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

(11) EP 2 062 734 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.05.2009 Bulletin 2009/22

(51) Int Cl.:
B41J 2/21 *(2006.01)* ***B41J 29/393*** *(2006.01)*

(21) Application number: **08167028.3**

(22) Date of filing: **20.10.2008**

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

(30) Priority: **22.11.2007 EP 07121313**

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(54) Method for calibrating an inkjet printhead and inkjet printing apparatus

(57) A method for calibrating an inkjet printhead comprises printing a test pattern on a medium. The test pattern comprises a number of parts, which parts are printed from separate virtual parts of a row of nozzles of the printhead. The parts of the test pattern are arranged such that a sensor having a limited field-of-view is enabled to sense the test pattern in a single sensing operation, such as a single scanning operation.
Further the parts of the test pattern are arranged such that a relatively large number of dot positioning errors may be detected and at least partly compensated by adjusting a jet timing per nozzle, for example.

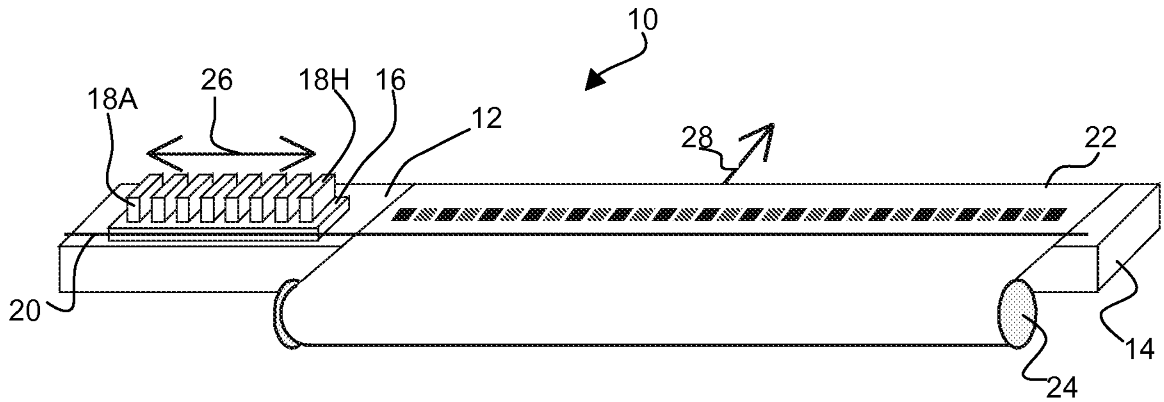

Fig. 1A

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Description

[0001] The present invention relates to a method for calibrating an inkjet printhead and to a printing apparatus configured for performing such a method. In particular, the method may be used with a printing apparatus comprising a printhead arranged for moving in a scanning direction and comprising a row of nozzles, the row of nozzles extending substantially in a medium advance direction, the medium advance direction being substantially perpendicular to said scanning direction.

[0002] It is known to calibrate an inkjet printhead arranged in an inkjet printing apparatus such that ink droplets ejected from the printhead impinge at a predetermined and intended position on the print medium, such as paper or any other suitable receiving medium, or at least at a position as close as possible to the intended position. The droplet may impinge at a different position due to a number of causes. For example, medium advancing may not be accurate, scanning movement of the printhead may not be accurate, the printhead may not be accurately positioned in the inkjet printing apparatus and/or an intended trajectory of the ejected nozzles is distorted due to dirt, nozzle defects, waste ink, and the like. The person skilled in the art readily recognizes that also other causes may exist.

[0003] In order to calibrate the printhead, it is known to use a test print. The test print comprises a predetermined test pattern from which it may be derived which droplets do not impinge at the intended position and preferably it may be derived how the printhead and thus the ejection of droplets may be controlled such that the droplet does impinge at the intended position, or at least as close to the intended position as possible. For example, a timing of the ejection of a droplet from a nozzle may be controlled by controlling the timing of the corresponding control signal, which control signal is to be supplied to the printhead in response to which the printhead will eject the droplet.

[0004] After printing the test pattern, the test pattern is to be examined in order to determine the misdirected droplets, their position and the corresponding error in the position. Based on the determined position error a correction, such as an adjusted ejection timing (hereinafter also referred to as jet timing). Thereto, it is known to provide the printing apparatus with a sensor such as an image sensor, for example a CCD sensor or a CMOS sensor, for *inter alia* imaging the test pattern. Thus, it is possible to obtain a (digital) representation of the printed test pattern and use well known image processing techniques to determine a position error and to determine a corresponding correction or adjustment.

[0005] In a known printing apparatus, a low-resolution image sensor, e.g. a single pixel sensor such as a photo-diode, is provided on a carriage carrying a printhead. The image sensor moves with the printhead and is as such suitable to be used as a test pattern sensor. However, the image sensor has a limited field of view and therefore, a test pattern having a size in the medium advance direction corresponding to a size of the row of nozzles of the printhead cannot be imaged by a single scanning movement of the image sensor. Hence, multiple scanning movements are required, thereby further requiring an advancing of the print medium for scanning. Then, the resulting scans need to be stitched together. In the process of multiple scans, medium advancing and stitching, additional errors may occur, deteriorating a result of the measurement and consequently of the calibration.

[0006] From US 7014289 it is known to use a multi-pass printing strategy in order to reduce or remove a measurement error due to a slanted printhead (mounted with skew), when using a low-resolution, small field-of-view imaging sensor. The row of nozzles of the slanted printhead is divided in a number of parts and each part of the row of nozzles print a number of pixels of a test pattern bar extending in the medium advance direction. Dots originating from different parts of the row of nozzles are intermingled. Thus, by averaging in the medium advance direction, an average position of the test pattern bar may be obtained. However, any information with respect to the dot position in relation to the part of the printhead is lost.

[0007] It is desirable to have a calibration method using a test pattern and to have a printing apparatus suitable for performing the method, wherein as much information about the printhead position as possible is preserved and wherein a sensor having a small field-of-view may be used to image the test pattern.

[0008] The object is achieved in a method according to claim 1 and a printing apparatus according to claim 16.

[0009] In an embodiment of the method according to the present invention, the test pattern has a predetermined pattern size in the medium advance direction. Hence, in an embodiment, the test pattern may be selected to have a pattern size that is equal to, or smaller than a size of the field-of-view of a sensor in the corresponding direction. The row of nozzles of the printhead extends substantially in the medium advance direction and is divided in a number of parts, wherein each part comprises an number of nozzles of the row of nozzles. Each part has a size in the medium advance direction that corresponds to the pattern size. A subset of nozzles comprised in each part used for printing the test pattern is used to print a part of the test pattern. Each part of the test pattern is build from dots originating from a single part of the row of nozzles, while elements of these parts of the test pattern may be intermingled. Since the elements of the separate parts may be intermingled, the elements may be averaged in order to obtain an average position, or the like, while information about the parts of the row of nozzles is still available from the respective parts of the test pattern.

[0010] In an embodiment, the predetermined medium advance distance corresponds to the predetermined pattern size. Thus, the medium is advanced over a distance that is substantially equal to the size of the part of the row of nozzles, and a subsequent part of the nozzle row may be adjacent to the previous part of the nozzle row. In this embodiment it is possible to obtain test results from each part of the row of nozzles.

[0011] In an embodiment, the first part and the second part of the test pattern each comprise a number of test elements and the test elements of the first part and the test elements of the second part are arranged alternatingly. The test elements of the parts of the test pattern are positioned alternatingly enabling to employ a number of nozzles of each part of the row of nozzles, which number of nozzles are spread over said part. Use of a spread number of nozzles provides test results that are representative for the whole corresponding part of the row of nozzles.

[0012] In an embodiment, the test elements are bar-shaped elements extending in the scanning direction. A bar shaped element enables to obtain insight in a number of print errors resulting from a printhead position error or a printhead orientation error.

[0013] In a further embodiment, the bar shaped elements may be adjacent to each other thereby forming a bar-shaped element extending in the media advance direction. In a further embodiment, the bar-shaped elements are spaced apart in the medium advance direction. In the former embodiment, an edge of the bar-shaped element still provides information about the respective parts of the row of nozzles. In the latter embodiment, the bar-shaped elements extending in the scanning direction are still individually recognizable and may be separately measured and handled. Thus, the latter embodiment may be better suited to be used in combination with automatic image processing for measuring any errors. The former embodiment may be more suited to be used in combination with a printhead in which a single adjustment factor, for example adjusting the jet timing, is applied to all nozzles of the row (compared to applying a respective adjustment to each separate nozzle).

[0014] In an embodiment, the row of nozzles is subdivided in a predetermined number of parts, wherein the number of parts is three or more. In such embodiment, the method further comprises repeating the steps of advancing the print medium and printing a further part of the test pattern for each of the third and further parts of the row of nozzles. It is noted that the number of parts of the row of nozzles may be selected based on a field-of-view of an available imaging sensor, as above described.

[0015] In the above-mentioned embodiment, in which all nozzles of the row of nozzles are controlled by a single adjustment factor, the method may comprise determining a test pattern profile by averaging the test pattern in the media advance direction and calibrating the printhead based on measurements taken from the test pattern profile. Thus, all errors of at least a part of the nozzles of the row are averaged and the single adjustment factor may be determined based on such an average error, thereby making the average error substantially as small as possible.

[0016] In an embodiment, each part of the test pattern is printed in a first scanning movement of the printhead in a positive scanning direction and in a second scanning movement in a negative scanning direction, the positive and the negative scanning direction being opposite to each other, the method comprising printing reference elements in the first scanning movement and printing calibration elements in the second scanning movement. In such embodiment, a difference in the scanning direction between the reference elements and the calibration elements corresponds to a bi-directional error. The bi-directional error indicates a difference in position between an ink dot jetted in the first scanning movement and an ink dot jetted in the second scanning movement, while both were intended to be printed at the same position.

[0017] In an embodiment, the inkjet printer comprises at least two rows of nozzles, the method comprising printing reference elements using a first row of nozzles and printing calibration elements using a second row of nozzles. An inkjet printer may comprise two row of nozzles, either by having (1) two or more printheads each comprising one or more rows of nozzles or (2) at least one printhead comprising two or more rows of nozzles. A difference in position in the scanning direction between the reference elements originating from the first row and the calibration elements originating from the second row corresponds to a mono-directional error. The mono-directional error indicates a difference in position between an ink dot jetted from the first row of nozzles and an ink dot jetted from the second row of nozzles, while both were intended to be printed at the same position. Both the bi-directional error and the mono-directional error should be as small as possible to obtain a good print quality.

[0018] In an embodiment for determining the mono-directional error, the test pattern is printed in a first scanning movement of the printhead in a positive scanning direction and a second scanning movement in a negative scanning direction, the positive and the negative scanning direction being opposite to each other. In this embodiment, the method comprises determining an average position of the reference elements; determining an average position of the calibration elements; and calibrating the inkjet printhead based on a distance between the respective average positions of the reference elements and the calibration elements.

[0019] In an embodiment, the method comprises determining a distance profile of a first row of nozzles over a full scanning range of a first printhead in the scanning direction, the distance profile indicating a distance between the nozzles of said first row of nozzles as a function of a position of the printhead in the scanning direction; printing the test pattern according to the present invention for each row of nozzles of each printhead over a part of the scanning range of each printhead in the scanning direction; and calibrating each row of nozzles of each printhead over the full scanning range by combining the distance profile of the first row of nozzles of the first printhead and the test patterns printed according to the present invention, taking into account a positional relationship between each row of nozzles and said first row of nozzles. In order to reduce a period of time needed for the calibration, each row of nozzles of each printhead may print only a small test pattern in the scanning direction and only one row of nozzles is used for determining any imperfections over the full width of the printer. The distance profile obtained from the one row of nozzles is compensated for the difference in position and orientation of each row of nozzles and then combined with the respective results of the respective rows of nozzles.

[0020] In an embodiment, the positional relationship between the rows of nozzles is determined from the test patterns printed according to the present invention. In particular, respective mono-directional test patterns as above described are suitable for accurately determining the actual positional relationship, although in an embodiment only the nominal positional relationship may be applied.

[0021] In an embodiment, the inkjet printer is configured to be operated in a first print mode and a second print mode, a printing parameter having a first value in the first print mode and having a second value in the second printing mode, the method comprising printing the test pattern according to the present invention in the first print mode and calibrating the printhead for operation in the second print mode based on the test patterns printed in the first print mode taking into account a difference between the first value and the second value of the printing parameter. For example, a speed of a carriage carrying the printhead may be set differently in the respective print modes, thus providing a high-speed print mode and a high-quality print mode. Based on such a difference, calibration of the second print mode may be estimated based on the calibration of the first print mode.

[0022] In an aspect, the present invention further provides a printing apparatus that is configured to perform the calibration method according to the present invention.

[0023] Hereinafter, the present invention is further elucidated with reference to the appended drawings showing non-limiting embodiments and in which:

Fig. 1A schematically illustrates an embodiment of an inkjet printing apparatus;

Fig. 1 B	schematically illustrates a printhead carriage for use in the printing apparatus of Fig. 1A;
Fig. 2A - 2B	schematically illustrate a first bi-directional print error;
Fig. 2C - 2D	schematically illustrate a first mono-directional print error;
Fig. 2E - 2F	schematically illustrate a second bi-directional print error;
Fig. 2G - 2H	schematically illustrate a second mono-directional print error;
Fig. 3A	schematically illustrates a test pattern for determining a bi-directional error;
Fig. 3B	schematically illustrates a test pattern for determining a mono-directional error;
Fig. 4	is a perspective view schematically illustrating a sensor assembly for sensing a test pattern;
Fig. 5A - 5B	schematically illustrate a method for generating a test pattern in accordance with the present invention;
Fig. 6A - 6B	show a test pattern resulting from a printhead rotated around a Y-axis;
Fig. 6C - 6D	show a test pattern resulting from a printhead rotated around a Z-axis; and
Fig. 6E - 6F	show a test pattern resulting from a medium advancing error.

[0024] In the drawings, same reference numerals refer to same elements.

[0025] In Fig. 1A and 1B, an embodiment of an inkjet printing apparatus 10 is illustrated. The inkjet printing apparatus 10 comprises a print surface 12 arranged on a base frame 14, a number of printheads 18A- 18H arranged on a printhead carriage 16 and a guide assembly 20 for guiding the printhead carriage 16 to scan over the print surface 12 in a scanning direction as indicated by arrow 26. A print medium 22 is supplied on a roll 24, but may as well be supplied as a separate sheet. The print medium 22 may be paper, or the like, or any other suitable print medium. The print medium 24 is movable in a medium advance direction as indicated by arrow 28. Referring to Fig. 1B, as used herein, the scanning direction 26 corresponds to a Y-axis and the medium advance direction 28 corresponds to a X-axis. In the illustrated embodiment, each printhead 18A- 18H comprises a first row of nozzles 34A and a second row of nozzles 34B. When mounted in the inkjet printing apparatus 10, each row of nozzles 34A - 34B extends substantially in the medium advance direction 28.

[0026] In operation, the print medium 22 is positioned on the print surface 12. The printhead carriage 16 is guided along the guide assembly 20 over the print surface 12. In response to a digitally input print image, each printhead 18A- 18H ejects drops of ink towards the print medium 22 such that a swath of the print image is printed on the print medium 22 as an array of ink dots. A swath may be printed by a single pass of the printhead carriage 16 or by a multiple pass of the printhead carriage 16 depending on a print strategy. In general, multiple passes allow a higher print quality, while a single pass provides a relatively short printing time. After each swath, the print medium 22 is advanced in the medium advance direction 28 over a distance corresponding to the swath size in the medium advance direction 28 such that a subsequent swath may be printed adjacent to the printed swath.

[0027] In order to obtain a sufficient print quality, the drops of ink that are ejected from the printheads 18A - 18H are required to impinge on the print medium 22 at a location that is within a predetermined distance from an intended location. Very small errors in a position and/or orientation of each printhead 18A - 18H may however lead to relatively large errors in location of the ejected drops. Also other error sources may lead to such dot positioning errors as is known to a person skilled in the art.

[0028] In Fig. 2A - 2H a printhead 18 is shown. For ease of illustration, it is assumed that each printhead 18 comprises a single row of nozzles. However, in an embodiment in which each printhead 18 comprises multiple rows of nozzles, in the below description relating to Fig. 2A - 2H, a reference to the printhead 18 should be interpreted as a reference to a row of nozzles of the printhead 18.

[0029] In Fig. 2A - 2H, the printhead 18 is moving in a positive or negative scanning direction as indicated by respective arrows 30. A (virtual) reference surface 32 is shown for illustrative purposes, which reference surface 32 is perpendicular to the scanning direction 30. Usually, it is desirable that a row of dots ejected by the row of nozzles of each printhead 18 is substantially parallel to the reference surface 32. An intended row location, i.e. an intended location of a printed row of dots, is indicated by respective dashed lines 36. A trajectory of the ink drops from the printhead 18 to the medium is indicated by dashed arrows 38 and 40. Further, an actual row location, i.e. an actual location of a printed row of dots, is indicated by respective lines 42 and the corresponding actual ink drop trajectory arrows 44 and 46. It is noted that in Fig. 2E - 2H, the intended trajectory and the actual trajectory coincide, as a consequence of which the dashed arrow 38 and the arrow 44 coincide.

[0030] Now referring to Fig. 2A - 2D, an example is shown in which ink drops do not impinge on the print medium at the intended row location, but each ink drop lands at a same distance from its intended location. Thus, the actual row location line 42 is substantially parallel to the intended row location line 36. The positioning errors may be corrected, or at least partly compensated, by adjusting an ejection timing. Moreover, a single adjustment factor may be applied to all nozzles, since the error is substantially equal for each nozzle. Such an error may result from a rotation of the printhead 18 around the X-axis, for example.

[0031] In Fig. 2A - 2B, the error is a bi-directional positioning error. A direction of a deviation depends on the direction of a movement of the printhead 18. For example, in Fig. 2A, the printhead 18 moves in a positive scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36. In Fig. 2B, the printhead 18 moves in a negative scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36.

[0032] In Fig. 2C - 2D, the error is a mono-directional positioning error. A direction of a deviation does not depend on the direction of a movement of the printhead 18. For example, in Fig. 2C, the printhead 18 moves in a positive scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36. In Fig. 2D, the printhead 18 moves in a negative scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in an opposite direction relative to the intended row location line 36. In particular, in Fig. 2D, the direction of deviation is the same as the direction of deviation in Fig. 2C.

[0033] It is noted that, in an embodiment, the direction of displacement of the actual row location line 42 may be opposite to the scanning direction 30 - for both positive and negative scanning direction - instead of being the same.

[0034] Now referring to Fig. 2E - 2H, an example is shown in which ink drops do not impinge on the print medium at the intended row location, but each ink drop lands at a distance from its intended location, but the distance varies per nozzle; in particular, the distance between the intended row location line 36 and the actual row location line 42 increases in a direction of the row of nozzles (X-axis). The positioning errors may be corrected, or at least partly compensated, by adjusting an ejection timing per nozzle. Thus each nozzle is provided with a respective adjustment factor. The error may result from a rotation of the printhead 18 around the Y-axis or the Z-axis, for example. Further, such an error may result from a medium advance error, if the medium is slanted while being advanced, for example.

[0035] In Fig. 2E - 2F, the error is a bi-directional positioning error. A direction of a deviation depends on the direction of a movement of the printhead 18. For example, in Fig. 2E, the printhead 18 moves in a positive scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36. In Fig. 2F, the printhead 18 moves in a negative scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36.

[0036] In Fig. 2G - 2H, the error is a mono-directional positioning error. A direction of a deviation does not depend on the direction of a movement of the printhead 18. For example, in Fig. 2G, the printhead 18 moves in a positive scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in the same direction relative to the intended row location line 36. In Fig. 2H, the printhead 18 moves in a negative scanning direction, as indicated by arrow 30, and the actual row location line 42 is displaced in an opposite direction relative to the intended row location line 36. In particular, in Fig. 2H, the direction of deviation is the same as the direction of deviation in Fig. 2G.

[0037] In general, a bi-directional positioning error is an error resulting from a difference in scanning movement direction of the printhead. A mono-directional positioning error is an error resulting from a difference in the row of nozzles from which the ink dots originate. Hence, for determining a bi-directional error, a single row of nozzles may be used and a distance between dots printed in a positive scanning movement direction may be determined; for determining a mono-directional error, two rows of nozzles may be used and a distance between dots printed by a first row of nozzles and dots printed by a second row of nozzles may be determined. This is elucidated below with reference to Fig. 3A and 3B.

[0038] It is noted that an actual positioning error is usually a combination of a bi-directional positioning error and a mono-directional positioning error. However, for correcting or at least partly compensating the actual positioning error the bi-directional positioning error and the mono-directional positioning error are determined. Then, a first timing adjustment factor for correcting or at least partly compensating the bi-directional positioning error and a second timing adjustment factor for correcting or at least partly compensating the mono-directional positioning error may be determined and introduced, thereby correcting or at least partly compensating the actual positioning error.

[0039] Fig. 3A shows a part of an embodiment of a test pattern 50 for determining a bi-directional positioning error. The test pattern 50 comprises a number of bar-shaped elements, in particular a first bar-shaped element 52, a second bar-shaped element 54 and a third bar-shaped element 56. For each bar-shaped element 52, 54, 56 a center line C52, C54, C56, respectively, is indicated. The bar-shaped elements 52, 54, 56 are alternatingly printed in a positive scanning movement and a negative scanning movement of the printhead to be calibrated as indicated by the arrows 58, 60, 62 indicating the scanning movement corresponding to the bar-shaped elements 52, 54, 56, respectively. An arrow d1 indicates a first distance between the center line C54 of the second bar-shaped element 54 and the center line C52 of the first bar-shaped element 52. An arrow d2 indicates a second distance between the center line C54 of the second bar-shaped element 54 and the center line C56 of the third bar-shaped element 56.

[0040] While printing the test pattern 50, the printhead to be calibrated is controlled such that the intended positions of the center lines C52, C54 and C56 are spaced apart at a same distance. Due to a bi-directional positioning error, the distance between adjacent bar-shaped elements may be disturbed as elucidated hereinafter with reference to Fig. 3A. In Fig. 3A, it is assumed that a bi-directional positioning error corresponding to the error as illustrated in Fig. 2A - 2B is present.

[0041] In Fig. 3A, as indicated by the corresponding arrows 58 and 62, the first and the third bar-shaped elements 52 and 56 are printed by the printhead moving in the positive scanning direction. The second bar-shaped element 54 is printed by the printhead moving in the negative scanning direction, as indicated by arrow 60. Due to the bi-directional positioning error, the first and the third bar-shaped elements 52, 56 are shifted in the negative scanning direction relative to the second bar-shaped element 54. Consequently, the first distance d1 is larger than the second distance d2. If no bi-directional positioning error would be present, the first distance d1 and the second distance d2 would have been equal.

[0042] The test pattern 50 is selected such that a mono-directional positioning error does not influence a measurement result. This is achieved by printing the bar-shaped elements 52, 54, 56 alternatingly in the positive and in the negative scanning direction. A position of each bar-shaped element 52, 54, 56 is influenced by a mono-directional positioning error. However, since the measurement result depends on the mutual distances d1, d2 the mono-directional positioning errors are eliminated from the measurement.

[0043] Fig. 3B shows a part of an embodiment of a test pattern 70 for determining a mono-directional positioning error. The test pattern 70 comprises a number of bar-shaped elements, in particular a first bar-shaped element 72, a second bar-shaped element 74 and a third bar-shaped element 76. For each bar-shaped element 72, 74, 76 a center line C72, C74, C76, respectively, is indicated. The bar-shaped elements 72, 74, 76 are each partly printed in a positive scanning movement and partly in a negative scanning movement of the printhead as indicated by the arrows 78A, 78B, 80A, 80B, 82A, 82B indicating the scanning movement corresponding to the bar-shaped elements 72, 74, 76, respectively. An arrow d3 indicates a third distance between the center line C74 of the second bar-shaped element 74 and the center line C72 of the first bar-shaped element 72. An arrow d4 indicates a fourth distance between the center line C74 of the second bar-shaped element 74 and the center line C76 of the third bar-shaped element 76.

[0044] While printing the test pattern 70, the printhead to be calibrated is controlled such that the intended positions of the center lines C72, C74 and C76 are spaced apart at a same distance. Due to a mono-directional positioning error, the distance between adjacent bar-shaped elements may be disturbed as elucidated hereinafter with reference to Fig. 3B. In Fig. 3B, it is assumed that a mono-directional positioning error corresponding to the error as illustrated in Fig. 2C - 2D is present.

[0045] In Fig. 3B, as indicated by the corresponding arrows 78A, 78B, and 82A, 82B, the first and the third bar-shaped elements 72 and 76 are constituted of dots printed by a first row of nozzles moving in the positive scanning direction and dots printed by the first row of nozzles moving in the negative scanning direction. The second bar-shaped element 74 is constituted of dots printed by a second row of nozzles moving in the positive scanning direction and dots printed by the second row of nozzles moving in the negative scanning direction, as indicated by arrows 80A, 80B. Due to the mono-directional positioning error, the center lines C72, C76 of the first and the third bar-shaped elements 72, 76, respectively, are shifted in the negative scanning direction relative to the center line C74 of the second bar-shaped element 74. Consequently, the third distance d3 is larger than the fourth distance d4. If no mono-directional positioning error would be present, the third distance d3 and the fourth distance d4 would have been equal.

[0046] The test pattern 70 is selected such that a bi-directional positioning error does not influence a measurement result. This is achieved by determining a position of the respective center lines of the bar-shaped elements 72, 74 and 76. Although each bar-shaped element 72, 74, 76 is influenced by a bi-directional positioning error, the bi-directional error only results in an increase of a size of the bar-shaped element in the scanning direction. An average position, such as the position of a center line, is not altered or influenced by such a widening of the bar-shaped element. Since the measurement result depends on the mutual distances d3, d4 between such center lines, the bi-directional positioning errors are eliminated from the measurement.

[0047] Fig. 4 shows an embodiment of a sensor assembly 90 for detecting a test pattern 92 comprising a number of pattern elements 94A, 94B, 94C. The sensor assembly comprises an imaging device 100 and an optical lens assembly 102. The sensor assembly 90 may further be provided with a lighting source. The sensor assembly 90 is mounted such that it may scan over the test pattern 92 in a scanning direction 96. For example, the sensor assembly 90 may be mounted on the printhead carriage (Fig. 1A - 1B). The sensor assembly 90 is arranged to detect light reflected on the test pattern 92 in order to generate a test signal that may be processed by suitable processing hardware and/or software.

[0048] In an embodiment, the imaging device 100 is a single pixel device, e.g. a photo diode. Such a single pixel imaging device 100 generates a signal that may be regarded as a result of an averaging over a measurement spot 98, hereinafter also referred to as a field-of-view of the imaging device 100. A person skilled in the art readily understands how the signal is constructed and how a center line of each element 94A - 94C may be determined from such a signal, e.g. using image processing techniques and/or suitable mathematical techniques such as correlation techniques.

[0049] In an embodiment, the field-of-view 98 of the sensor assembly 90, in particular in the medium advance direction, is smaller than the row of nozzles in the medium advance direction. Multiple scans of the sensor assembly 90 over the test pattern 92 in order to build an image of the whole test pattern 92 in the medium advance direction may result in introduction of unknown artifacts and consequently undesired measurement errors. Fig. 5A and 5B illustrate how a test pattern may be constructed in order to eliminate a need to perform multiple imaging scans.

[0050] In Fig. 5A and 5B, a printhead 130 is illustrated having a single row of nozzles 140. The row of nozzles 140 is virtually divided in four similar parts 142, 144, 146 and 148. The number of parts may be selected based on a size of a measurement spot or field-of-view of an imaging device (see also Fig. 4 and the description relating thereto), for example.

[0051] On the left-hand side of Fig. 5A, a first intermediate result 110A after a first step of printing the test pattern is shown. On the right-hand side of Fig. 5A, a second intermediate result 110B after a second step of printing the test pattern is shown.

[0052] In a first step of printing the test pattern, a first part of test pattern is partly printed. In the first step, a first part of bar-shaped elements 112A, 116A are printed, while the printhead 130 moves in a positive scanning direction 120. In a second step of printing the test pattern, the first part of the test pattern is completed by printing a first part of a bar-shaped element 114B. In the second step, the printhead 130 moves in the negative scanning direction 122. Thus, after the first step and the second step, the second intermediate result 110B is generated. The second intermediate result 110B corresponds to the first part of the test pattern. The first part of the test pattern corresponds to the part of the test pattern that is printed by a first part 148 of the row of nozzles 140.

[0053] After the second step, the medium is moved relative to the printhead 130 in the medium advance direction 124. For example, the medium is advanced such that the bar-shaped elements 112B, 114B and 116B are aligned with a second part 146 of the row of nozzles 140. Then, a third step and a fourth step may be performed by scanning the printhead 130 in a positive scanning direction and in a negative scanning direction 120, 122, respectively, thereby printing a second part of the test pattern. The second part of the test pattern may comprise further parts of the bar-shaped elements 112B, 114B, 116B. These further parts may be adjacent to the parts comprised in the first part of the test pattern. After the fourth step, a fifth step and a sixth step may be performed using a third part 144 of the row of nozzles 140.

[0054] After the sixth step, a seventh step may be performed using a fourth part 142 of the row of nozzles 140 scanning in a positive scanning movement 126. A third intermediate result 110C - after the seventh step - is illustrated on the left-hand side of Fig. 5B. After the seventh step, the bar-shaped elements 112C and 116C have obtained their final shape, each comprising four parts of the test pattern, each part of the test pattern corresponding to a part of the row of nozzles 140. The bar-shaped element 114C has a shape that comprises three parts of the test pattern. The fourth part is added to the bar-shaped element 114C in an eighth step by scanning in a negative scanning movement 128, thereby obtaining its final shape as illustrated on the right-hand side of Fig. 5B.

[0055] On said right-hand side of Fig. 5B, a final result 110D is illustrated having three bar-shaped elements 112D, 114D and 116D. Each bar-shaped element 112D, 114D, 116D comprises a number of sub-bars extending in the scanning direction. Each sub-bar comprises an element of each one of the four parts of the test pattern. In another embodiment, all sub-bars may be adjacent such that a single bar-shaped element extending in the medium advance direction is constructed. In yet another embodiment, all elements originating from separate parts of the row of nozzles are spaced apart, thus resulting in a bar-shaped element extending in the medium advance direction, which element is formed by a number of lines extending in the scanning direction, as illustrated in Fig. 6A - 6F.

[0056] In Fig. 5A - 5B, a method for constructing a test pattern 110D for determining a bi-directional positioning error is elucidated. The test pattern 110D thus corresponds to the test pattern 50 as illustrated in Fig. 3A. The test pattern 70 as illustrated in Fig. 3B may likewise be constructed by virtually dividing a row of nozzles of the printhead in a number of parts. Then, a first and a third bar-shaped element are printed using a first row of nozzles, while a second bar-shaped element, positioned between the first and the third bar-shaped element, is printed using another row of nozzles.

[0057] Further, in Fig. 3A, 3B, 5A and 5B test patterns are illustrated for at least partly compensating a positional error that may be compensated by applying a single timing adjustment for all nozzles (cf. Fig. 2A - 2D). However, the method and corresponding test pattern may as well be applied for determining a compensation for each nozzle (cf. Fig. 2E - 2H), albeit that a higher resolution imaging device is required in such a method.

[0058] In Fig. 6A - 6F, six test patterns are shown, each comprising three bar-shaped elements 210, 220, 230; 310, 320, 330; 410, 420, 430; 510, 520, 530; 610, 620, 630; 710, 720, 730, respectively, each extending in a medium advance direction 201. Fig. 6A and 6B are printed with a printhead being rotated around the Y-axis (Fig. 1A - 1B). Fig. 6A is a test pattern for determining a bi-directional positioning (cf. Fig. 3A); Fig. 6B is a test pattern for determining a mono-directional positioning error (cf. Fig. 3B). Fig. 6C and 6D are printed with a printhead being rotated around the Z-axis (Fig. 1A- 1B). Fig. 6C is a test pattern for determining a bi-directional positioning (cf. Fig. 3A); Fig. 6D is a test pattern for determining a mono-directional positioning error (cf. Fig. 3B). Fig. 6E and 6F are printed with a printing apparatus in which the medium is slanted, i.e. rotated around the Y-axis. Fig. 6E is a test pattern for determining a bi-directional positioning (cf. Fig. 3A); Fig. 6F is a test pattern for determining a mono-directional positioning error (cf. Fig. 3B).

[0059] In Fig. 6A, three bar-shaped elements 210, 220, 230 are shown. The bar-shaped elements 210, 220, 230 extend in the medium advance direction 201, as above mentioned. The bar-shaped elements 210, 220, 230 are formed by a number of lines extending in a scanning direction 202, which lines are spaced apart. The lines are alternatingly printed from a respective part of a row of nozzles of a printhead. In particular, as illustrated in Fig. 5A and 5B, the row of nozzles of the printhead has been virtually divided in four parts. A first line 211 is a part of a first part of the test pattern and has been printed by a subset of nozzles comprised in a first part of the row of nozzles. A second line 212 is a part of a second part of the test pattern and has been printed by a subset of nozzles comprised in a second part of the row of nozzles. A third line 213 is a part of a third part of the test pattern and has been printed by a subset of nozzles comprised in a third part of the row of nozzles. A fourth line 214 is a part of a fourth part of the test pattern and has been printed by a subset of nozzles comprised in a fourth part of the row of nozzles. A set 240 of four lines is repeated, thereby alternating the lines originating from different parts of the row of nozzles. The same is applicable to a set 340 (Fig. 6B), a set 440 (Fig. 6C), a set 540 (Fig. 6D), a set 640 (Fig. 6E) and a set 740 (Fig. 6F).

[0060] It is noted that a shape of each set 240, 340, 440, 540, 640, 740 provides information about a positioning error of the dots ejected from the row of nozzles. Despite the serrated edges of the bar-shaped elements 210, 220 and 230, an average position of the bar-shaped elements 210, 220 and 230 is not influenced. Hence, the bi-directional and mono-directional positioning errors described in relation to Fig. 3A and 3B, respectively, are still derivable from the bar-shaped elements 210, 220 and 230. The serrated edges may however be examined in order to determine further adjustments of the jet timing of individual nozzles.

[0061] A detailed description of the patterns illustrated in Fig. 6A - 6F is omitted here as a person skilled in the art is deemed to be enabled to determine from the shape of the bar-shaped elements 210, 220, 230; 310, 320, 330; 410, 420, 430; 510, 520, 530; 610, 620, 630; 710, 720, 730 the above indicated error sources. It is noted that the lines extending in the scanning direction 202 are illustrated spaced apart. However, the lines may be adjacent or may be grouped or the like, e.g. as illustrated in Fig. 5A and 5B.

[0062] It is noted that over a width of the printer, i.e. a dimension of the printer in the scanning direction (see e.g. Fig. 1A, 1B), the mono-directional and the bi-directional errors may vary e.g. due to a variation in a nozzle - medium distance, i.e. a distance between a nozzle and the medium, resulting from a variation of a distance between the guiding means (20, Fig. 1A) and the print surface (12, Fig. 1A). Thereto, a bi-directional error may be determined over the width of the printer for a reference row of nozzles. Once a nozzle - medium distance is determined for the reference row of nozzles over the width of the printer, the mono-directional and bi-directional error for each of the rows of nozzles may be determined using a test pattern over a part of the width and extrapolating the results obtained from such a partial test pattern using the results of the full-width test pattern of the reference row of nozzles.

[0063] Further, if the printer is configured to operate in one of a number of possible modes, wherein a difference in a carriage speed of the carriage (16, Fig. 1A) between print modes exists, it is noted that the calibrated jet timing of the nozzles needs to be adjusted to the carriage speed used in each print mode.

[0064] Even further, a difference in nozzle - medium distance between individual rows of nozzles may be at least partly compensated by considering errors due such a difference as a difference in ink drop ejection velocity. From a test pattern it is virtually impossible to retrieve which difference (nozzle - medium distance or ink drop ejection velocity) causes an error. However, in an embodiment, it is determined that a maximum error due to ejection velocity difference is substantially larger than a maximum error due to nozzle - medium distance difference. Now, by treating any error as an error due to velocity difference, a velocity difference between the individual rows of nozzles may be determined and may be used in estimating a correction factor for other print modes.

[0065] For the above indicated estimation of a correction factor, the below equation may be used:

$$Y_{bidir} = 2zv_{carriage} / v_{drop} = 2(z_{average} + \Delta z(y))v_{carriage} / v_{drop} \qquad \text{(Eq. 1)}$$

wherein Y_{bidir} represents the bi-directional error, if no jet timing compensation is applied, z represents the nozzle - medium distance, $v_{carriage}$ represents the carriage velocity, v_{drop} represents the ink drop ejection velocity, $z_{average}$ represents an average nozzle - medium distance over the width of the printer, and $\Delta z(y)$ represents a local deviation from the average nozzle - medium distance at position *y*.

[0066] It is apparent to a person skilled in the art that a single full-width test pattern may be employed for determining $\Delta z(y)$ over the full width, i.e. for each possible value of *y*. This $\Delta z(y)$ is applicable to each row of nozzles and may be determined from a reference row of nozzles. Further from Eq. 1, a correction factor for estimating a bi-directional error in another print mode employing another carriage velocity ($v_{carriage}$) may be easily determined by a skilled person. Likewise, differences between individual rows of nozzles may be compensated by considering the differences as resulting from a difference in ink drop ejection velocity (v_{drop}). Thus, from Eq. 1, a compensation factor may be easily determined by the person skilled in the art.

[0067] Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any advantageous combination of such claims are herewith disclosed. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention.

[0068] The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly.

Claims

1. Method for calibrating an inkjet printhead in an inkjet printer using a predetermined test pattern, the printhead being arranged for moving in a scanning direction and comprising a row of nozzles, the row of nozzles extending substantially in a medium advance direction, the medium advance direction being substantially perpendicular to said scanning direction, the test pattern having a predetermined pattern size in the media advance direction, the method comprising:

   (a) printing a first part of a predetermined test pattern on a print medium using a predetermined first subset of nozzles, the first subset of nozzles being comprised in a first part of the row of nozzles, the first part having a size in the media advance direction that is substantially equal to the predetermined pattern size;
   (b) advancing the print medium in the medium advance direction relative to the printhead over a predetermined medium advance distance;
   (c) printing a second part of the predetermined test pattern on the print medium using a predetermined second subset of nozzles, the second subset of nozzles being comprised in a second part of the row of nozzles, the second part having a size in the media advance direction that is substantially equal to the predetermined pattern size.

2. Method according to claim 1, wherein the predetermined medium advance distance corresponds to the predetermined pattern size.

3. Method according to claim 1, wherein the first part and the second part of the test pattern each comprise a number of test elements, the test elements of the first part and the test elements of the second part being arranged alternatingly.

4. Method according to claim 3, wherein the test elements are bar-shaped elements extending in the scanning direction.

5. Method according to claim 3, wherein the test elements are spaced apart in the media advance direction.

6. Method according to claim 1, wherein the row of nozzles is subdivided in a predetermined number of parts, the number of parts being three or more, the method comprising repeating the steps (b) and (c) for each of the third and further parts.

7. Method according to claim 1, wherein the inkjet printer comprises an imaging device for imaging the test pattern, the imaging device having a predetermined field of view, the predetermined pattern size being selected to be equal to or smaller than a size of said field of view in the media advance direction, the method further comprising imaging the test pattern after printing the test pattern.

8. Method according to claim 1, wherein the method comprises adjusting a jet timing of each nozzle of the row of nozzles based on the printed test pattern.

9. Method according to claim 1, wherein the method comprises determining a test pattern profile by averaging the test pattern in the media advance direction and calibrating the printhead based on measurements taken from the test pattern profile.

10. Method according to claim 1, wherein each part of the test pattern is printed in a first scanning movement of the printhead in a positive scanning direction and a second scanning movement in a negative scanning direction, the positive and the negative scanning direction being opposite to each other, the method comprising printing reference elements in the first scanning movement and printing calibration elements in the second scanning movement.

11. Method according to claim 1, wherein the inkjet printer comprises at least two rows of nozzles, the method comprising printing reference elements using a first row of nozzles and printing calibration elements using a second row of nozzles.

12. Method according to claim 10 or 11, wherein the test pattern is printed in a first scanning movement of the printhead in a positive scanning direction and a second scanning movement in a negative scanning direction, the positive and the negative scanning direction being opposite to each other, the method comprising:

- ■ determining an average position of the reference elements;
- ■ determining an average position of the calibration elements; and
- ■ calibrating the inkjet printhead based on a distance between the respective average positions of the reference elements and the calibration elements.

13. Method according to claim 1, wherein the method comprises:

- determining a distance profile of a first row of nozzles over a full scanning range of a first printhead in the scanning direction, the distance profile indicating a distance between the nozzles of said first row of nozzles as a function of a position of the printhead in the scanning direction;
- performing steps (a) - (c) for each row of nozzles of each printhead over a part of the scanning range of each printhead in the scanning direction;
- calibrating each row of nozzles of each printhead over the full scanning range by combining the distance profile of the first row of nozzles of the first printhead and the test patterns printed according to steps (a) - (c), taking into account a positional relationship between each row of nozzles and said first row of nozzles.

14. Method according to claim 13, wherein the positional relationship between the rows of nozzles is determined from the test patterns printed according to steps (a) - (c).

15. Method according to claim 1, wherein the inkjet printer is configured to be operated in a first print mode and a second print mode, a printing parameter having a first value in the first print mode and having a second value in the second printing mode, the method comprising performing the steps (a) - (c) in the first print mode and calibrating the printhead for operation in the second print mode based on the test patterns printed in the first print mode taking into account a difference between the first value and the second value of the printing parameter.

16. Inkjet printing apparatus comprising at least one inkjet printhead, the inkjet printhead being arranged for moving in a scanning direction and comprising a row of nozzles, the row of nozzles extending substantially in a medium advance direction, the medium advance direction being substantially perpendicular to said scanning direction, the printing apparatus being configured to print a predetermined test pattern in accordance with any one of the preceding claim

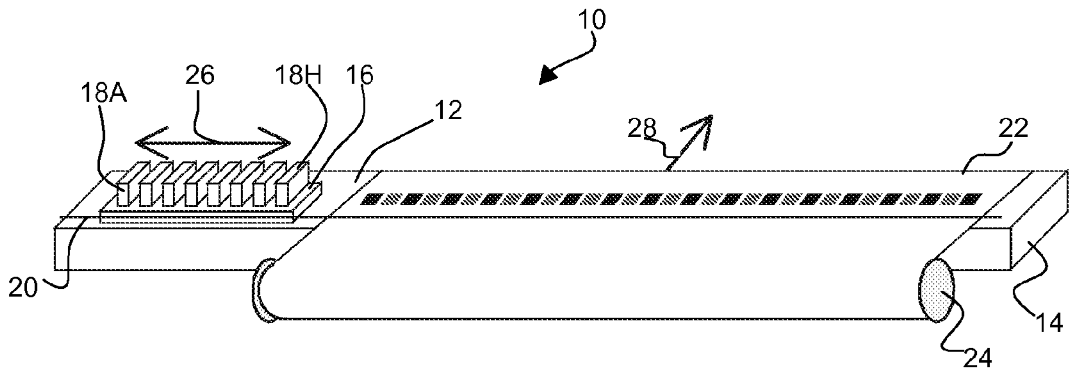

Fig. 1A

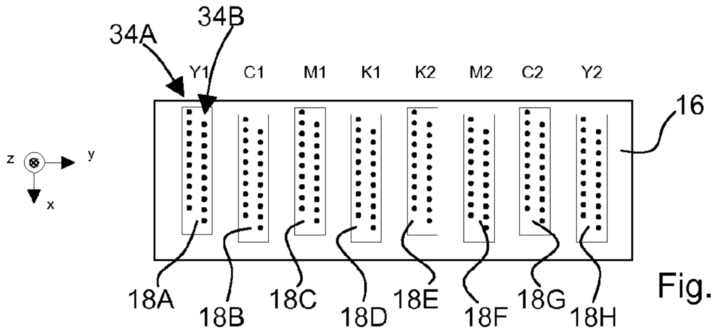

Fig. 1B

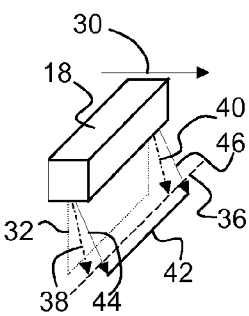

Fig. 2A

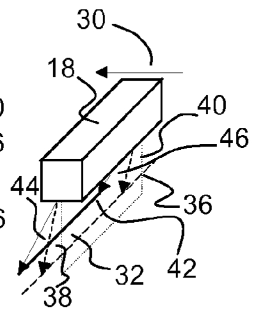

Fig. 2B

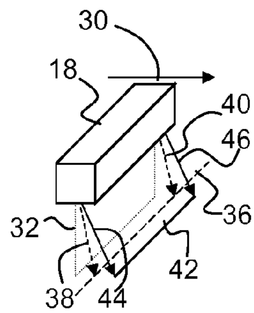

Fig. 2C

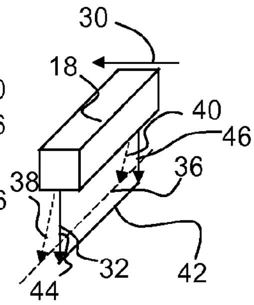

Fig. 2D

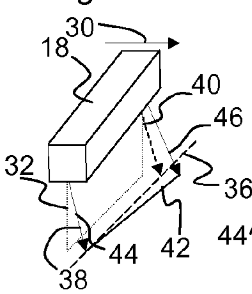

Fig. 2E

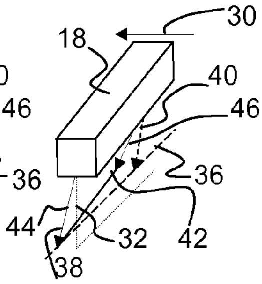

Fig. 2F

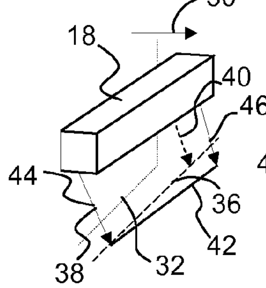

Fig. 2G

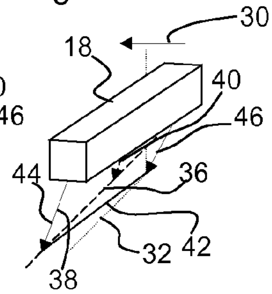

Fig. 2H

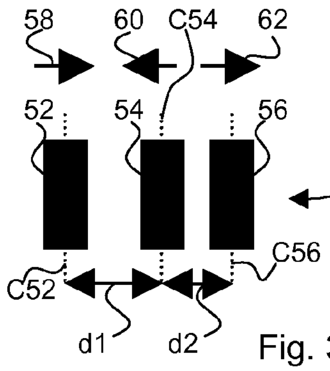

Fig. 3A

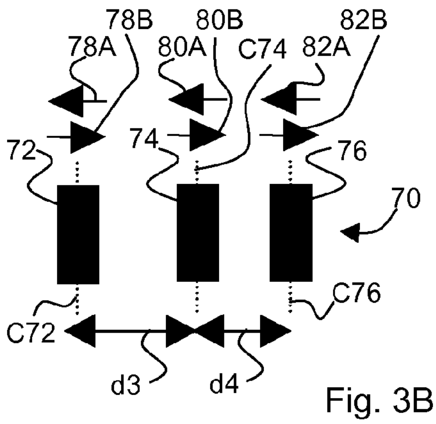

Fig. 3B

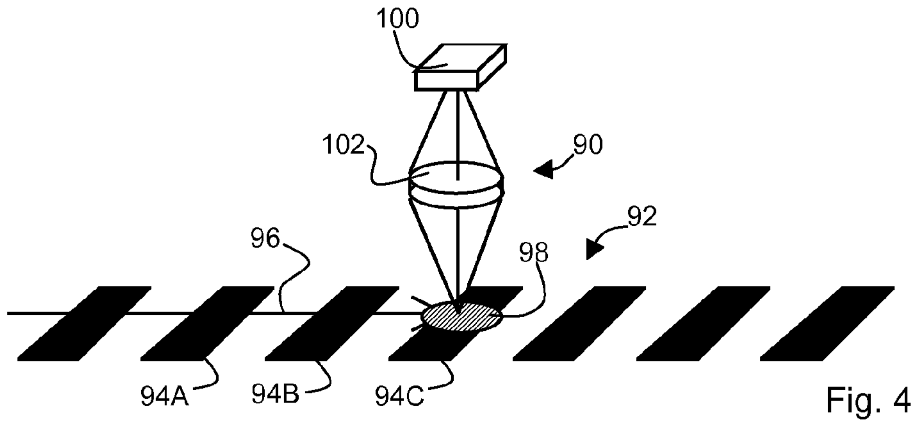

Fig. 4

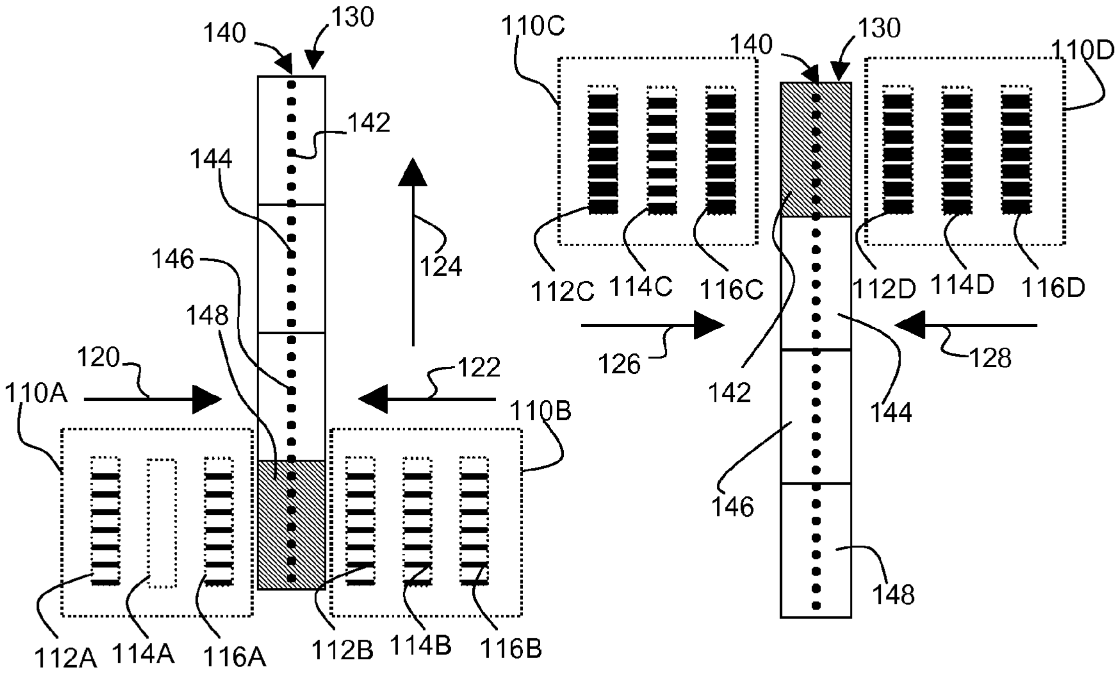

Fig. 5A

Fig. 5B

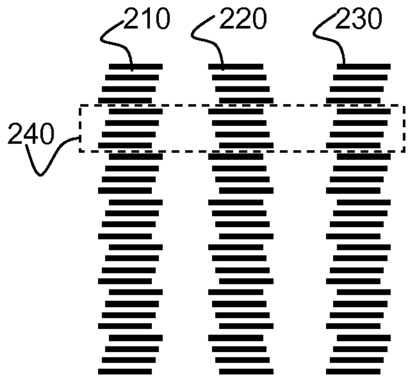

Fig. 6A

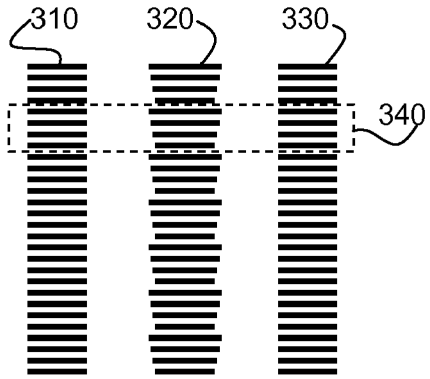

Fig. 6B

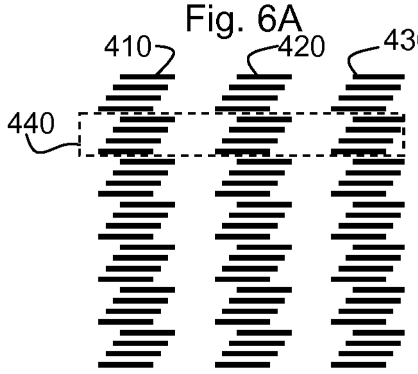

Fig. 6C

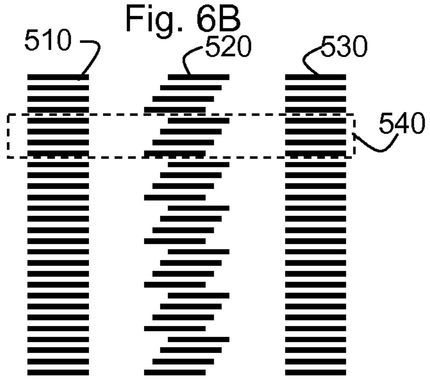

Fig. 6D

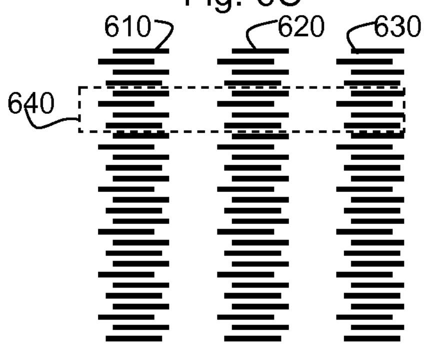

Fig. 6E

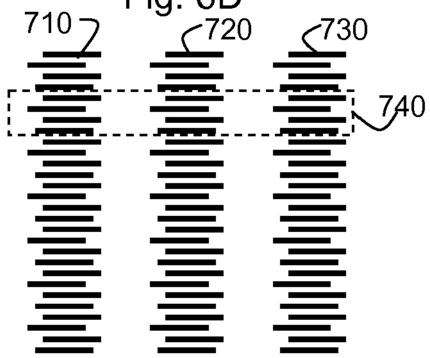

Fig. 6F

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EUROPEAN SEARCH REPORT

Application Number
EP 08 16 7028

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 741 560 A (CANON KK [JP]) 10 January 2007 (2007-01-10) * paragraphs [0022], [0042] - [0046]; figures 6A,6B *	1-16	INV. B41J2/21 B41J29/393
X	WO 2007/039444 A (AGFA GRAPHICS N V [BE]; VAN DE WYNCKEL WERNER [BE]; VERHOEST BART [BE]) 12 April 2007 (2007-04-12) * page 10, lines 2-8; figures 6A,6B * * page 15, line 6 - page 16, line 27 *	1-16	
X	US 2003/048326 A1 (YAMASAKI KEIGO [JP] ET AL) 13 March 2003 (2003-03-13) * paragraph [0234]; figure 29 *	1-16	
X,D	US 7 014 289 B1 (MATSUDA YUJI [JP]) 21 March 2006 (2006-03-21) * column 13, line 11 - column 15, line 14 *	1-16	

TECHNICAL FIELDS SEARCHED (IPC)

B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 February 2009	Axters, Michael

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2
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19-02-2009

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1741560	A	10-01-2007	JP	2007038649	A	15-02-2007
			KR	20070006615	A	11-01-2007
			US	2007013732	A1	18-01-2007
WO 2007039444	A	12-04-2007	NONE			
US 2003048326	A1	13-03-2003	NONE			
US 7014289	B1	21-03-2006	CN	1347368	A	01-05-2002
			DE	60037118	T2	28-08-2008
			EP	1195247	A1	10-04-2002
			WO	0064677	A1	02-11-2000

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Patent documents cited in the description

- US 7014289 B **[0006]**