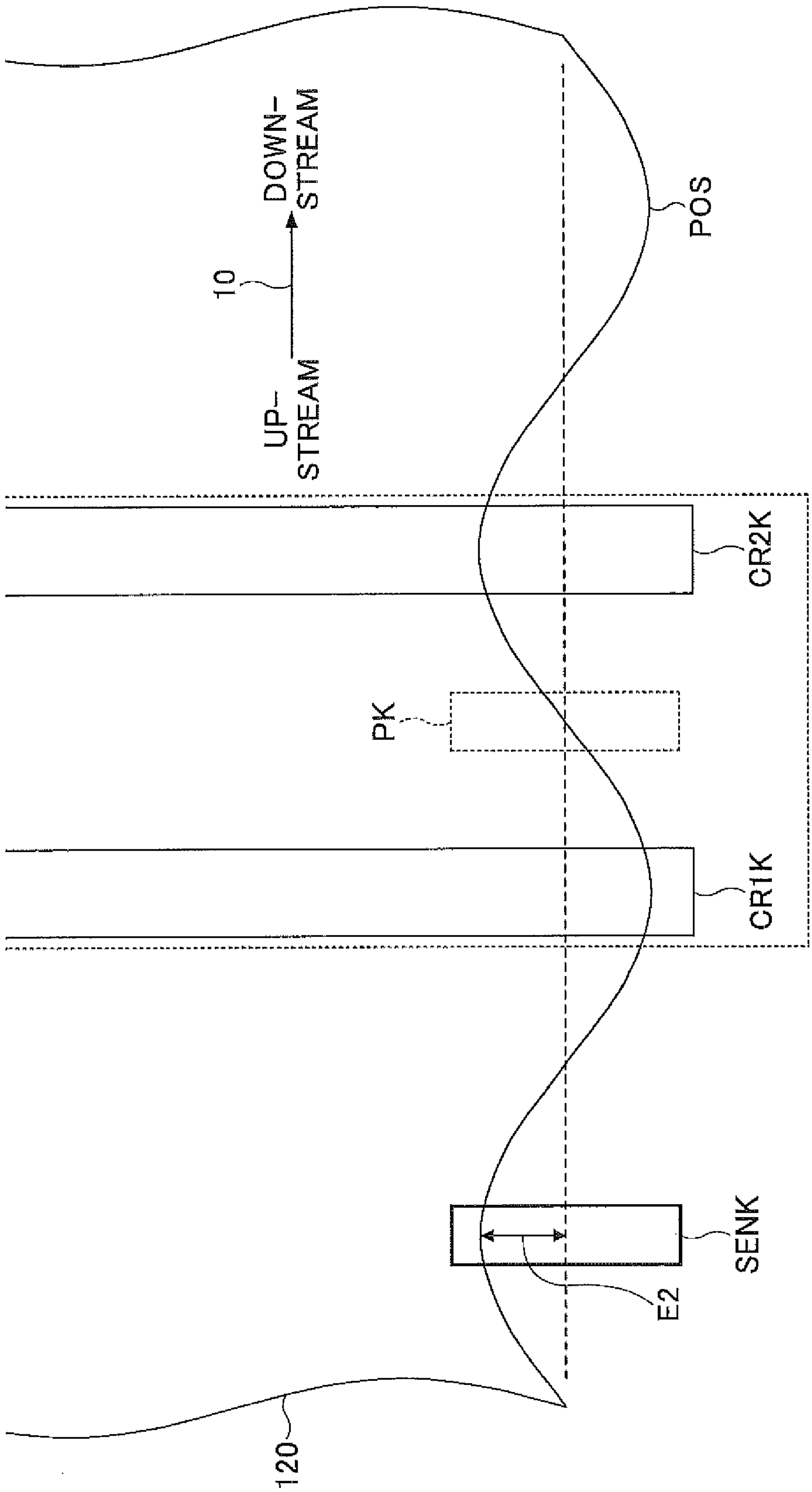

210Y
Ly2
Py
SENY
1.75d
210M
Lm2
Pm=0
SENM
210C
Lc2
Pc
10
SENC
1.75d
210K
Lk2
Pk=0
SENK
d
POS
OS

FIG.22



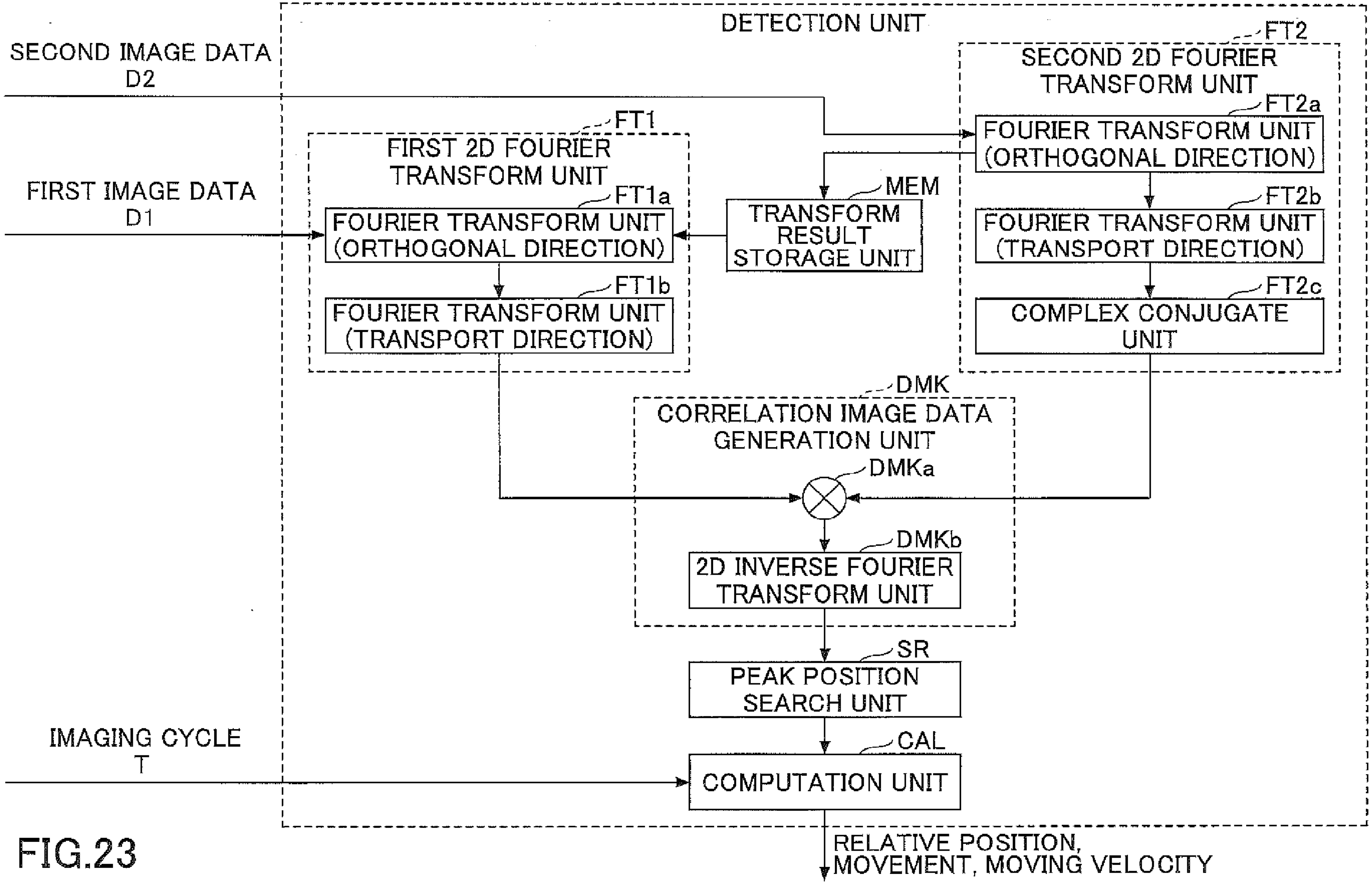

DETECTION UNIT
SECOND IMAGE DATA
D2
FIRST IMAGE DATA
D1
IMAGING CYCLE
T
FT1
FIRST 2D FOURIER
TRANSFORM UNIT
FT1a
FOURIER TRANSFORM UNIT
(ORTHOGONAL DIRECTION)
FT1b
FOURIER TRANSFORM UNIT
(TRANSPORT DIRECTION)
MEM
TRANSFORM
RESULT
STORAGE UNIT
FT2
SECOND 2D FOURIER
TRANSFORM UNIT
FT2a
FOURIER TRANSFORM UNIT
(ORTHOGONAL DIRECTION)
FT2b
FOURIER TRANSFORM UNIT
(TRANSPORT DIRECTION)
FT2c
COMPLEX CONJUGATE
UNIT
DMK
CORRELATION IMAGE DATA
GENERATION UNIT
DMKa
DMKb
2D INVERSE FOURIER
TRANSFORM UNIT
SR
PEAK POSITION
SEARCH UNIT
CAL
COMPUTATION UNIT
RELATIVE POSITION,
MOVEMENT, MOVING VELOCITY

FIG.23

FIG.24

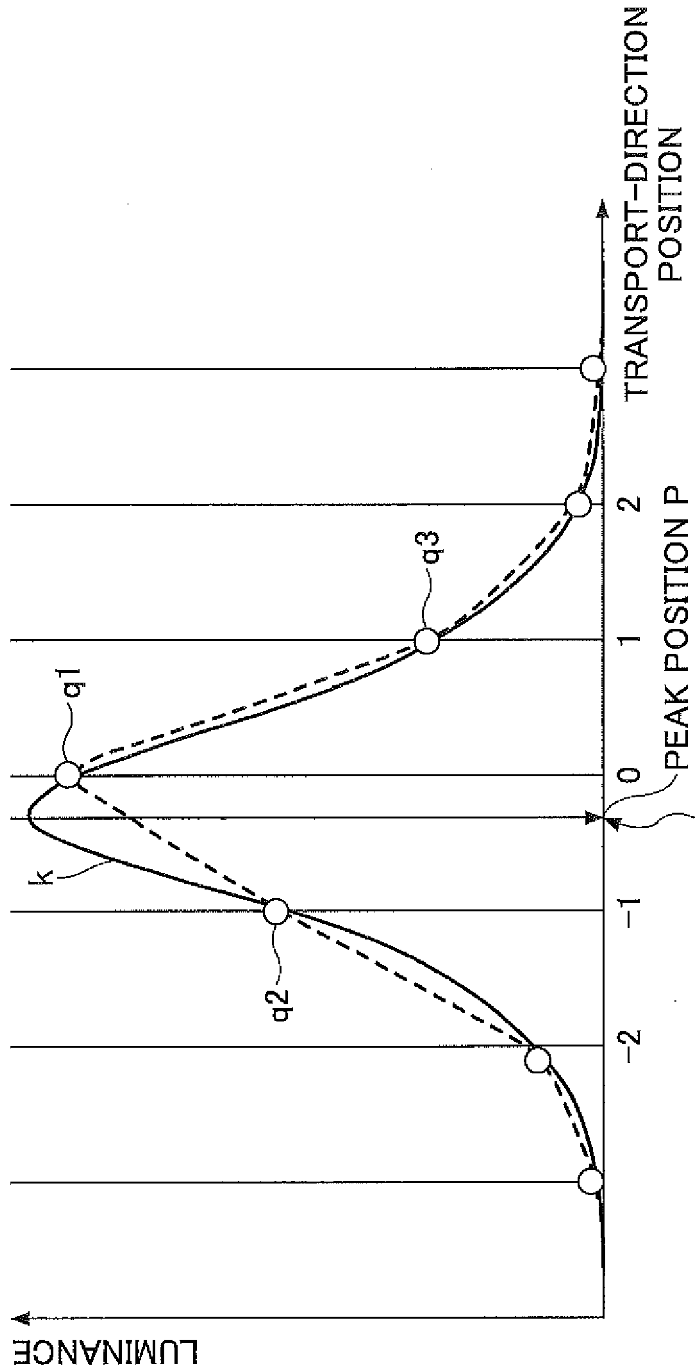
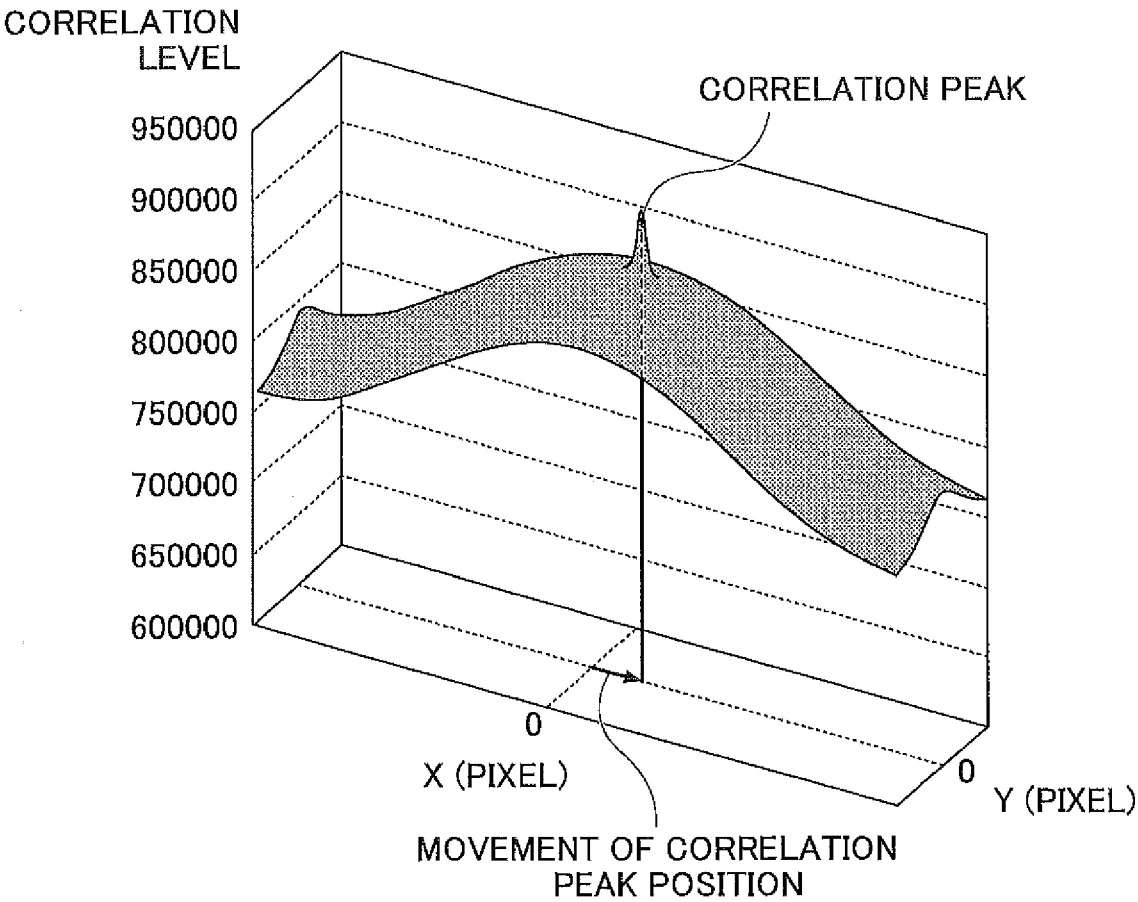

LUMINANCE
TRANSPORT-DIRECTION POSITION
PEAK POSITION P
−0.3
q1
q2
q3
k
−2
−1
0
1
2

FIG.25


CORRELATION LEVEL
950000
900000
850000
800000
750000
700000
650000
600000
CORRELATION PEAK
0
X (PIXEL)
0
Y (PIXEL)
MOVEMENT OF CORRELATION PEAK POSITION

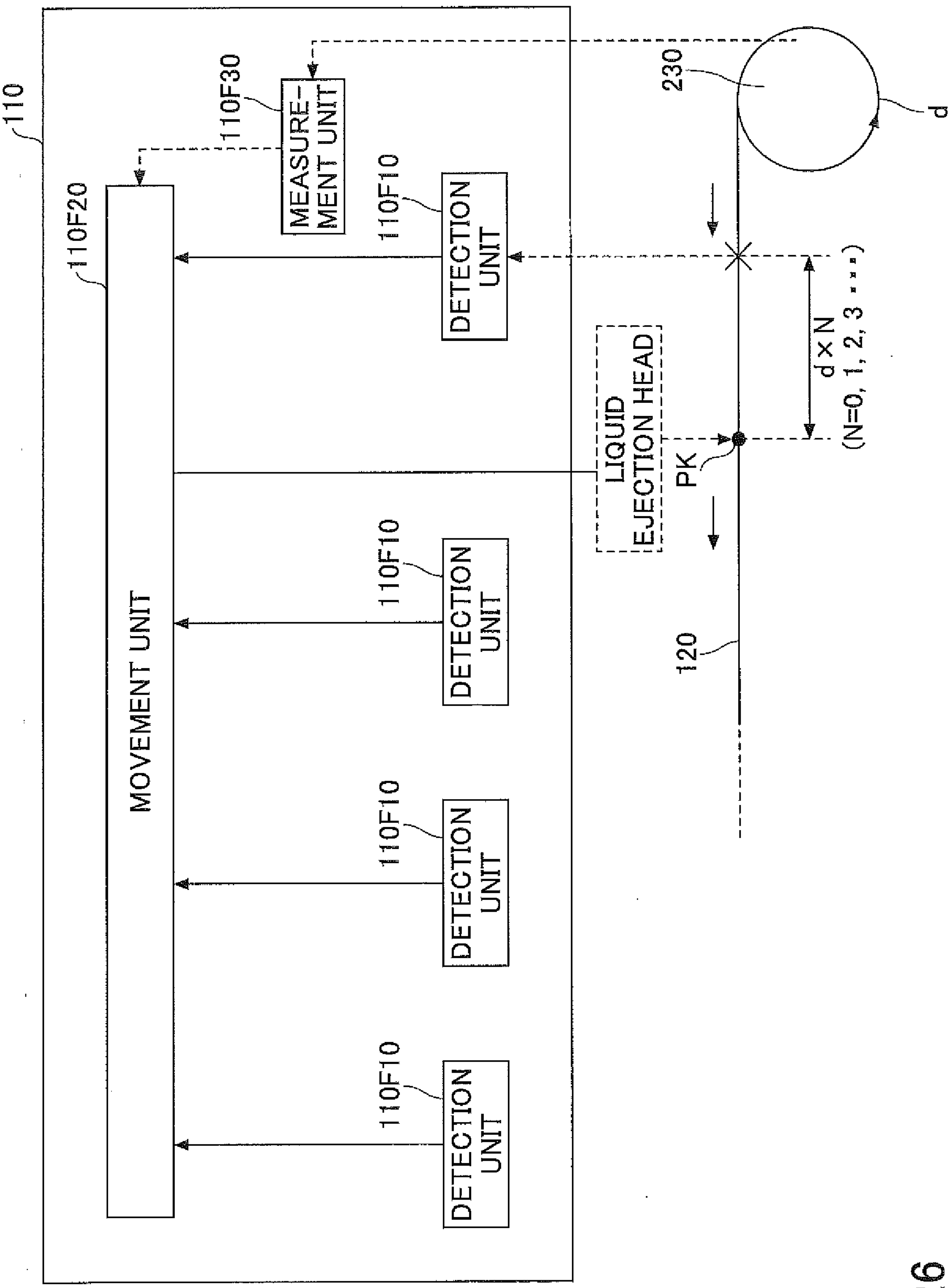
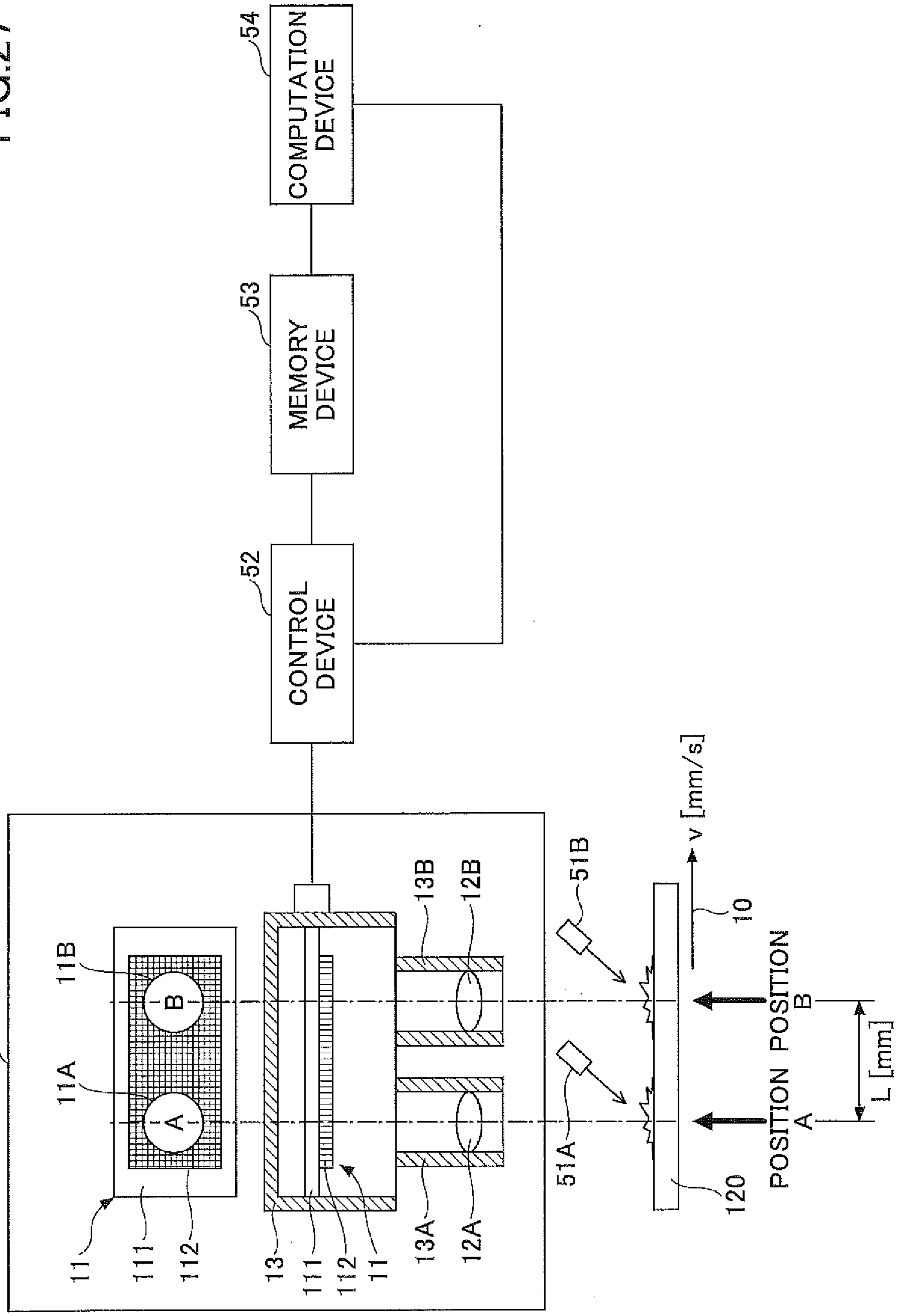

110
110F30
MEASURE-
MENT UNIT
110F20
MOVEMENT UNIT
110F10
DETECTION
UNIT
110F10
DETECTION
UNIT
110F10
DETECTION
UNIT
110F10
DETECTION
UNIT
LIQUID
EJECTION HEAD
PK
230
d
d×N
(N=0, 1, 2, 3 ...)
120

FIG.26

FIG.27



COMPUTATION DEVICE
54
MEMORY DEVICE
53
CONTROL DEVICE
52
50
11A
11B
A
B
11
111
112
13
111
112
11
13A
12A
13B
12B
51A
51B
120
10
v [mm/s]
POSITION A
POSITION B
L [mm]

FIG.28

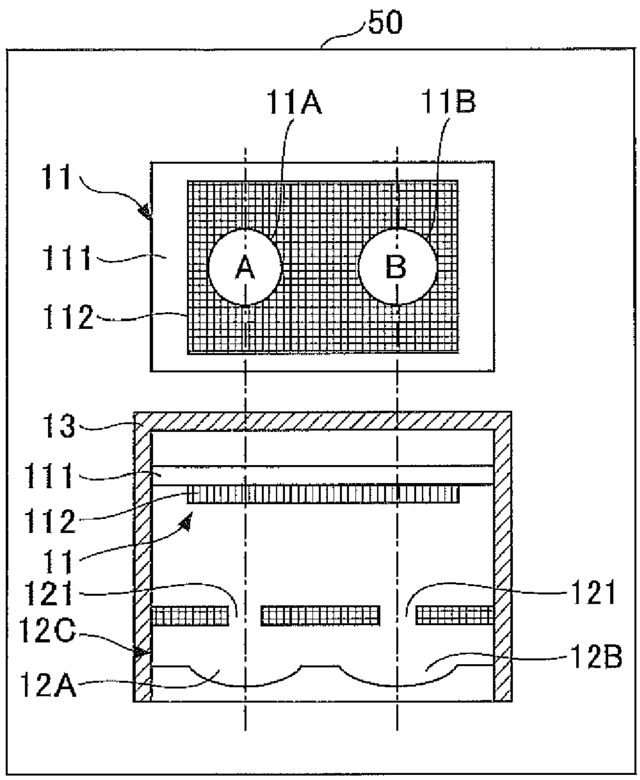


FIG.29B

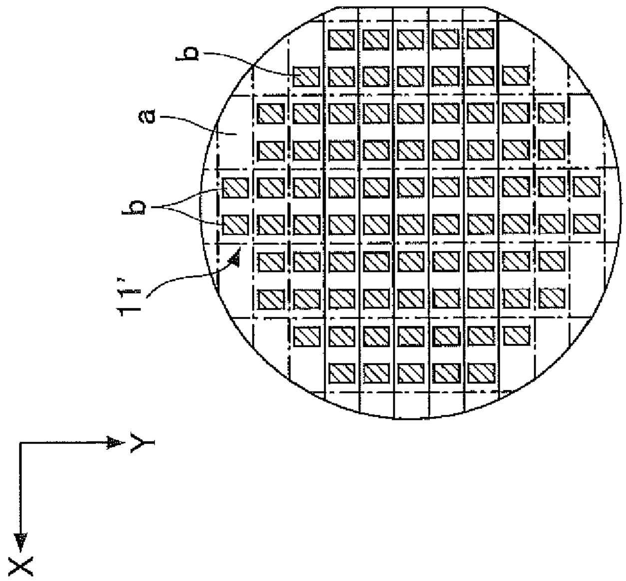


FIG.29A

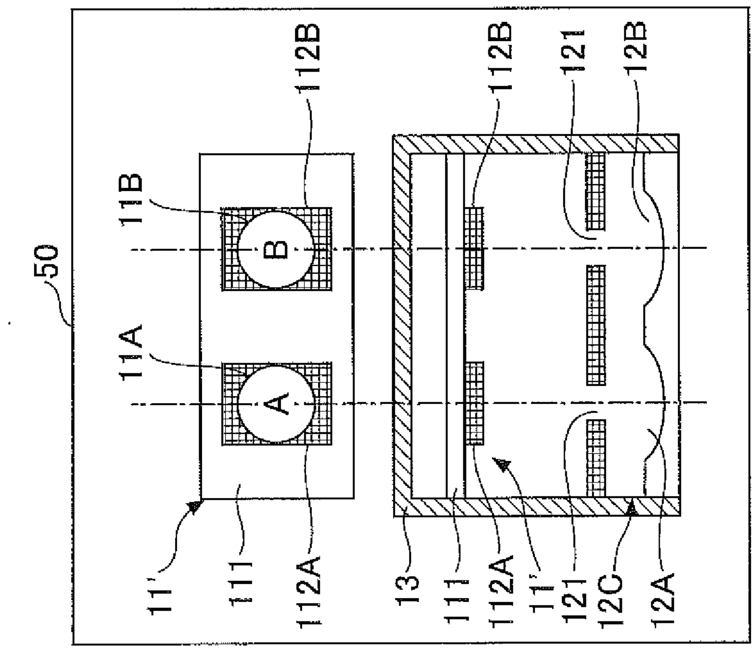


FIG.30

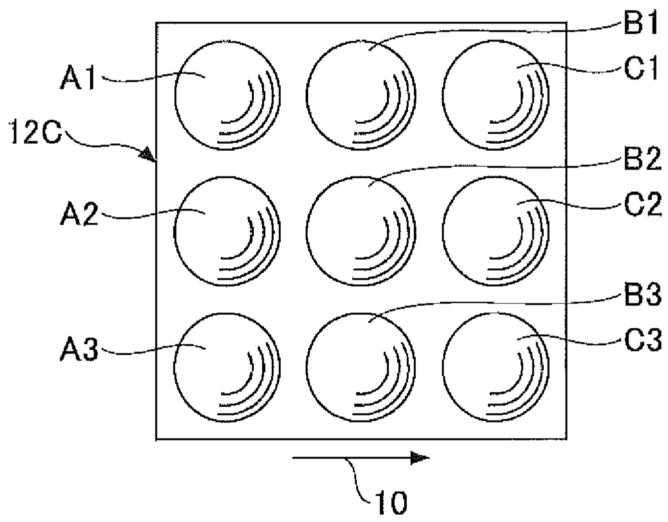


FIG.31

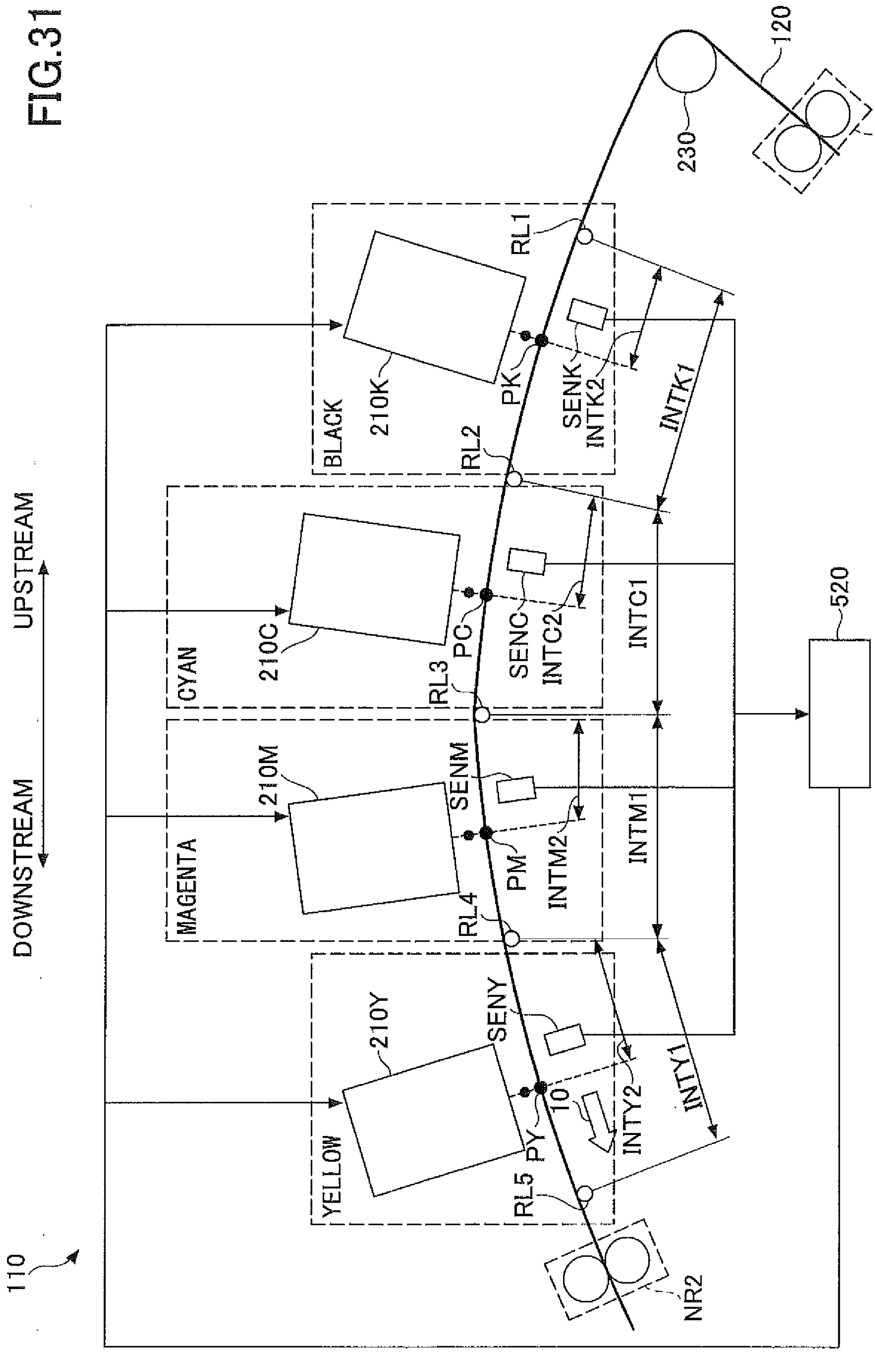
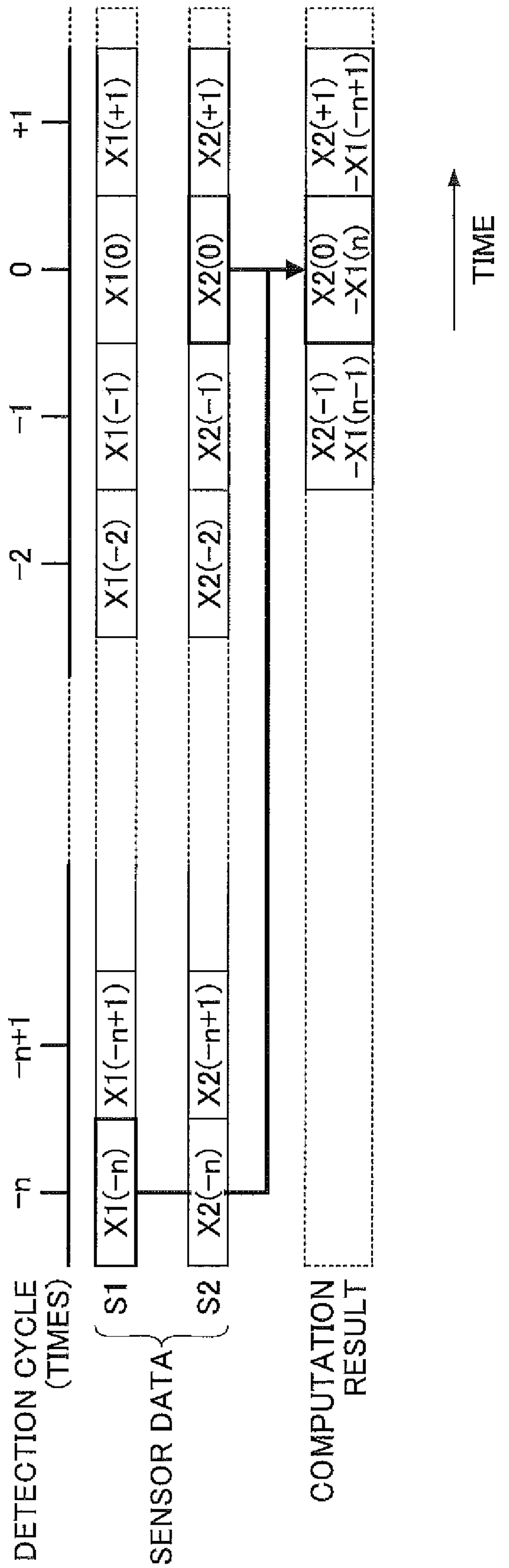

110
DOWNSTREAM
UPSTREAM
YELLOW
MAGENTA
CYAN
BLACK
210Y
210M
210C
210K
SENY
SENM
SENC
SENK
PY
PM
PC
PK
RL1
RL2
RL3
RL4
RL5
INTY1
INTY2
INTM1
INTM2
INTC1
INTC2
INTK1
INTK2
10
NR1
NR2
120
230
520

FIG.32


DETECTION CYCLE (TIMES)
−n
−n+1
−2
−1
0
+1
SENSOR DATA
S1
X1(−n)
X1(−n+1)
X1(−2)
X1(−1)
X1(0)
X1(+1)
S2
X2(−n)
X2(−n+1)
X2(−2)
X2(−1)
X2(0)
X2(+1)
COMPUTATION RESULT
X2(−1) −X1(n−1)
X2(0) −X1(n)
X2(+1) −X1(−n+1)
TIME

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 15 9874

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2015/009262 A1 (BELL RICHARD [US] ET AL) 8 January 2015 (2015-01-08) * paragraph [0024] * * paragraph [0031] * * figure 4 * -----	1-14	INV. B41J2/21 B41J11/00 B41J15/04

TECHNICAL FIELDS SEARCHED (IPC)

B41J

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	17 July 2017	Christen, Jérôme

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 15 9874

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-07-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015009262 A1	08-01-2015	EP 2857208 A1	08-04-2015
		JP 2015013476 A	22-01-2015
		US 2015009262 A1	08-01-2015

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2015013476 A **[0003]**
- JP 2016048248 A **[0194]**
- JP 2017018113 A **[0194]**