



(86) Date de dépôt PCT/PCT Filing Date: 2007/05/30
(87) Date publication PCT/PCT Publication Date: 2007/12/06
(85) Entrée phase nationale/National Entry: 2008/11/28
(86) N° demande PCT/PCT Application No.: GB 2007/002001
(87) N° publication PCT/PCT Publication No.: 2007/138318
(30) Priorités/Priorities: 2006/05/30 (GB0610659.5);
2007/03/01 (GB0704009.0)

(51) Cl.Int./Int.Cl. *B41J 2/45* (2006.01),
B41J 11/00 (2006.01), *G06K 15/12* (2006.01)

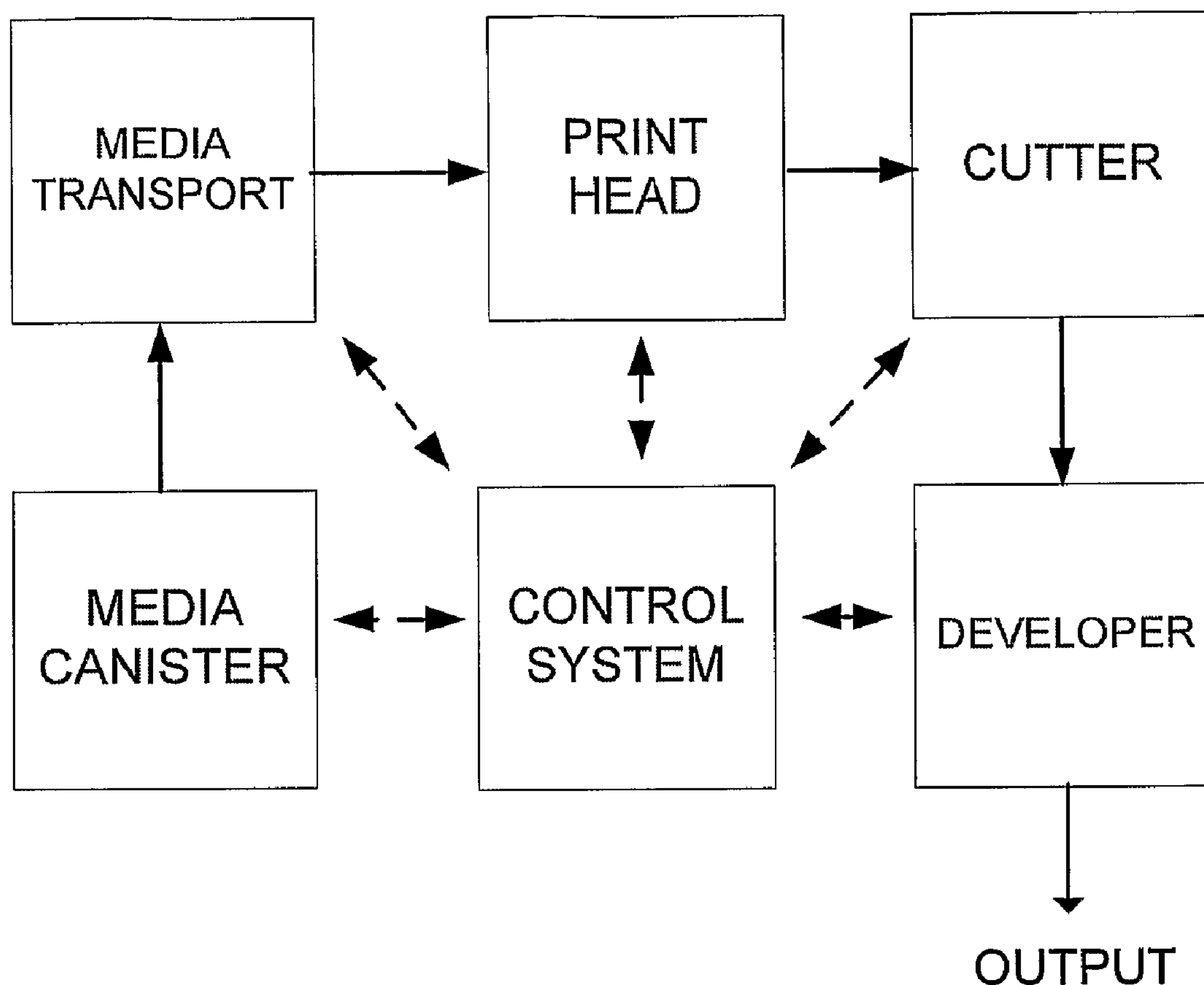
(71) Demandeur/Applicant:
DIGEPRINT LIMITED, GB

(72) Inventeurs/Inventors:
ELWORTHY, TREVOR, GB;
BILSON, DUNCAN, GB;
HOMAN, NICHOLAS, GB

(74) Agent: ADAMS PATENT & TRADEMARK AGENCY

(54) Titre : AMELIORATIONS RELATIVES A DES IMPRIMANTES OPTIQUES

(54) Title: IMPROVEMENTS RELATING TO OPTICAL PRINTERS



(57) Abrégé/Abstract:

One aspect of this invention relates to an illumination device for an optical printer, the illumination device comprising: a first array of light sources (20) comprising a plurality of light source elements (14) that are each operable to emit light within a red band of the

(57) Abrégé(suite)/Abstract(continued):

visible electromagnetic spectrum; a second array of light sources (21) comprising a plurality of light source elements (14) that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and a third array of light sources (22) comprising a plurality of light source elements (14) that are each operable to emit light within a green band of the visible electromagnetic spectrum; wherein said first, second and third arrays of light sources (20, 21, 22) are generally linearly arranged along respective substantially parallel notional lines (34) on a substrate (15); and said plurality of light source elements (14) of each said array (20, 21, 22) are arranged such that respective adjacent light source elements of said plurality are offset from one another with respect to the associated notional line (34). Other aspects relate to printing heads, printing head assemblies, optical printers, and methods and apparatus for calibrating an optical printer.

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
6 December 2007 (06.12.2007)

PCT

(10) International Publication Number
WO 2007/138318 A3

(51) International Patent Classification:

B41J 2/45 (2006.01) **G06K 15/12** (2006.01)
B41J 11/00 (2006.01)

Nicholas [GB/GB]; Digeprint Limited, Unit A2, Phase 1
The Viscount Centre, Millburn Hill Road, University of
Warwick Science Park, Coventry CV4 7H (GB).

(21) International Application Number:

PCT/GB2007/002001

(74) **Agent:** **MILHENCH, Marc, Lorne**; First Thought IP
Limited, 35 New Broad Street House, New Broad Street,
London EC2M 1NH (GB).

(22) International Filing Date: 30 May 2007 (30.05.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

0610659.5 30 May 2006 (30.05.2006) GB
0704009.0 1 March 2007 (01.03.2007) GB

(71) **Applicant** (for all designated States except US): **DI-GEPRINT LIMITED** [GB/GB]; Unit A2, Phase 1 The Viscount Centre, Millburn Hill Road, University of Warwick Science Park, Coventry CV4 7HS (GB).

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

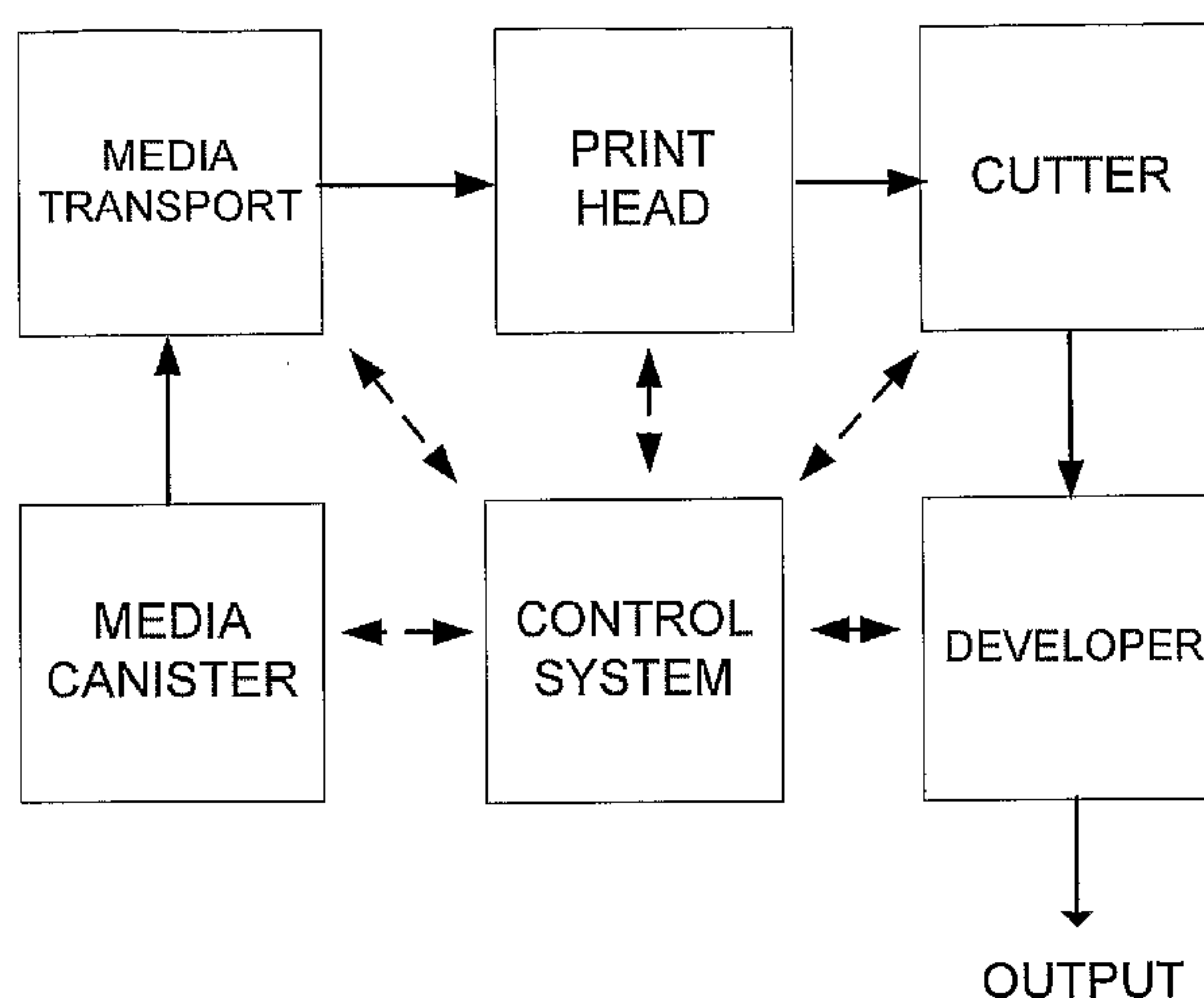
(72) Inventors; and

(75) **Inventors/Applicants** (for US only): **ELWORTHY, Trevor** [GB/GB]; Digeprint Limited, Unit A2, Phase 1 The Viscount Centre, Millburn Hill Road, University of Warwick Science Park, Coventry CV4 7H (GB). **BILSON, Duncan** [GB/GB]; Digeprint Limited, Unit A2, Phase 1 The Viscount Centre, Millburn Hill Road, University of Warwick Science Park, Coventry CV4 7H (GB). **HOMAN,**

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: IMPROVEMENTS RELATING TO OPTICAL PRINTERS



(57) **Abstract:** One aspect of this invention relates to an illumination device for an optical printer, the illumination device comprising: a first array of light sources (20) comprising a plurality of light source elements (14) that are each operable to emit light within a red band of the visible electromagnetic spectrum; a second array of light sources (21) comprising a plurality of light source elements (14) that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and a third array of light sources (22) comprising a plurality of light source elements (14) that are each operable to emit light within a green band of the visible electromagnetic spectrum; wherein said first, second and third arrays of light sources (20, 21, 22) are generally linearly arranged along respective substantially parallel notional lines (34) on a substrate (15); and said plurality of light source elements (14) of each said array (20, 21, 22) are arranged such that respective adjacent light source elements of said plurality are offset from one another with respect to the associated notional line (34). Other aspects relate to printing heads, printing head assemblies, optical printers, and methods and apparatus for calibrating an optical printer.

WO 2007/138318 A3



Published:

- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
10 April 2008

Improvements Relating to Optical PrintersField of the Invention

In general terms, this invention relates to improvements to optical printers.
5 Some of the preferred embodiments described hereafter in detail relate to an illumination device for an optical printer. Other embodiments relate to a printing head for an optical printer, and to a printing head assembly for an optical printer.

Additional embodiments are concerned with calibration of an optical printer, further embodiments relate to a transport mechanism for an optical printer. An optical
10 printer incorporating one or more of these arrangements is also disclosed.

Background to the Invention

An optical printer is a device that can convert a digitally stored image into light , and can project this light onto a light-sensitive medium to generate an image. Optical
15 printers were originally used to form photoresist masks for electronic circuit boards, and were relatively easy to manufacture as the optical exposure was either "on" or "off".

The variant of optical printer described in this patent is predominantly designed for producing photographic-style images, although the teachings of the present invention are not limited to the production of photographic-style images.

20 Optical printers are distinct from laser-printers and inkjet printers as they do not deposit material (toner in the case of laser-printers and ink in the case of ink-jet printers) onto the medium, instead exposing the medium to light, which is subsequently chemically processed. Whilst the name "printer" is therefore something of a misnomer (in that such devices do not actually "print", in the conventional sense of the word,
25 anything onto the medium), devices of the type described herein are commonly known in the art as printers.

Photographic images are usually considered to be of a higher quality than ink- or laser-jet images, as photographic medium (e.g. photographic paper) has the capability to vary the intensity of each pixel in the image. Ink or laser-jet printers deposit material
30 that is either there, or isn't. Consequently, the apparent resolution of an ink- or laser-jet printer (in dots-per-inch, or DPI) needs to be significantly higher than that of a photo-printer to achieve similar quality.

Several styles of optical photographic printer are commercially available, and use a variety of optical exposure mechanisms, including lasers, liquid-crystal masks, micro-
35 mirrors and light-emitting diodes.

Fig. 1 is a schematic illustration of the typical components of an optical printer. As shown, the printer comprises a media canister from which a continuous length of

unexposed photographic media (such as photographic paper) is drawn. The media is drawn from the canister by precision mechatronics, the media transporter, which provides media to the print head and positions the media with respect thereto. The print head comprises a plurality of optical elements (such as light emitting diodes) that can be energised to generate light which exposes the region of the media located immediately underneath the print head.

The print head is moved over the media to expose the media in swathes, and data is fed to the print head by a control system which arranges for the correct combination of elements to be energised to expose the media in such a way that the media is exposed with a desired final image.

Once the media has been exposed it is passed through the cutter by the media transporter and the cutter is operated to cut the exposed section of media from the remaining unexposed length of media. The exposed length of media is then passed to a chemical developer for developing. The developing process reveals the image on the media, and the finished printed image is output.

As shown, each of the elements of the system is carefully controlled by a control system. The control system may comprise a personal computer running appropriate software, purpose-built electronic circuits or a combination of the two.

For all printers, a key point of concern is the resolution at which the printer can print and much work has been done, particularly in the field of ink jet printing, to improve the number of dots per inch that can be printed on a substrate (typically paper). In an optical printer a key limiting factor for the achievable resolution is the size of the illumination device used to generate the light that impinges on the photographic medium.

Our previous patent (European Patent No. 1228633) discloses an illumination device (depicted in Figs 2(a) and 2(b) hereafter) that comprises three arrays of LED (light emitting diode) illumination elements 14 - one column of red LEDs 20, one column of green LEDs 21 and one column of blue LEDs 22 - mounted on a substrate 15. The illumination device is arranged to emit light, when energised, towards a light receiving face 13 of a tapered optic fibre light pipe 10. The light pipe conveys the light received from the LEDs at the light receiving face to a light emitting face (not shown) which has a smaller surface area than the light receiving face. Light emitted by the light emitting face then impinges on a photographic medium (such as photographic paper) to generate an image. As depicted in Fig. 2(a) the LEDs are mounted on the substrate in parallel columns, and (as shown in Fig. 2(b)) the LEDs of each respective column are spaced from adjacent LEDs to enable the necessary electrical connections to be made.

Tapering the optic fibre light pipe in the manner described in this patent reduces

the size of the illuminated "spot" generated by the illumination device on the photographic medium (as compared to that which would otherwise be produced were the illumination device to directly illuminate the photographic medium), thereby enabling the optical resolution of the resulting photographic image to be increased.

5 Whilst this arrangement has greatly increased the resolution that was previously achievable with previous optical printers, there is a desire in the market for higher resolution images and to respond to this market need we have attempted to further improve the achievable resolution by reducing yet further the physical size of the illumination device. However, we have found that our attempts to reduce the physical
10 size of the illumination device have been hampered *inter alia* by the physical size of the - typically LED - light emitting elements of the red, green and blue arrays that make up the illumination device, and the spacing between the elements that must be provided to enable the elements to be connected to an electrical power source.

 A first aspect of the present invention seeks to address this technical problem of
15 how to reduce the size of the illumination device given the constraints of the minimum physical size of the light emitting elements, and the space that must be provided to enable those elements to be coupled to a source of power.

 A second aspect of the present invention is concerned with addressing issues concerning the quality of the printed image, in particular the quality of the image as
20 perceived by the human eye.

 With previously proposed devices, such as that disclosed in our prior patent, we have noticed that the quality of the image can sometimes be adversely affected by a so-called "banding" effect that can occur at the junction between successive printing swathes as the image is being formed on the photographic medium.

25 As is illustrated schematically in Fig. 2(c), photographic medium 1 (typically comprising a roll of photographic paper) is transported through the printing apparatus in a direction A, and the illumination device 3 (consisting of red, green and blue light emitting element arrays 5) is moved from point B to point C to illuminate a swathe of the photographic medium immediately below the device and generate part of the final
30 image. Light from the elements, as previously described, impinges on the light receiving face of a tapered light pipe provided between the illumination device and the photographic medium 1 (hence the light pipe is not visible in Fig. 2(c)), and exits from the light pipe via a light transmitting face that is considerably smaller than the light receiving face to thereby illuminate an area of the photographic medium that is much
35 less than that which would otherwise be illuminated were the arrays to directly illuminate the photographic medium. The illumination device then returns from point C to point B, the photographic medium is advanced by a distance X that is substantially equal to the

length of the aforementioned light emitting face of the tapered light pipe (and smaller than the length of the illumination device), and the illumination device is then moved from point B to point C to print to print the next swathe of the image.

Whilst this arrangement works well, apparently insignificant errors in the amount
5 paper advanced between the printing of successive swathes, and other operational irregularities, can detrimentally affect the final image. For example, advancing the paper by a length greater than X can cause a detectable gap (visible as a white line) between successive swathes, whereas advancing the paper by a length less than X can result in an overexposure of the photographic medium (visible as a noticeably darker band) in the
10 region where the swathes overlap.

The aforementioned second aspect of the present invention seeks to address this technical problem of how to improve the quality of the printed image, in particular the quality of the image as perceived by the human eye (particularly, but not exclusively, to reduce the impact of the above described "banding" effect).

15 A third aspect of the present invention is concerned with the structure of the illumination device, and the printing head incorporating that device.

Our previously proposed illumination device is essentially as depicted in Fig. 2(b), and comprises a substrate 15 on which the individual light emitting elements 14 are mounted. The substrate is then encapsulated within a transparent layer 33 to protect
20 the LEDs and the electrical connections 34 thereto. The illumination device is spaced from the tapered optic fibre light pipe 10, and an anti reflection layer 32 may be added to the transparent layer or to the light receiving face 13 of the light pipe 10.

Whilst this previously proposed illumination device has functioned adequately, we have noted that the quality of the final image can sometimes be adversely affected
25 by crosstalk between adjacent LED elements, and by variations in the relative intensities of the red, green and blue arrays. It is also the case that maintenance of the gap between the illumination device and fibre optic light pipe must be carefully controlled (to avoid aberrations in the final image) and such control can be difficult to achieve in practice.

30 The third aspect of the present invention seeks to address such problems.

A fourth aspect of the present invention is concerned with calibration of the optical printer so as to improve the quality of the final image.

A persistent problem for optical printers, particularly those printers that use LEDs for light sources, is that the characteristics of the light sources vary dramatically from
35 one to the other. For example, for any two LEDs of a particular colour both the intensity profile and wavelength profile of the light emitted by the LEDs, when driven by the same current, will vary considerably. These variations from one LED to another can show up

as lines within swathes of a final printed image. It is also the case that light emitting diodes tend to vary non-linearly in both their output intensity and wavelength with input voltage variations, and a compounding problem is that the photographic medium (typically photographic paper) used for a particular print will directly affect the quality of that print and, furthermore, the characteristics of a given photographic paper will typically be quite different from those of another type of paper.

All of these different variations must be addressed if the quality of the final image is to be improved, and to this end it has previously been postulated that one could employ a series of photocells as a photographic medium, and feed back the output of those photocells to the light source elements to adjust the output of those elements and hence provide a uniform illumination of the paper.

However, whilst this would appear at first sight to be an attractive means of mitigating such problems, it is unfortunately the case that photocells respond very differently to photographic medium, such as photographic paper, and as such adjusting the system to be best suited for a set of photocells will not necessarily provide an appropriate setting for printing on photographic paper.

The fourth aspect of the present invention addresses these problems, and in general terms relates to the concept of calibrating a printer from one or more processed images printed with that printer. This approach is advantageous as the image will of course incorporate any of the aforementioned variations, and as such by calibrating to the image one inevitably addresses any such variations.

A fifth aspect of the present invention is concerned with improving the transport mechanism for the photographic medium.

A particular requirement of that transport mechanism is that to enable the printer to achieve a high resolution and to provide a high quality output, the components of the transport mechanism must be carefully designed and controlled to enable photographic medium movement with a tolerance of in the region of a few microns, typically roughly four microns. By this we mean that when it is desired to move the photographic medium a given distance through the printer, then the mechatronics of the transport mechanism must be such that the actual transport distance is within plus or minus up to a few microns (e.g. four microns) of the desired distance.

As will no doubt be appreciated by persons skilled in the art, if the actual transport distance should be greater than the desired distance then visible white bands may be produced in the final image. Similarly, if the transport distance should be less than the desired distance by more than four microns, then adjacent swathes of the image will overlap to a noticeable degree and the final image will be spoiled. It is critical, therefore, that the transport mechanism design is such that highly accurate photographic

medium transport is enabled, and a fifth aspect of the present invention addresses this problem.

5 A sixth aspect of the present invention also relates to the transport of photographic medium through an optical printer. This aspect of the present invention relates to the fact that we have identified that it would be advantageous if a printer could be devised that provided a greater throughput of photographic medium. It would also be advantageous if such a printer could readily accommodate photographic medium of different sizes.

10 One relatively simple way to increase photographic medium throughput would be to increase the speed at which the optical head assembly travels over the photographic medium, however such an approach would not provide that great an increase in speed as the head must be over a given point on the photographic medium for a fixed minimum amount of time (for a given photographic medium and a given light output from the light source) to expose that point to the requisite amount of optical energy required
15 to generate the image, and hence it is impossible - without adversely affecting the quality of the final image - to increase the speed of the head to a point where it is over a given point of the photographic medium for less than this fixed minimum period of time.

The sixth aspect of the present invention addresses these problems.

20 Summary

It is an object of aspects of the present invention to address one or more of the aforementioned problems.

To this end a first aspect of the present invention provides an illumination device for an optical printer, the illumination device comprising: a first array of light sources
25 comprising a plurality of light source elements that are each operable to emit light within a red band of the visible electromagnetic spectrum, a second array of light sources comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and a third array of light sources comprising a plurality of light source elements that are each operable to emit light within
30 a green band of the visible electromagnetic spectrum; wherein said first, second and third arrays of light sources are generally linearly arranged along respective substantially parallel notional lines on a substrate; and said plurality of light source elements of each said array are arranged such that respective adjacent light source elements of said plurality are offset from one another with respect to the associated notional line.

35 By arranging the light source arrays along notional parallel lines on the substrate, and offsetting the individual elements of each array with respect to the associated notional line - in effect by providing arrays of castellated light emitting elements - it is

possible to more closely arrange the light emitting elements in a dimension parallel to the aforementioned notional lines than it is in the prior art arrangement depicted in Fig. 2(a). By more closely arranging the elements in this way the spacing of individual components of the final image that are attributable to respective elements can be
5 reduced, thereby improving the resolution of that image.

In one particularly preferred arrangement, the offset of each element with respect to the associated notional line on the substrate is arranged such that the emission profiles of adjacent elements in each array overlap to such a degree that elements of an image printed by the optical printer on a photographic medium and attributable to
10 adjacent LED elements are not readily be resolved (for example without magnification).

A second aspect of the present invention provides an illumination device for an optical printer, the illumination device comprising: a first array of light sources comprising a plurality of light source elements that are each operable to emit light within a red band of the visible electromagnetic spectrum, a second array of light sources
15 comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and a third array of light sources comprising a plurality of light source elements that are each operable to emit light within a green band of the visible electromagnetic spectrum; wherein said first, second and third arrays of light sources are generally linearly arranged along respective substantially
20 parallel notional lines on a substrate; said first, second and third arrays of light sources are each operable to emit a strip of light, and said printing head is configured such that a first of said arrays of light sources emits a strip of light when energised that is linearly offset along the associated notional line from a strip of light that is emitted when a second adjacent one of said arrays of light sources is energised.

By adopting this arrangement, a join between adjacent components of the final image resulting from illumination of the photographic medium by the red array (say) occurs at a different location on the photographic medium to joins between adjacent components of that image which are attributable to the green and blue arrays. By virtue of this arrangement, junctions between components of the final image attributable to one
25 of the three arrays, will never coincide with junctions between components attributable to the other two arrays.

In effect, by adopting such an arrangement errors at junctions between image swathes for the three arrays are not compounded (as they were in the device disclosed in the abovementioned patent), and as such for one of the arrays an error occurring at a
35 junction between image swathes attributable to that array occurs at a point where there should be no errors in the components attributable to the other arrays and hence such errors are less perceptible to the human eye than they would be if all three arrays were

aligned.

A third aspect of the present invention provides an illumination device for an optical printer, the illumination device comprising: a first array of light sources comprising a plurality of light source elements that are each operable to emit light within
5 a red band of the visible electromagnetic spectrum, a second array of light sources comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and a third array of light sources comprising a plurality of light source elements that are each operable to emit light within a green band of the visible electromagnetic spectrum; a substrate having a first surface
10 on which said first, second and third light source arrays are mounted, said first surface being configured to reduce light reflection between adjacent arrays of light source elements; and (optionally) a mask located in front of said arrays of light source elements, the mask having a plurality of apertures provided therein, said apertures being arranged so as to be generally coincident with the light source elements of said arrays to
15 permit light to travel through the mask.

This aspect of the present invention is advantageous because the first surface of the substrate reduces cross-talk between adjacent arrays, and the mask reduces cross-talk between adjacent elements of an array and between elements of adjacent arrays. By this we mean that, for a given element, a greater component of the light coming from
20 that part of the array (which light illuminates a group of fibres in the taper) is actually attributable to that element (as opposed to being light reflected from adjacent elements or arrays).

A fourth aspect of the present invention provides a method of calibrating an optical printer having a plurality of light source arrays each comprising a plurality of light
25 source elements, the method comprising: (a) controlling the printer to print a predetermined test pattern onto a first photographic medium; (b) electronically scanning and digitising the test pattern printed onto said first photographic medium; (c) processing said digitised printed test pattern to determine for each said light source element of the plurality of arrays, a measure of the intensity of light emitted by that element; (d)
30 determining for each said light source element an adjustment factor by which the light output of that element should be adjusted if all elements of the array of which that element forms part are to have substantially the same light output; (e) populating a calibration table with said adjustment factors; (f) controlling the printer to adjust the light output of each of the light source elements of the arrays by the corresponding
35 adjustment factor indicated in the calibration table; (g) operating the printer to reprint the predetermined test pattern onto a second photographic medium identical to the first; and (h) iteratively repeating steps (a) to (g) until the predetermined test pattern printed onto

the photographic medium meets a predetermined set of criteria and is determined to be of acceptable quality

A fifth aspect of the present invention provides a transport mechanism for an optical printer, the mechanism comprising: a transport roller for transporting photographic medium, at least one region of the exterior surface of the transport roller being configured to grip and drag photographic medium through the transport mechanism and towards a printing head assembly; a pressure roller configured to press photographic medium against the transport roller to thereby reduce the possibility of the medium slipping as it is advanced by the transport roller; guide means for guiding photographic medium from at least one storage canister to the pressure roller and transport roller; a stepper motor configured to rotate the transport roller; means for detecting rotation of the transport roller and generating a signal that is representative thereof; and a controller that is configured to control the stepper motor to drive the transport roller to advance medium a predetermined distance through the transport mechanism, to derive from said signal a measure of the distance rotated by the roller, and to control the stepper motor to cease rotation of the roller when the measured distance is equal to said predetermined distance.

In one embodiment, a sixth aspect of the present invention provides a component for an optical printer, which component is configured and arranged to define a plurality of printing channels through each of which discrete lengths of media may be passed for exposure by an optical light source, the component being configurable so that discrete lengths of media may be passed through more than one of said channels for exposure by said light source to enable the formation of an image on each length of media, or so that a single length of media may be passed simultaneously through more than one of said channels for exposure by said light source to enable the formation of a single image on said single length of media.

In another embodiment, the sixth aspect of the present invention provides a component for an optical printer, which component has at least two printing channels through which discrete lengths of media may simultaneously be passed, and at least one optical printing head configured to expose lengths of media in each said channel in one printing pass and thereby enable the formation of an image on each length of media.

Another aspect of the present invention relates to an illumination device for an optical printer, the illumination device comprising respective arrays of red, green and blue illumination elements that are each arranged along respective notional parallel lines on a substrate so as to be linearly offset from one another along their respective notional lines, the arrangement being such that in the event of a swathe overlap when the device

is operated to expose adjacent swathes of a photographic medium, the respective regions of the photographic medium that are overexposed by each of the arrays as a result of said overlap do not coincide with another.

Yet another aspect of the present invention relates to an illumination device for an optical printer, the illumination device comprising respective arrays of red, green and blue illumination elements that are each arranged along respective notional parallel lines on a substrate so as to be linearly offset from one another along their respective notional lines, the arrangement being such that in the event of a gap between swathes when the device is operated to expose adjacent swathes of a photographic medium, a first region of the photographic medium where a gap exists between regions of the photographic medium that have been exposed by any one of the arrays does not coincide with second and third regions of the photographic medium where a gap exists between respective regions of the photographic medium that have been exposed by the other arrays.

A final aspect of the present invention relates to a method of calibrating an optical printer from an image printed by the printer, the method comprising: (i) assessing the contribution made to the image by each optical element of a printing head of the printer; (ii) adjusting the contributions for each element for a next print to be printed with the printer so that the contributions from each element are closer to being equal to one another; (iii) printing the next image; (iv) determining whether the image is acceptable, and (v) if the image is not acceptable, repeating steps (i) to (iv) until the printed image is determined to be acceptable.

Other features and advantages of the foregoing aspects of the invention are set out in the following detailed description of preferred embodiments, and elsewhere in the present application.

Brief Description of the Drawings

Various preferred embodiments of the present invention will now be described by way of illustrative example and with reference to the accompanying drawings, in which:

Fig. 1 is a schematic representation of an illustrative optical printer;

Fig. 2a is a schematic representation of the optical illumination device disclosed in our prior European patent;

Fig. 2b is another view of the device shown in Fig. 2a;

Fig. 2c illustrates how an illumination device moves over a photographic medium to expose successive swathes of an image;

Figs. 3 to 5 illustrate the configuration of optical elements on illumination devices according to three embodiments;

Fig. 6 is a schematic cross-sectional view of an illumination device;

Fig. 7 is a schematic representation of a printing head assembly;

Fig. 8 is a flow diagram illustrating steps of an illustrative calibration method;

Fig. 9 is a schematic representation of an illustrative test pattern;

Fig. 9a is an enlargement of part of Fig. 9;

Fig. 10 is a chart depicting the relationship between LED colour and the colour of
5 a corresponding image on photographic paper;

Fig. 11 is an illustrative representation of a transport mechanism for an optical
printer;

Fig. 12 is a schematic perspective view (from a photographic medium entry end)
of a photographic medium transport, processing and cutting component of an optical
10 printer;

Fig. 13 is a schematic perspective view from a photographic medium exit end of
the component depicted in Fig. 12; and

Fig. 14 is a schematic perspective view of the component shown in Fig. 12 from
another direction.

15

Detailed Description of Preferred Embodiments

Various preferred embodiments of the present invention will now be described in
detail. The following description is merely illustrative, and should not be construed as
limiting – in any way – the scope of the present invention. It will be appreciated that
20 many modifications and alterations may be made to the particular embodiments that are
hereafter described, and notice is hereby given that all such modifications and
alterations are within the scope of the present invention. For example, whilst the
following description refers to the individual illuminating elements of the arrays as being
light emitting diodes, it will be immediately apparent to someone of ordinary skill in the
25 art that a variety of different types of illumination devices may instead be provided and
as such a reference herein to LEDs should not be construed as a limitation of the scope
of the present invention.

The term “photographic medium”, as used herein, refers to any medium that may
be optically exposed so that an image can then be generated by developing the
30 medium. An illustrative example of such a medium is photographic paper. It should
also be remembered that where the term “printing” or other related terms are used, we
do not intend to refer to the deposition of inks and such like onto a medium. In general
terms, “printing” in the context of the present application is the exposure of a
photographic medium with light, and the developing of that medium to yield an image.

35 As mentioned above, one aspect of the present invention is concerned with
improving the resolution achievable with an optical printer by reducing the physical size
of the illumination device. However, we have found that our attempts to reduce the

physical size of the illumination device have been hampered *inter alia* by the physical size of the LEDs of the red, green and blue arrays, and the spacing between the elements that must be provided to enable the elements to be connected to an electrical power source. One might think that the LEDs could be more closely mounted on the substrate if they were simply to be abutted one against the other. However, such an arrangement is not a practical possibility as there is then insufficient space for the electrical connections that must be provided to enable the individual LEDs to be energised.

To address this problem, as shown in Fig. 3, we arrange arrays 20, 21 & 22 of LEDs 14 in columns along notional parallel lines 34 on a substrate 15, and in each column of LEDs we arrange the individual LEDs 14 so that they are offset from the associated notional line 34 (the dashed line in Fig. 3) - in effect to provide arrays of "castellated LEDs".

As shown therein the LEDs 14 of each array (red 20, green 21 and blue 22) are more closely arranged in a vertical dimension (as orientated) than in the prior art arrangement depicted in Fig. 2(b). By more closely arranging the LEDs 14 in this way the spacing of individual components of the final image that are attributable to respective elements can be reduced, thereby improving the resolution of that image.

The offset of each LED 14 with respect to the associated notional line 34 on the substrate 15 is arranged such that the emission profiles of adjacent LEDs 14 in each array overlap to such a degree that components of an image printed by the optical printer on a photographic medium and attributable to adjacent LEDs are not readily resolvable. By this we mean that the image elements cannot be resolved when the image is viewed normally, only when the image is magnified several times. In a vertical dimension (as illustrated) the spacing between adjacent LEDs may be zero. In another arrangement the spacing between adjacent LEDs (in the vertical dimension) the spacing between adjacent LEDs may be less than zero so that the respective emission profiles of adjacent LEDs overlap to such a degree that components of an image printed by the optical printer on a photographic medium and attributable to those adjacent LEDs are not readily resolvable

As aforementioned, another aspect of the present invention is concerned with addressing issues concerning the quality of the printed image, in particular the quality of the image as perceived by the human eye. With previously proposed devices, such as that disclosed in our prior abovementioned patent, we have noticed that the quality of the final image can sometimes be adversely affected by a so-called "banding" effect that can occur at the junction between successive printing swathes as the image is being exposed on the photographic medium. For example, we have noted that an

overexposure of the photographic medium (visible as a noticeably darker band) can occur in the region where the swathes overlap.

Figs. 4 and 5 of the accompanying drawings show two arrangements that address such problems. In each of these arrangements the red 20, green 21 and blue 22 arrays are linearly offset (along the aforementioned notional lines 34) from one another. By adopting this arrangement, a join between adjacent swathes of the final image resulting from exposure of the photographic medium by the red array (say) occurs at a different location on the photographic medium to joins between adjacent swathes of that image which are attributable to the green and blue arrays. By virtue of this arrangement, junctions between swathes of the final image that are attributable to one of the three arrays, are unlikely to coincide with junctions between swathes attributable to the other two arrays.

In effect, by adopting such an arrangement errors at junctions between image swathes for the three arrays are not compounded (as they were in the device disclosed in the abovementioned patent), and as such for one of the arrays an error occurring at a junction between image components attributable to that array occurs at a point where it is unlikely that there will be errors in the components attributable to the other arrays and hence such errors are less perceptible to the human eye than they would be if all three arrays were aligned.

As aforementioned, these problems can be addressed in one embodiment (depicted in Fig. 4) by physically off-setting the three arrays 20, 21, 22 from one another. In another embodiment (depicted in Fig. 5), selected groups of LEDs 14 at one or both ends of the arrays 20, 21, 22 can be configured so that they are not illuminated (either by not connecting those LEDs to the power source, or alternatively by opting not to switch on those LEDs) to achieve the same off-setting effect. With reference to Fig. 5, those LEDs which are not illuminated are shown cross-hatched.

The offset between arrays is preferably chosen to correspond to a distance at the light receiving face of the fibre taper which provides an offset distance between arrays at the light emitting face of the fibre taper which is slightly greater than the largest likely positioning distance error that might occur when photographic medium is moved through the printer. In the specific example mentioned hereafter where the positioning error may be in the region of up to 4 microns, the offset distance between arrays at the light emitting face of the taper would preferably be slightly larger than this (say up to 6 microns), and the actual offset between arrays on the illumination device would be the offset distance at the light emitting face (in this instance up to six microns) multiplied by a factor corresponding to the magnification provided by the fibre taper (in a dimension parallel to the notional lines of the illumination device) from the emitting face to the

receiving face.

As aforementioned, another aspect of the present invention is concerned with the structure of the illumination device, and the printing head incorporating that device. In particular, we have sought to address the problems associated with the fact that the
5 quality of a given final image can sometimes be adversely affected by crosstalk between adjacent LEDs, and by variations in the relative intensities of the red, green and blue arrays. It is also the case that maintenance of the gap between the illumination device and fibre optic light pipe must be carefully controlled (to avoid aberrations in the final image) and such control can be difficult to achieve in practice.

10 To address such problems we have devised a novel illumination device structure that is illustrated in Fig. 6 (where Fig. 6 is a cross-sectional view of the device generally along one of the aforementioned notional lines on the substrate).

As shown, the illumination device 40 according to this aspect of the present invention comprises a substrate 42 on which the individual LEDs 14 are mounted. The
15 substrate 42, at least on the side on which the LEDs 14 are mounted, is configured to reduce light reflection between adjacent arrays of LEDs and/or to reduce light reflection between adjacent LEDs in a said array.

Both of these features can be achieved by rendering selected parts or the whole of at least this side of the substrate 42 non-reflective - for example by covering it with a
20 non-reflecting coating (e.g. black paint) - so as to reduce light reflection between LEDs or arrays (and hence cross-talk) via the substrate surface.

The LEDs are encapsulated within a light transmissive encapsulant 44, preferably a polymer encapsulant, so as to protect the elements and the electrical connections thereto (not shown). The encapsulated LEDs are then covered with a light
25 transmissive medium 46, preferably a relatively viscous fluid medium, and a filter 48 is mounted on top of the medium. Baby oil has been found to be particularly suitable as a medium for covering the LEDs. By providing a fluid medium between the filter and encapsulated LEDs, it is possible to reduce reflections between LEDs by matching the refractive indices.

30 The filter 48 is, in the preferred implementation, different for one or more of the three arrays of light emitting elements. One function of the filter is to act as a band pass filter to reduce the exposure of the wrong colour (colour cross-talk) from each LED. A second function of the filter, if required for the particular array with which it is associated, is to absorb some of the emitted light so that the light intensities for all of the arrays are
35 substantially equal, allowing easier electronic control of the LEDs. This is particularly the case for the blue LED array as blue LEDs tend to emit a greater intensity of useful light than similarly sized red or green LEDs, and because most photographic media tend

to be more sensitive to blue wavelengths. To account for this, the filter associated with the blue LED array may absorb some of the emitted light as well as restricting that light to a predetermined range of wavelengths.

5 A mask layer 50 with apertures 52 is mounted on the filter layer so that the apertures (which are each slightly larger than the associated LEDs) are aligned with the LEDs. The provision of the mask again helps reduce cross-talk between neighbouring light emitting elements.

Fig. 7 is a schematic representation of a printing head 54 consisting of the illumination device 40 abutted against a light receiving face 56 of a tapered optic fibre
10 light pipe 58 so that light emitted by the LED arrays falls on the light receiving face of the light pipe. A light transmissive fluid medium 60, for example a relatively viscous fluid with an appropriate refractive index, may be provided between the LED arrays and the light pipe 58.

Light is conveyed by the light pipe from the light receiving face 56 to a light
15 emitting face 62, and from there to the photographic medium 64 via an optical lens relay 66. The relay is provided to avoid problems such as dust-pick up, and aberrations (e.g. spreading) that might otherwise be introduced were the light emitting face very close to the photographic medium, so as to illuminate it directly.

In the depicted arrangement the relay 66 is symmetrically arranged (i.e. the
20 centre of the relay is a constant distance "l" from both the light emitting face and the photographic medium) to provide a 1:1 transference of light from the light emitting face 62 of the tapered light pipe 58 to the photographic medium 64. It may, however, be desirable to provide for an asymmetric transference of light to the photographic medium to reduce or expand the image produced on the photographic medium. The position of
25 the lens relay with respect to the light emitting face and the photographic medium may be adjustable, and could be user-adjustable.

In one envisaged arrangement a plurality of different lens relays (each providing a different transference of light) may be arranged on a rotor so that different transferences of light may be achieved by rotating the appropriate lens relay into the
30 light path between the light emitting face and the photographic medium.

In the preferred arrangement the tapered light pipe and the substrate are covered by a non-reflective cover 68 leaving only the light emitting face of the light pipe exposed.

In the context of the above and the present application as a whole, it will be
35 appreciated that variations may be made. For example, it may not be necessary to provide band-pass filters. If filters are required or desirable, then high or low pass filters may be provided in addition to or instead of one or more band pass filters. It is also the

case that the light source elements need not necessarily be LEDs. Other light sources, such as laser diodes or illuminated LCD arrays, may instead be employed. Lastly, it will of course be appreciated by those persons skilled in the art that the illumination devices shown in the drawings are purely illustrative. In practice it is likely that each array will
5 comprise many more light emitting elements than are illustrated in the accompanying drawings.

As mentioned above, a persistent problem for optical printers, particularly those printers that use LEDs for light sources, is that the characteristics of the light sources vary dramatically from one to the other. For example, for any two LEDs of a particular
10 colour both the intensity profile and wavelength profile of the light emitted by the LEDs, when driven by the same current, will vary considerably. These variations from one LED to another can show up as lines within swathes of a final printed image. It is also the case that light emitting diodes tend to vary non-linearly in both their output intensity and wavelength with input voltage variations, and a compounding problem is that the
15 photographic medium (typically photographic paper) used for a particular print will directly affect the quality of that print and, furthermore, the characteristics of a given photographic paper will typically be quite different from those of another type of paper.

All of these different variations must be addressed if the quality of the final image is to be improved, and to this end it has previously been postulated that one could
20 employ a series of photocells as an photographic medium, and feed back the output of those photocells to the light source elements to adjust the output of those elements and hence provide a uniform illumination of the paper. Although this would at first sight appear to be an attractive solution to the problem, it is unfortunately the case that photocells respond very differently to photographic paper, and as such adjusting the
25 system to be best suited for a set of photocells will not necessarily provide an appropriate setting for printing on photographic paper.

To alleviate these problems, we have proposed to provide a calibration method and system whereby the printer is calibrated from one or more images printed with that printer. This approach is advantageous as the final image will of course incorporate all
30 of the aforementioned non-linear variations, and as such by calibrating to the image one inevitably addresses all of the non-linear variations in the printer.

The process that we have developed is an iterative process whereby the printer is adjusted at each iteration by a predetermined factor less than the currently determined optimum adjustment factor. This arrangement has been deliberately
35 employed as the calibration process could be unstable if the printer were adjusted to the currently determined optimum at each iteration.

Referring now to Fig. 8 of the accompanying drawings, the first step in the

process is to print a test pattern (of the type depicted in Fig. 9a) at the resolution of the printer – for example at approximately 400 DPI. It will be understood by persons skilled in the art, of course, that a resolution of 400 DPI for an optical printer is equivalent to a very much larger resolution provided by a typical inkjet printer, for example. Typically,
5 the resolution achievable with an optical printer is about five times better than that achievable with an inkjet printer when printing at the same notional DPI resolution (in other words, a 400 DPI resolution for an optical printer is roughly equivalent to a 2000 DPI resolution for an inkjet printer).

Once the test pattern has been printed, the next step in the process is to
10 ascertain whether or not the final printed image is acceptable. As is explained in greater detail below, this can be done manually by the operator or automatically.

If the printed test pattern image is not acceptable, the next step in the process is to scan the printed image with a colour scanner having a relatively high resolution, for example 1600 DPI. The test pattern is scanned directly to memory in a computer
15 coupled to the scanner, and the next step in the process is to use the computer to process that scanned image to arrive a measure of its final quality.

Once the scanned image has been processed, or indeed as it is being processed, the computer generates a calibration table which defines a series of adjustments for each of the light emitting elements in the illumination device of the
20 optical printer.

Once the calibration table has been completed, the next step in the process is to program the printer with the calibration table (to adjust the output of each of the light emitting elements) and once this has been completed the next step in the process is to print another test pattern.

25 Once this second test pattern has been printed it is, in one embodiment, visually assessed by the operator of the printer to determine whether or not the image is acceptable. If the image is acceptable, then the calibration process is halted and the printer is ready for use. On the other hand, if the image is not acceptable, the process continues (in the manner described above) until a final image is printed that is visually
30 acceptable to the operator.

In a second embodiment of this process not depicted in the drawings, the printed final test pattern may be output to a scanner that is under the control of the computer and is configured to scan the image, following which the computer may automatically assess the quality of the scanned image (in accordance with predetermined criteria the
35 like of which are well known to persons skilled in the art) before processing the image to generate a calibration table, and continuing with the calibration process as previously described until an acceptable image is printed.

Fig. 9a, as aforementioned, is a schematic representation of a test pattern that we have developed for use with our calibration process. However, before explaining the detail of this pattern it is useful first to explain that when a photographic medium, such as photographic paper for example, is illuminated with a green LED a magenta image is produced on the paper. Similarly, when the paper is illuminated with a blue LED a yellow image is produced on the paper, and when the paper is illuminated with a red LED a cyan image is produced on the paper. This relationship between LED colour and the colour of the corresponding image on the paper is depicted schematically in Fig. 10.

Referring now to Fig. 9a, the test pattern proposed for use with our calibration process consists of a number of discrete test areas - each of which has a specified function. The first of these consists of three scan areas 70, 72 and 74 printed at a low intensity, a medium intensity and a high intensity respectively. Whilst it would be possible to calibrate the printer using only one such scan area, three areas at different intensities is preferred as the output of a given LED varies non-linearly with input voltage. More or less test areas may be employed depending on the exact specification of the printer resolution.

Each scan area consists of a colour block 76, 78 and 80 for each array (red, green, blue), and an LED identification print area 82, 84 and 86 for each array (red, green, blue). As shown in Fig. 9a (and in greater detail in Fig. 9b), the LED identification print areas are printed immediately adjacent their associated colour block. Thus, in the particular example depicted the printer has energised all of the red LEDs to print colour block 76, following which a subset of those red LEDs has been energised to print LED identification print area 82. Then the red LEDs have been switched off and the green LEDs have been switched on to print colour block 78, following which a subset of those green LEDs has been energised to print identification print area 84. Finally, the green LEDs have been switched off and all of the blue LEDs have been energised to print colour block 78, following which a subset of those blue LEDs has been energised to print identification area 86.

Fig. 9b is a magnified view of a region 79 of the test pattern depicted in Fig. 9a showing a cyan colour block and associated identification area as generated by illumination of a photographic medium with a Red LED array. As is clearly visible the identification area consists of a plurality of parallel lines, and each line is attributable to a specified LED. In the particular example shown, the subset energised to print the identification area consists of every fourth LED of the associated array (i.e. the first line results from the first LED in the array, the second line results from the fourth LED, the third from the eighth LED and so on). The parallel lines allow the computer to identify a particular row of the associated colour block that results from the particular LED that

printed the line, and by interpolating between adjacent printed parallel lines the computer can attribute a row of the accompanying colour block to each LED of each array.

Each scan area of the test print is bounded by a dashed line which enables the computer to identify each scan area in the printed test image for further processing, and the first LED identification area of each scan area includes a pair of crosses "+" that provide an indication of the orientation of the array, and hence enable the computer to autorotate the scan area in the event that the test image was slightly askew when scanned.

To generate the scanned image for processing by the computer, a printed test pattern (of the type depicted in Fig. 9) is scanned with a colour scanner, preferably a flatbed scanner. For an optical printer printing at 400 DPI, the scanner should have a resolution of at least 1,600 DPI and a colour density range of at least $2\frac{1}{2}D$. The image is scanned directly to memory of the computer, for processing.

Processing of the scanned test pattern consists of the following steps. First, the computer identifies a desired scan area (using the aforementioned dashed lines as boundary markers) of the scanned image. Next the computer interrogates the scan area to find the aforementioned orientation markers (the crosses - "+"), and if necessary rotates the scan image to correct any skew that has arisen in the scanning process.

The computer then looks for the first parallel line in the first LED identification print area to establish a Y position for the first LED of that array (in this instance the red array). The computer then interpolates between adjacent parallel lines to establish the exact Y position of each LED in the array.

Next the computer scans the colour block to the left (as depicted) of the LED identification area for each LED of this first array and measures, in an X direction, the intensity of the printed image. The computer then averages the measured intensity to establish, for each LED of the array, an average intensity profile.

The computer then normalises the calculated average intensity profiles for each of the LEDs to the dimmest of those LEDs, and generates a calibration table consisting of (for each LED) a factor by which the exposure time must be reduced (from a maximum) so that the output of all the LEDs in the array are substantially constant. Of note at this point is the fact that variation of the exposure is effected by varying the time for which each of the LED elements illuminates the photographic medium, rather than by varying the current driving the LEDs as LED output tends to vary non-linearly with current. It is also of note, as mentioned above, in our process we reduce the exposure time by a predetermined factor less than the optimum determined for that iteration. For example, the computer may be configured to calculate an exposure time reduction that

is only 90% of the value that the optimum reduction has been determined to be for that iteration. Effectively, the calibration table consists of a plurality of multipliers (one for each LED) specifying the extent to which the switch-on time for each of the LEDs should be reduced.

5 In another embodiment of this invention, the exposed "blocks" of colour are superimposed to give "grey" blocks. The exposure of individual LEDs can be measured in these blocks simply by selecting a single colour channel in the software analysis of the scanned image. The advantage of this embodiment is that it enables correction to be made for "colour cross-talk", i.e. the exposure of a colour by the wrong colour of LED.

10 Another aspect of the present invention, as mentioned above, is concerned with improving the transport mechanism for the photographic medium.

A particular requirement of that transport mechanism is that to enable the printer to achieve resolutions of the scale aforementioned and provide a high quality output, the components of the transport mechanism must be carefully designed and controlled to
15 enable photographic medium movement with a tolerance of in the region of a few microns, typically roughly four microns. By this we mean that when it is desired to move the photographic medium a given distance through the printer, then the mechatronics of the transport mechanism must typically be such that the actual transport distance is within plus or minus four microns of the desired distance.

20 As will no doubt be appreciated by persons skilled in the art, if the actual transport distance should be greater than the desired typical distance by more than four microns then visible white bands may be produced in the final image. Similarly, if the transport distance should be less than the desired distance by more than four microns, then adjacent swathes of the image may overlap to a noticeable degree and the final
25 image will be spoiled. It is critical, therefore, that the transport mechanism design is such that highly accurate photographic medium transport is enabled.

Referring now to Fig. 11 of the accompanying drawings, the transport mechanism 100 of this preferred embodiment comprises a photographic medium transport roller 102 that is driven by a motor (not shown) and includes an outer surface
30 that is configured to provide a relatively high level of grip. For example, in the preferred arrangement the roller 102 is electroplated with graded diamond chips that are extremely durable and provide the outer surface of the roller with the required high level of grip.

The transport roller 102 is of metal, and in this instance comprises a steel roller
35 that is accurately ground so as to have, within acceptable tolerances, a circular cross-section. Steel is particularly preferred as a material for the roller due to its strength, durable nature and ease of electroplating.

The transport roller includes a central axle 103 that is driven by the aforementioned motor, and it is preferred for that motor to comprise an accurate stepper motor. Mechanical damping (for example to counteract inertia effects that might otherwise cause a degree of continued transport roller rotation after the stepper motor has stopped) of a known friction brake type is provided on the axle to ensure, again within acceptable tolerances, that the roller stops at a desired position when the motor stops.

An optical encoder is mounted concentrically with the axle and includes a slotted disk 104 and an optical emitter/detector pair (not shown) provided on respective sides of the disk. As the slotted disk rotates, light from the optical emitter passes through the slots of the disk and is detected by the detector to generate a pulsed signal that is interpreted to derive a measure of the distance that the disk has rotated (and optionally also the speed of rotation). This signal is passed to a controller (not shown), such as a computer or ASIC (application specific integrated circuit), which operates in a feedback loop (preferably a closed feedback loop) with the stepper motor to control the stepper motor to drive the transport roller axle and hence the transport roller.

Advantageously, by providing a slotted disk which is substantially larger in diameter than the diameter of the roller it is possible to detect a smaller angular rotation of the roller than would otherwise be possible were the disk to be of the same or similar diameter to that of the roller.

In addition to the transport roller, the printer also includes a pressure roller 108 that is mounted to the printer, for example to the chassis 112 thereof, by means of one or more moveable arms that are biased by a spring 114 or other resilient biasing means to bear upon the transport roller 102.

In the preferred arrangement the pressure roller 108 comprises a plurality of free running rollers mounted on a common axis and separated from one another and from the one or more arms by appropriate resilient biases (such as springs). The pressure roller functions to press photographic medium against the transport roller to thereby reduce the possibility of the photographic medium slipping as it is advanced by the transport roller.

Photographic medium is supplied from a canister 118 that includes an exit slot 120 which is shielded so as to prevent inadvertent exposure of the photographic medium before the canister is inserted in a printer for use. Photographic medium is provided as a roll 122 and the roll 122 is mounted on a plurality of rollers 124 which are driven by a motor (not shown). The rollers 124 are configured to provide sufficient gription to wind photographic medium from the roll out of the slot 120 via a set of pinch rollers 126 in a photographic medium transport direction generally indicated by the arrow

“A”, and to wind photographic medium back into the canister to take up any slack that might occur. The amount of gription provided by the rollers is carefully chosen so that once any slack has been taken up the roll slips on the rollers and winding of photographic medium back into the canister halts. The motor is controlled by a
5 controller (potentially the same controller that controls the transport roller) to control the rollers 124 to wind photographic medium into or out of the canister.

One or more supply rollers (indicated generally by reference numeral 125) are provided between the canister 118 and the transport roller 102. The supply rollers 125 and the pressure roller 108 are arranged, with respect to the transport roller 102, so that
10 the photographic medium makes a 90 degree contact with the transport roller 102. This arrangement is preferred as it avoids the possibility of point contact between the photographic medium and one or more of the rollers, which contact could cause a jam.

Immediately after the transport roller 102, in the direction A of photographic medium transport, there is provided a vacuum bed 128 which is operable to apply a
15 downwards force (as depicted) to the photographic medium to ensure that the photographic medium is flat when passing under the printer's optical printing head 130. Without such a vacuum bed the photographic medium may not be absolutely flat, and any curvature would cause problems with focusing of the optical image on the photographic medium and the size of the printed swathe.

20 Immediately after the head 130 and vacuum bed 128, in the direction A of photographic medium transport, there is provided a cutter blade 132 that is operable to bear against a suitable anvil 134 to cut photographic medium passing therebetween. For reasons that will now be explained, the distance from the trailing edge of the printing head in the direction of photographic medium transport (i.e. the edge nearest to the
25 cutter blade 132) is known, as is the length of the transport path from the canister to the cutter blade 132.

When a new canister is inserted in the printer (typically with a standard length of photographic medium projecting out of the slot 120), the control system of the printer detects the presence of the canister and controls the canister motor to drive the rollers
30 124 to wind photographic medium from the roll 122 out of the canister and to the transport roller by way of the supply rollers 125. The transport roller is rotated and the photographic medium is pressed against the high grip surface of the roller by the pressure roller 118. The photographic medium is fed by the transport roller via the vacuum bed between the cutter blade 132 and the anvil 134 until a known length of
35 photographic medium (greater than the standard length of photographic medium that was originally projecting from the canister) has passed therethrough. At this point the canister motor and the transport roller motor are stopped, the cutter is moved against

the anvil to cut off the length of photographic medium that has passed therethrough (which length is then treated as waste and passed from the printer in the normal way).

The motor for the transport roller is then energised to rotate the roller in the opposite direction by a known distance corresponding to the distance between the
5 aforementioned trailing edge of the optical printing head 130 and the cutter blade 132. The transport roller motor is then stopped and the canister motor is energised to drive the rollers 124 in the opposite direction to take up any slack in the photographic medium that has been fed from the canister.

With the photographic medium properly located the head can be moved over the
10 surface of the photographic medium to expose a swathe of the photographic medium so that an image can be generated. Once the swathe is completed the transport roller motor is energised to rotate the transport roller to advance the photographic medium so that that next image swathe can be exposed.

This process continues, with the canister motor being intermittently energised as
15 required to drive the canister rollers in reverse take up any slack, until the image to be printed is completed. The transport roller is then rotated to transport the photographic medium by a known distance corresponding to the distance between the leading edge of the optical head (i.e. the edge closest to the transport roller) and the cutter, following which the cutter is operated to separate the portion of photographic medium that has
20 been exposed from the remainder (which portion is carried from the cutter by a further transport mechanism (not shown) for further processing (e.g. developing within the printer).

The transport roller motor is then energised to drive the transport roller in reverse to draw the photographic medium back from the cutter by a known distance
25 corresponding to the distance between the trailing edge of the optical head and the cutter blade, and the canister motor is energised to drive the canister rollers to take up any slack in the photographic medium supplied from the canister. Once the slack has been taken up the printer can then be operated to print another image.

A final aspect of the present invention relates to the fact that it would be
30 advantageous if a printer could be devised that provided a greater throughput of photographic medium. It would also be advantageous if such a printer could readily accommodate photographic medium of different sizes.

As mentioned above, one relatively simple way to increase photographic medium throughput would be to increase the speed at which the optical head assembly travels
35 over the photographic medium, however such an approach would not provide that great an increase in speed as the head must be over a given point on the photographic medium for a fixed minimum amount of time (for a given photographic medium) to

expose that point to the requisite amount of optical energy required to generate the image, and hence it is impossible - without adversely affecting the quality of the final image - to increase the speed of the head to a point where it is over a given point of the photographic medium for less than this fixed minimum period of time.

5 To address this problem this embodiment provides for processing of multiple media simultaneously by arranging discrete media in a side-by-side fashion and exposing respective swathes of the so-arranged media with one pass of the optical head assembly. By virtue of this arrangement it is possible to greatly increase (for example to almost double) the rate of media transport through the printer.

10 Another advantage of this arrangement is that as the printer is configured to enable simultaneously processing of two side-by-side media, the length of head travel has been increased to a point where processing of much larger (wider) media is possible. In the particular arrangement hereafter described a novel transport mechanism is provided that enables printing on side-by-side media of a given size as
15 well as on media of approximately double the size of either of the individual side-by-side photographic mediums.

Referring now to Fig. 12, the photographic medium transport, processing and cutting component 200 (hereafter referred to as the TPC component) comprises a first photographic medium transport assembly 202 mounted on top of a base plate 204, and
20 a second photographic medium transport assembly 206 mounted below the base plate 204. As shown, the second photographic medium transport assembly 206 is significantly wider than the first transport assembly 202, and as will later be described this transport assembly provides a means whereby media larger than the width of the first transport assembly can be processed by the printer.

25 Media is fed to the component depicted from one or more media cassettes (not shown), and fed out of the component depicted into a developing component (also not shown) where the exposed photographic image is developed.

The first photographic medium transport assembly (shown upstanding from the base plate) comprises a first pair of rollers 208 that abut through slots formed in a
30 curved media guide 210 (best viewed in Fig. 13), a second pair of rollers 212 (one of which is visible in Fig. 12, and the other of which is visible in Fig. 13) disposed below the first pair, a third pair of rollers 214 (one of which is visible in Fig. 13) disposed below the second pair, and a fourth pair of rollers 216 provided slightly below the base plate 204 and the third pair of rollers 214.

35 The first to fourth pairs of rollers each comprise a driven roller (driven by belt drive assembly 220 and associated motor 222) and a free-running roller, the driven and free running rollers being mounted in a chassis component upstanding from the base

plate 204. The second photographic medium transport assembly comprises a fifth pair of rollers 218 that abut through slots provided in a second media guide 224, and which are provided below the aforementioned fourth pair of rollers 216.

5 The fifth pair of rollers are significantly longer (typically more than twice as long as the first to fourth pairs of rollers and provide, in a first configuration, an entry to the TPC component 200 for media wider than the length of the first to fourth pairs of rollers. Furthermore, that portion of the fifth pair of rollers which is longer than the fourth pair provides, in a second configuration, an entry to the TPC component 200 for a second length of media to thereby enable simultaneous processing of both a first and the
10 second lengths of media.

Considering this first configuration, media having a width larger than that of the first to fourth roller pairs enters the TPC component 200 between the fifth pair of rollers 218 and passes along and above the media guide 224 to a set of rollers (the drive mechanism for which is visible in Fig. 14 under the base plate 204) provided beneath
15 the base plate 204, which rollers turn the media towards the base plate 204 and upwards through a slot in the base plate 204 into contact with a diamond coated transport roller (not visible) of the type shown in Fig. 11.

In the second configuration, a first length of media passes between the first roller pair 208 to the underside of the media guide 210 and from thence between the second,
20 third and fourth pairs of rollers. The first length of media exits from the fourth pair of rollers and passes over the topmost roller of the fifth roller pair before passing between the rollers of the fifth roller pair 218 (in direction A) and above and along the media guide 224 to the aforementioned rollers mounted beneath the base plate 204, which rollers turn the first length of media towards the base plate 204 and upwards through a
25 slot in the base plate 204 into contact with the diamond coated transport roller.

A second length of media (typically (but not necessarily) of equal width to the first length of media) passes in direction B between the fifth roller pair and along and above the media guide 224 to a set of rollers (not visible) provided beneath the base plate 204, which rollers turn the media towards the base plate 204 and upwards through a slot in
30 the base plate 204 into contact with the diamond coated transport roller. The first and second lengths of media are, in this arrangement, disposed substantially parallel to one another with a small gap therebetween. The two lengths of media, as will later be described, pass under the optical head assembly 226 (which comprises in this arrangement two offset illumination devices), and the head moves across both of the
35 lengths of media to print (i.e. optically expose) successive swathes of an image (in a preferred arrangement the same image) on each of the two media lengths. In an alternative arrangement, two printing heads could be provided, each being arranged to

expose a respective one of the two lengths of media.

As with the arrangement depicted in Fig. 11, media is urged into abutment with the diamond coated roller by a pressure roller 228 that is mounted on a pair of moveable arms that extend in the direction of media transport. To facilitate adjustment of media
5 alignment within the TPC component 200 there is provided a cam 230 to which a laterally extending bar 232 is fastened. The cam is drivable by a motor 234 to bring the bar 232 down towards the base plate 204 and against free ends of the arms (not visible) on which the pressure roller 228 is mounted to pivot the arms and thereby lift the pressure roller 228 away from the diamond coated transport roller so that media
10 alignment within the TPC component can be adjusted.

In the arrangement shown in Fig. 11, a cutter is provided immediately behind the optical head assembly in the direction of media transport through the printer.

In this arrangement (as shown in Fig. 13), however, the cutter 236 has been moved forwards (relative to the optical head assembly) in the direction of media
15 transport so that there is a gap 238 between a first beam 240 on which the optical head assembly is mounted and a second beam 242 on which the cutter 236 is mounted.

In this gap 238 there is provided a flap (not visible in the drawings) which is moveable to open a slot in the base plate 204 and provide access to a dead loop (also not shown) under the base plate 204 through which media travels before returning
20 above the base plate and moving forwards through the cutter 236. This dead loop is provided so that the path length for media traveling through the TPC component 200 can be varied as the media processing speed and media transport speed vary with different media sizes, and ultimately so that operation of the cutter can be properly synchronised with media transport so that each section of media is cut at the correct point.

25 To the front (in the direction of media transport) of the cutter assembly there is provided a pair of rollers consisting of a free-running roller 244 and a clamp roller 246 mounted thereabove. The clamp roller comprises larger deformable sections 248 (for example of foam material) that can rotate about the axis of the clamp roller, and smaller non-deformable sections 250. Immediately above the clamp roller there is provided a
30 lateral bar 252 that is supported at either end on blocks 254 that are each movable against a spring bias on respective locating pins 256. The bar is configured to be driven by a motor 258 to depress the blocks and press the non-deformable sections of the clamp roller 246 against the free-running roller to clamp media therebetween. Once the media has been clamped in place, the cutter 236 can be operated to separate the
35 exposed sections of media for subsequent developing in the adjacent developing section (not shown) of the optical printer.

Once the cutter has been operated, the blocks (and bar) move away from the

free-running roller 244 and the cut sections of media that were previously clamped between the free-running roller and the clamp roller are released to be carried into the developing section by driven belts. In a particularly preferred arrangement, the driven belts continue to be driven (to pull the media) whilst the media is clamped between the
5 free-running roller and the clamp roller for cutting, and to avoid tearing of the media by the force applied by the driven belts, it is preferred for the belts to be passed over swinging rollers that are configured to swing against a spring bias towards the TPC component whilst the media is clamped. The advantage of this arrangement is that as soon as the clamped media is released the spring bias suddenly accelerates the cut
10 sections of media away from the cutter blade and on into the processing section of the printer.

Thus there has herein been described a component for an optical printer, which component is configured and arranged to define a plurality of printing channels through each of which discrete lengths of media may be passed for exposure by an optical light
15 source, the component being configurable so that discrete lengths of media may be passed through more than one of said channels for exposure by said light source to enable the formation of an image on each length of media, or so that a single length of media may be passed simultaneously through more than one of said channels for exposure by said light source to enable the formation of a single image on said single
20 length of media.

There has also been described a component for an optical printer, which component has at least two printing channels through which discrete lengths of media may simultaneously be passed, and at least one optical printing head configured to expose lengths of media in each said channel to enable the formation of an image on
25 each length of media.

As mentioned earlier, it will be understood by those persons skilled in the art, that whilst several preferred arrangements have been described above in detail, the scope of the present disclosure is not limited solely to the particular arrangements described. Rather the scope of the present disclosure includes any and all modifications
30 to those embodiments which fall within the spirit and teachings of the foregoing.

For example, it may be the case that for some applications it is not necessary to provide a lens assembly in the printing head assembly. It is also the case that the printing head may comprise multiple illumination devices. In another modification of the above described arrangements, it is particularly preferred for the print head assembly to
35 move over a vacuum table and the photographic medium to be passed therebetween, The vacuum table is advantageous as it gently holds the media substantially flat to the table and this avoids aberrations in the image that might otherwise occur if the media

were to be slightly curved. In another modification, the printer may comprise more than two print heads, printing assemblies or be configurable to provide more than two channels.

5 It will also be apparent to persons skilled in the art, that the benefits associated with linearly offsetting the arrays (i.e. in a direction parallel to the notional lines) from one another may be enjoyed independently of the benefits associated with offsetting adjacent light source elements in a given array from one another. That is to say, the arrays may each comprise a simple column of elements (as depicted in Fig. 2(a)), with adjacent arrays being offset from one another in the manner depicted in Fig. 4 or 5.

10 Lastly, it should also be noted that the scope of the present invention encompasses any combination of features herein described or claimed, irrespective of whether that particular combination has been identified in the accompanying claims at this time.

CLAIMS

1. An illumination device for an optical printer, the illumination device comprising:
a first array of light sources comprising a plurality of light source elements that
5 are each operable to emit light within a red band of the visible electromagnetic spectrum,
a second array of light sources comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and
10 a third array of light sources comprising a plurality of light source elements that are each operable to emit light within a green band of the visible electromagnetic spectrum;
wherein said first, second and third arrays of light sources are generally linearly arranged along respective substantially parallel notional lines on a substrate; and said
15 plurality of light source elements of each said array are arranged such that respective adjacent light source elements of said plurality are offset from one another with respect to the associated notional line.
2. An illumination device for an optical printer, the illumination device comprising:
20 a first array of light sources comprising a plurality of light source elements that are each operable to emit light within a red band of the visible electromagnetic spectrum,
a second array of light sources comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic
25 spectrum; and
a third array of light sources comprising a plurality of light source elements that are each operable to emit light within a green band of the visible electromagnetic spectrum;
wherein said first, second and third arrays of light sources are generally linearly
30 arranged along respective substantially parallel notional lines on a substrate; said first, second and third arrays of light sources are each operable to emit a strip of light, and said printing head is configured such that a first of said arrays of light sources emits a strip of light when energised that is linearly offset along the associated notional line from a strip of light emitted when energised by a second adjacent one of said arrays of light
35 sources.

3. An illumination device according to Claim 2, wherein said plurality of light source elements of each said array are arranged such that respective adjacent light source elements of said plurality are offset from one another with respect to the associated notional line.

5

4. An illumination device according to Claim 1 or 3, wherein respective adjacent light source elements of said plurality are offset from one another to either side of the associated notional line.

10

5. An illumination device according to Claim 1, 3 or 4, wherein each said light source element has a light intensity emission profile, and respective adjacent light source elements of a said array are arranged such that the light intensity emission profile of a first source element overlaps that of a second source element to such a degree that elements of an image printed by said optical printer on a photographic medium and attributable to said first and second source elements are not resolvable.

15

6. An illumination device according to Claim 5, wherein the degree of overlap between adjacent light source elements is substantially constant for each said array of light sources.

20

7. An illumination device according to Claim 5 or 6, wherein said light source elements are arranged such that said light intensity emission profiles of respective pairs of adjacent light source elements overlap by less than 20 percent, and preferably by at least 2 percent.

25

8. An illumination device according to any of claims 1 to 7, comprising electrical circuitry for coupling each said light source element of respective arrays of light sources to a power source and control means for energising said light source elements.

30

9. An illumination device according to Claim 8, wherein said electrical circuitry is printed on said substrate.

10. An illumination device according to Claim 9, wherein said electrical circuitry is printed on a first side of said substrate and said light source elements are mounted on a second opposite side of said substrate, said light source elements being connected to said electrical circuitry by respective electrical pathways passing through said substrate.

35

11. An illumination device according to any of Claims 8 to 10, wherein said electrical circuitry is configured to enable each of said first, second and third arrays to be individually energised.
- 5 12. An illumination device according to Claim 2 or 3, or to any of Claims 4 to 11 when dependent on Claim 2 or 3, wherein each said array of light sources comprises a predetermined number of light source elements at one or both ends of the array that are arranged not to be energised so that when said light source arrays are energised a first
10 of said arrays of light source elements emits a strip of light that is linearly offset along the associated notional line from a strip of light emitted by a second of said arrays of light source elements.
13. An illumination device according to Claim 2 or 3, or to any of Claims 4 to 11 when dependent on Claim 2 or 3, wherein each light source array is linearly offset along
15 the associated notional line from an adjacent light source array such that, when energised, a first of said arrays of light sources emits a strip of light that is linearly offset along the associated notional line from a strip of light emitted by a second of said arrays of light sources.
- 20 14. An illumination device according to any preceding claim, wherein said light source elements comprise light emitting diodes.
15. An illumination device according to any preceding claim, wherein said substrate is configured so as to reduce light reflection between adjacent arrays of light source
25 elements.
16. An illumination device according to Claim 14 or 15, wherein said substrate is configured so as to reduce light reflection between adjacent light source elements in a
30 said array.
17. An illumination device according to any of claims 14 to 16, wherein said substrate is rendered substantially non-reflective, at least on a side thereof on which said light source elements are mounted.
- 35 18. An illumination device according to any of Claims 14 to 17, wherein each said LED light source element is encapsulated for protection by an optically transmissive material.

19. An illumination device according to any of Claims 14 to 18, comprising one or more optical filters arranged for illumination by one or more of said arrays of light source elements so that the light emanating from said illumination device has predetermined properties.
20. An illumination device according to Claim 19, comprising first, second and third filters respectively associated with each of said first, second and third arrays of light source elements.
21. An illumination device according to Claim 20, wherein one or more of said first, second and third filters comprises a band pass filter.
22. An illumination device according to Claim 20 or 21, wherein one or more of said filters is less optically transmissive than one or more other said filters so as to reduce the relative intensity of a component of the light emanating from the illumination device that is attributable to the array of light source elements associated with said less transmissive filter.
23. An illumination device according to Claim 21, wherein said less transmissive optical filter is associated with said second array of light source elements.
24. An illumination device according to any of Claims 15 to 23, further comprising an optically transmissive medium provided between said filters and said encapsulated LEDs.
25. An illumination device according to Claim 24, wherein said optically transmissive medium comprises a fluid medium.
26. An illumination device according to any of Claims 15 to 25, further comprising a mask having a plurality of apertures provided therein, said apertures being arranged so as to be generally coincident with a said light element when said mask is located in front of said arrays of light source elements.
27. An illumination device for an optical printer, the illumination device comprising:

a first array of light sources comprising a plurality of light source elements that are each operable to emit light within a red band of the visible electromagnetic spectrum,

5 a second array of light sources comprising a plurality of light source elements that are each operable to emit light within a blue band of the visible electromagnetic spectrum; and

a third array of light sources comprising a plurality of light source elements that are each operable to emit light within a green band of the visible electromagnetic spectrum;

10 a substrate having a first surface on which said first, second and third light source arrays are mounted, said first surface being configured to reduce light reflection between adjacent arrays of light source elements; and

a mask having a plurality of apertures provided therein, the mask being located in front of said arrays of light source elements so that said apertures are generally
15 coincident with the light source elements of said arrays to enable light from the arrays to travel through the mask.

28. An illumination device according to Claim 27, the device further comprising any one or more of the features of any of claims 1 to 26.

20

29. A printing head comprising:

an illumination device according to any preceding claim, and

an optic fibre light pipe having a light receiving face, said light pipe being arranged to receive light at said light receiving face from said light source arrays of said
25 illumination device,

wherein said light pipe further comprises a light transmitting face for transmitting light from said light source arrays to illuminate a photographic medium, and a tapered region between the light receiving face and the light transmitting face so that the light receiving face has a substantially greater surface area than the light transmitting face.

30

30. A printing head according to Claim 29, wherein said illumination device is abutted against said light receiving face of said optic fibre light pipe.

31. A printing head according to Claim 30, comprising an optically transmissive
35 medium provided between said illumination device and said light receiving face of said light pipe.

32. A printing head according to Claim 31, wherein said optically transmissive medium comprises a fluid medium.

5 33. A printing head according to any of Claims 30 to 32, wherein said printing head further comprises means for reducing access for ambient light to said light receiving face of said light pipe.

10 34. A printing head according to Claim 33, wherein said abutted illumination device and light pipe are covered by a substantially non-reflective medium that does not cover said light emitting face of said light pipe.

15 35. A printing head assembly for an optical printer comprising a printing head according to any of claims 29 to 34, and an optical lens relay provided between said printing head and a transport surface along which a photographic medium is transported in use.

36. A printing head assembly according to Claim 35, wherein said lens relay comprises a plurality of lenses.

20 37. A printing head assembly according to Claim 35 or 36, wherein said optical lens relay is configured and arranged so as to provide a symmetric 1:1 transfer of light from said light emitting face to a photographic medium transported along said transport surface in use.

25 38. A printing head assembly according to Claim 35 or 36, wherein said optical lens relay is configured and arranged so as to provide an asymmetric transfer of light from said light emitting face to a photographic medium transported along said transport surface in use.

30 39. A printing head assembly according to Claim 38, wherein said optical lens relay is configured and arranged to increase or reduce the area of said photographic medium illuminated by the light emitting face of said printing head.

35 40. A printing head assembly according to Claim 35 or 36, wherein said optical lens relay is configured and arranged to provide a user selectable symmetric or asymmetric transfer of light from said light emitting face to said photographic medium.

41. A printing head assembly according to Claim 40, wherein the position of said optical lens relay between said light emitting face and said transport surface is user adjustable.
- 5 42. A printing head assembly according to Claim 40 comprising a first optical lens relay configured to provide a 1:1 symmetric transfer of light from said light emitting face to said photographic medium, and a plurality of other optical relays each of which provides a different asymmetric transfer of light, said first relay and said plurality of other relays being selectably insertable between said light emitting face and said carrier surface.
- 10 43. An optical printer comprising at least one illumination device according to any of Claims 1 to 28.
- 15 44. An optical printer comprising a printing head according to any of Claims 29 to 34.
45. An optical printer comprising at least one printing head assembly according to any of Claims 35 to 42.
- 20 46. A method of calibrating an optical printer having a printing head that comprises a plurality of arrays of light emitting elements, each array comprising a plurality of elements, the method comprising:
- 25 (a) operating the printing head to expose a test pattern on a first segment of photographic medium, each of the elements of each array being configured to illuminate the first medium segment at at least one location;
- (b) developing the first medium segment to provide a first image of said test pattern;
- (c) determining, for each element, the light output by that element which exposed the medium segment to form a portion of the image at the at least one location associated with that element;
- 30 (d) determining an adjustment factor for each element, the adjustment factor being associated with an estimated adjustment for the light output of the associated element which, when the element is adjusted in accordance with that adjustment and operated, should provide a light output for that element that is substantially the same as that provided by the other elements.
- 35 (e) generating a calibration table from the factors calculated for said elements, the table defining how the light output for each element should be adjusted,

(f) operating the printing head in accordance with the calibration table to expose the same test pattern on a second segment of photographic medium identical to the first,
(g) developing the second segment of medium to provide a second image of said test pattern;

- 5 (h) determining whether said second image is of acceptable quality, and
(i) if said image is not of acceptable quality iteratively repeating steps (c) to (h) until the quality of the image is determined to be acceptable.

10 47. A method according to Claim 46, wherein each of the elements of each array are configured to expose the photographic medium at a plurality of locations.

48. A method according to Claim 47, wherein step (c) comprises determining, for each element, the average light output at said plurality of locations.

15 49. A method according to any of Claims 46 to 48, wherein step (c) is accomplished automatically from a digital image of said test pattern acquired by digitising said first image.

20 50. A method according to Claim 49, comprising the step of scanning the first image to generate said digitised image.

25 51. A method according to any of Claims 46 to 50, wherein step (h) comprises determining whether said second image of the test pattern meets a predetermined set of criteria, and determining the second image to be of acceptable quality if said set of criteria has been met.

30 52. A method according to Claim 51, wherein said predetermined set of criteria comprise a plurality of physical attributes that a printed test pattern should have before it can be deemed to be acceptable.

35 53. A method according to Claim 52, wherein step (h) is accomplished by scanning said second image, measuring the physical attributes of the test pattern, comparing the measured physical attributes for the test pattern with the corresponding physical attributes defined in said set of criteria, and indicating that said printed test pattern is acceptable if said measured physical attributes are at least equal to the attributes defined in said set of criteria.

54. A method according to Claim 53, wherein said scanning, measuring, comparing and indicating steps are automatically accomplished under the control of a computer.

55. A method according to any of Claims 46 to 54, wherein the light output of a said
5 element is adjusted by controlling the period of time for which said element is energised.

56. A method according to any of Claims 46 to 54, wherein said elements are initially arranged to illuminate the first segment of photographic medium with a maximum light output.
10

57. A method according to Claim 55 and 56, wherein the adjustment factor for a said element comprises a factor by which the period of time for which said element was energised to create the test pattern should be reduced.

58. A method according to any of Claims 46 to 57, wherein the adjustment factor for a given iteration for each said light source element is less than an optimum adjustment factor for that element, which optimum factor is estimated for that iteration to be the adjustment for each element that would cause all elements of the array of which that element forms part to have exactly the same light output.
15

59. A method according to Claim 58, wherein the adjustment factor is at least 5% less than the optimum adjustment factor.
20

60. A method according to Claim 58 or 59, wherein the adjustment factor is at least
25 10% less than the optimum adjustment factor.

61. A method according to any of Claims 46 to 60, wherein the test pattern includes a discrete block for each of said light source arrays within which the photographic medium has been exposed only by light from elements within that array.
30

62. A method according to any of Claims 46 to 61, wherein the test pattern includes a combined region that has been exposed by more than one of said arrays, the method further comprising the step of determining from said combined region a measure of the degree of cross-talk between said arrays.
35

63. Printer control instructions embodied in a carrier wave, the control instructions being configured to control an optical printer to print a calibration test pattern, wherein

said optical printer has a plurality of light source arrays each comprising a plurality of light source elements and the pattern comprises:

a discrete printed block for each of said light source arrays within which the photographic medium is to be exposed only by light from elements within that array.

5

64. Printer control instructions according to Claim 63, configured so that each of said light source elements expose a plurality of pixels within the block, each plurality of pixels being associated with one element.

10

65. Apparatus for calibrating an optical printer having a printing head that comprises a plurality of arrays of light emitting elements, each array comprising a plurality of elements, the apparatus comprising:

15

(a) means operating the printing head to expose a test pattern on a first segment of photographic medium, each of the elements of each array being configured to illuminate the first medium segment at at least one location;

(b) means for developing the first medium segment to provide a first image of said test pattern;

20

(c) means for determining, for each element, the light output by that element which exposed the medium segment to form a portion of the image at the at least one location associated with that element;

25

(d) means for determining an adjustment factor for each element, the adjustment factor being associated with an estimated adjustment for the light output of the associated element which, when the element is adjusted in accordance with that adjustment and operated, should provide a light output for that element that is substantially the same as that provided by the other elements.

30

(e) means for generating a calibration table from the factors calculated for said elements, the table defining how the light output for each element should be adjusted, (f) means for operating the printing head in accordance with the calibration table to expose the same test pattern on a second segment of photographic medium identical to the first,

(g) means for developing the second segment of medium to provide a second image of said test pattern; and

(h) means for determining whether said second image is of acceptable quality, and

35

(i) control means configured and arranged such that if said second image is not of acceptable quality components (c) to (h) are repeatedly operated until the quality of the image is determined to be acceptable.

66. A computer program comprising one or more computer program components that when executed by a computer are operable to implement at least steps (b) to (e) of the method of Claim 46.

5 67. A calibration pattern substantially as hereinbefore described or as shown in the accompanying drawings.

68. A transport mechanism for an optical printer, the mechanism comprising:
a transport roller for transporting photographic medium, at least one region of the
10 exterior surface of the transport roller being configured to grip and drag photographic medium through the transport mechanism and towards a printing head assembly;
a pressure roller configured to press photographic medium against the transport roller to thereby reduce the possibility of the medium slipping as it is advanced by the transport roller;
15 guide means for guiding photographic medium from at least one storage canister to the pressure roller and transport roller;
a stepper motor configured to rotate the transport roller;
means for detecting rotation of the transport roller and generating a signal that is representative thereof; and
20 a controller that is configured to control the stepper motor to drive the transport roller to advance medium a predetermined distance through the transport mechanism, to derive from said signal a measure of the distance rotated by the roller, and to control the stepper motor to cease rotation of the roller when the measured distance is equal to said predetermined distance.

25

69. A transport mechanism according to Claim 68, wherein substantially the entire exterior surface of the transport roller is configured to grip and drag photographic medium.

30 70. A transport mechanism according to Claim 69, wherein the transport roller is of a durable metal that has poor thermal conductivity.

71. A transport mechanism according to Claim 70 and 71, wherein the outer surface of the transport roller is electroplated with graded diamond chips.

35

72. A transport mechanism according to any of Claims 68 to 72, comprising resilient biasing means for biasing said pressure roller towards the transport roller.

73. A transport mechanism according to Claim 72, wherein the pressure roller comprises a plurality of free-running rollers mounted on a common axle, said free-running rollers being separated one from the other on said axle by a plurality of resilient
5 biases provided therebetween.

74. A transport mechanism according to any of claims 68 to 73, wherein the guide means comprises one or more supply rollers, at least one of said supply rollers and said pressure roller being arranged and configured to supply photographic medium to the
10 transport roller so that the medium does not make a point contact with the transport roller.

75. A transport mechanism according to Claim 74, wherein the supply rollers and pressure roller are arranged and configured so that the photographic medium makes a
15 90 degree contact with the pressure roller.

76. A transport mechanism according to any of Claims 68 to 75, wherein each storage canister comprises a light-tight enclosure having a void and a shielded exit through which photographic medium can be drawn by the transport roller, the void
20 comprising a plurality of rollers for supporting a roll of photographic medium and guiding the medium to the exit.

77. A transport mechanism according to Claim 76, wherein the rollers are configured to be able to be driven to rotate a roll of photographic medium supported thereon so as
25 to draw photographic medium back into the canister.

78. A transport mechanism according to Claim 77, wherein said rollers are each provided with an outer surface that exhibits sufficient gription to enable the rollers to advance photographic medium from or withdraw photographic medium into the canister,
30 but will allow the roll to slip on the rollers if the withdrawal of medium into the canister is prevented.

79. A transport mechanism according to Claim 78, comprising a motor for driving said rollers.
35

80. A transport mechanism according to Claim 79, wherein said motor is controlled by said controller.

81. A transport mechanism according to any of Claims 68 to 80, wherein said means for detecting rotation comprises a slotted wheel that is configured to rotate in synchronism with said transport roller, an optical emitter provided on one side of said wheel and configured to illuminate the slots in the wheel, and an optical detector provided on the other side of the wheel that is configured to detect light which is emitted by the emitter and passes through the slots in the wheel, the detector being configured to output a pulsed signal wherein the number of pulses generated for a given movement of the wheel provides a measure of the distance rotated by the wheel and transport roller.

82. A transport mechanism according to Claim 81, wherein measurement of the number of pulses per unit time enables the calculation of a measure of the speed of rotation of the wheel and transport roller.

83. A transport mechanism according to Claim 81 or 82, comprising on which the transport roller is mounted for rotation, said slotted wheel being mounted on said axle for synchronised rotation with the transport roller.

84. A transport mechanism according to any of Claims 81 to 83, wherein the slotted wheel has a greater diameter than the transport roller so as to improve the angular resolution of the rotation detection means.

85. A transport mechanism according to any of Claims 68 to 84, comprising means for detecting the attachment of a new medium canister to the transport mechanism and to output a signal indicative thereof.

86. A transport mechanism according to Claim 85 when dependent on Claim 80, wherein the controller is configured on receipt of said signal from the detecting means to:

- (i) operate the canister motor and transport roller motor to rotate the canister rollers and the transport roller to draw from the new canister, through the transport mechanism, under the printing head assembly and on through a cutter assembly a predetermined length of medium that includes a length of waste medium at a free end thereof;
- (ii) to stop the transport roller motor and the canister motor once the length of waste medium has been advanced through the cutter assembly;

(iii) to operate the cutter assembly to cut the medium and discard said waste medium;

(iv) to operate the transport roller motor to drive the transport roller in reverse to draw the length of photographic medium back towards the printing head assembly;

5 (v) to cease operation of the transport roller motor once the photographic medium is properly aligned for exposure by said printing head assembly; and

(vi) to operate said canister motor to drive said canister rollers in reverse to take up any slack in photographic medium.

10 87. A transport mechanism according to any of claims 68 to 86, wherein the mechanism is provided within a light-tight enclosure.

88. A transport mechanism according to any of claims 68 to 87, wherein the guide means includes means defining a plurality of channels through the transport
15 mechanism, each of said channels being capable of receiving a discrete length of photographic media.

89. A transport mechanism according to Claim 88, wherein each said channel is configured to interface with a discrete canister of photographic medium.

20

90. A transport mechanism according to Claim 88, wherein the channel defining means is configured so that one length of photographic media may be simultaneously received through at least part of a plurality of said channels.

25 91. A transport mechanism according to Claim 90, wherein said plurality of channels are configured to interface with a single canister of photographic medium.

92. A transport mechanism according to Claim 89 and 91 wherein said single canister of photographic medium that interfaces with a plurality of said channels
30 contains photographic medium that is wider than the photographic medium contained with the discrete canisters that each interface with a single one of said plurality of channels.

93. A transport mechanism according to any of Claims 88 to 92, wherein the guide
35 means defines two channels, and the transport mechanism is operable in two modes.

94. A transport mechanism according to Claim 93, wherein in said first mode the guide means is configured to supply two discrete lengths of photographic media each through a respective one of said channels to said transport roller.

5 95. A transport mechanism according to Claim 94, wherein said transport roller provides said two photographic media to a printing head assembly for exposure, thereby enabling the formation of two images.

10 96. A transport mechanism according to any of Claims 91 to 93, wherein in said second mode the guide means is configured to supply a single length of photographic media to said transport roller through at least part of both of said channels at the same time.

15 97. A transport mechanism according to any of Claims 91 to 96, wherein a first of said two channels is only capable of receiving photographic medium having a width of up to a first width, and a second of said channels is capable - in said first mode of operation - of receiving photographic medium having a width of up to said first width, and - in said second mode of operation - of receiving photographic medium having a width of up to a second width larger than said first.

20

98. A transport mechanism according to Claim 97, wherein said second width is roughly twice said first width.

25 99. A transport mechanism according to any of Claims 90 to 98, wherein the transport mechanism includes a base plate to which components of the mechanism are mounted, and in said first mode a first supply of photographic medium enters the mechanism from above said plate and a second supply of photographic medium enters the mechanism from below said plate.

30 100. A transport mechanism according to Claim 99, wherein in said second mode said second supply of photographic medium is offset, in a direction transverse to a direction in which media is transported through the transport mechanism from the photographic medium canisters, from said first supply of photographic medium.

35 101. A transport, processing and cutting (TPC) component for an optical printer, said component comprising a transport mechanism according to any of Claims 68 to 87, a printing head assembly according to any of Claims 35 to 42, and a cutter arranged so

that photographic media passes through said transport mechanism, under said printing head assembly and through said cutter, the cutter being operable to cut the photographic media to separate a length of exposed media from a remaining length of unexposed media.

5

102. A transport, processing and cutting (TPC) component for an optical printer, said component comprising a transport mechanism according to any of Claims 88 to 100, a printing head assembly according to any of Claims 35 to 42, and a cutter arranged so that photographic media passes through said transport mechanism, under said printing
10 head assembly and through said cutter, the cutter being operable to cut the photographic media to separate one or more lengths of exposed media from one or more remaining lengths of unexposed media.

103. A TPC component according to Claim 102, wherein said the printing head of said
15 printing head assembly comprises two illumination devices offset from one another in a direction parallel to a direction of photographic medium movement through the TPC component from the at least one photographic medium canister.

104. A TPC component according to Claim 102 or 103 when dependent on Claims 99
20 and 100, wherein the printing head assembly is configured to print two swathes in each pass of the printing head assembly, and each said pass includes both of said supplies of photographic media.

105. A TPC component according to Claim 104, wherein one of said channels
25 includes a delay loop through which one of said exposed lengths of media can selectively be directed to thereby compensate for differences in path length between said first and second channels.

106. A TPC component according to Claim 105, wherein said delay loop is located in
30 one of said two channels between said printing head assembly and said cutter.

107. An optical printer comprising a TPC component according to any of Claims 101 to 106.

35 108. An optical printer according to Claim 107, further comprising a developing unit arranged to receive cut lengths of exposed media from said cutter, and to develop said received lengths of exposed media to reveal an image.

109. A component for an optical printer, which component is configured and arranged to define a plurality of printing channels through each of which discrete lengths of media may be passed for exposure by an optical light source, the component being
5 configurable so that discrete lengths of media may be passed through more than one of said channels for exposure by said light source to enable the formation of an image on each length of media, or so that a single length of media may be passed simultaneously through more than one of said channels for exposure by said light source to enable the formation of a single image on said single length of media.

10

110. A component for an optical printer, which component has at least two printing channels through which discrete lengths of media may simultaneously be passed, and at least one optical printing head configured to expose lengths of media in each said channel in one printing pass and thereby enable the formation of an image on each
15 length of media.

111. An illumination device for an optical printer, the illumination device comprising respective arrays of red, green and blue illumination elements that are each arranged along respective notional parallel lines on a substrate so as to be linearly offset from one
20 another along their respective notional lines, the arrangement being such that in the event of a swathe overlap when the device is operated to expose adjacent swathes of a photographic medium, the respective regions of the photographic medium that are overexposed by each of the arrays as a result of said overlap do not coincide with another.

25

112. An illumination device for an optical printer, the illumination device comprising respective arrays of red, green and blue illumination elements that are each arranged along respective notional parallel lines on a substrate so as to be linearly offset from one
30 another along their respective notional lines, the arrangement being such that in the event of a gap between swathes when the device is operated to expose adjacent swathes of a photographic medium, a first region of the photographic medium where a gap exists between regions of the photographic medium that have been exposed by any one of the arrays does not coincide with second and third regions of the photographic medium where a gap exists between respective regions of the photographic medium
35 that have been exposed by the other arrays.

113. A method of calibrating an optical printer from an image printed by the printer, the method comprising: (i) assessing the contribution made to the image by each optical element of a printing head of the printer; (ii) adjusting the contributions for each element for a next print to be printed with the printer so that the contributions from each element are closer to being equal to one another; (iii) printing the next image; (iv) determining whether the image is acceptable, and (v) if the image is not acceptable, repeating steps (i) to (iv) until the printed image is determined to be acceptable.

Fig. 1

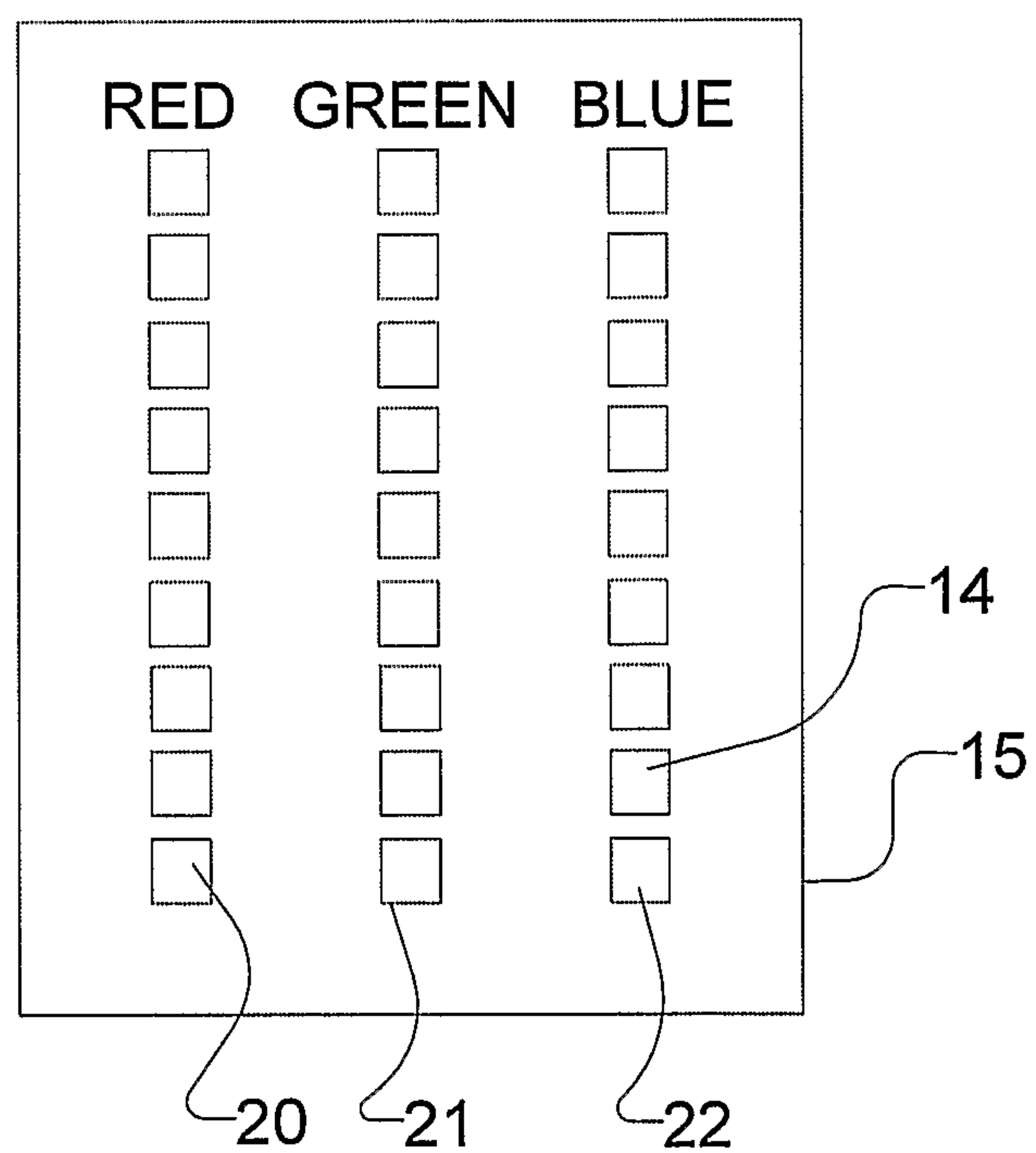
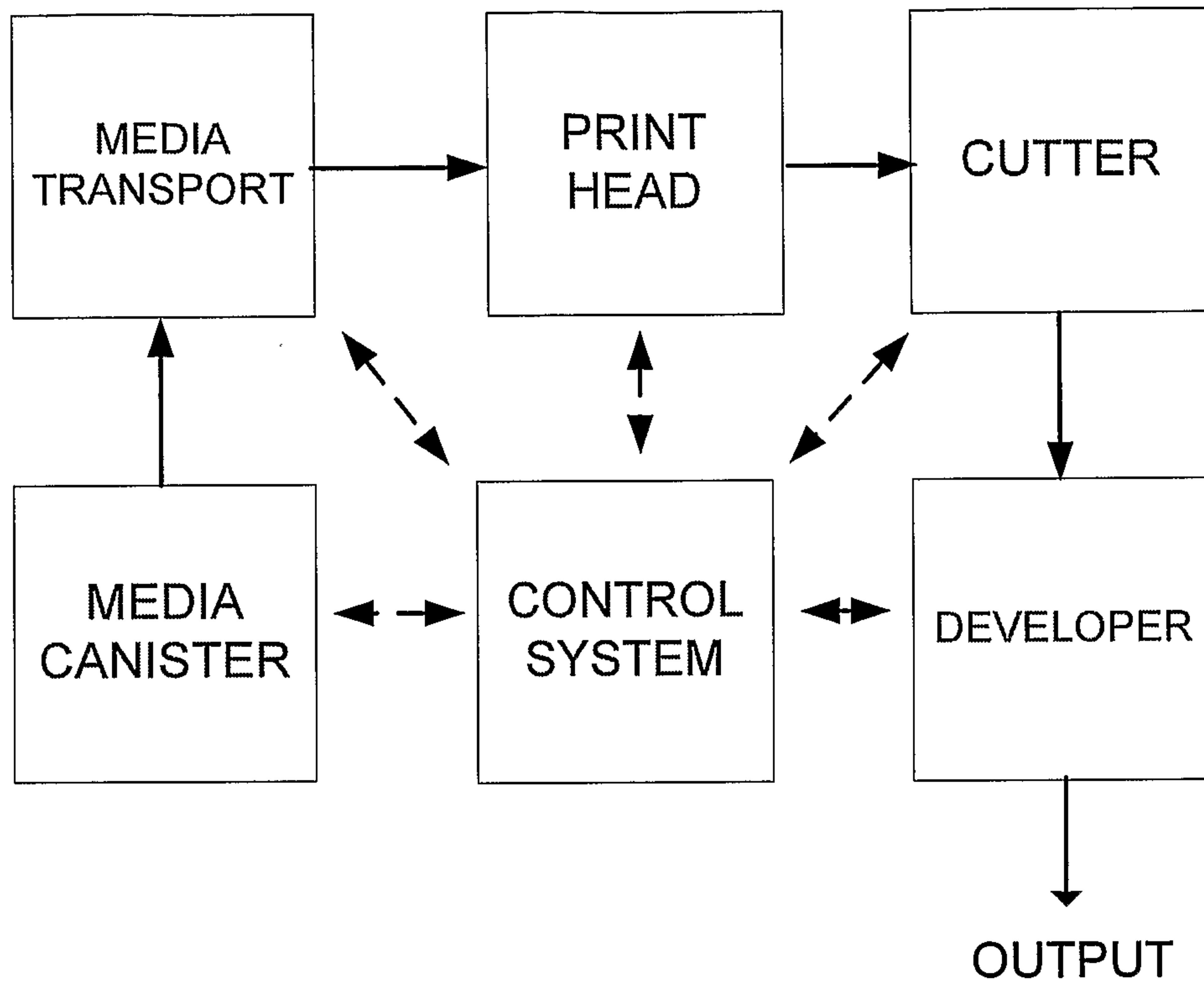


Fig. 2(a)

Fig. 2(b)

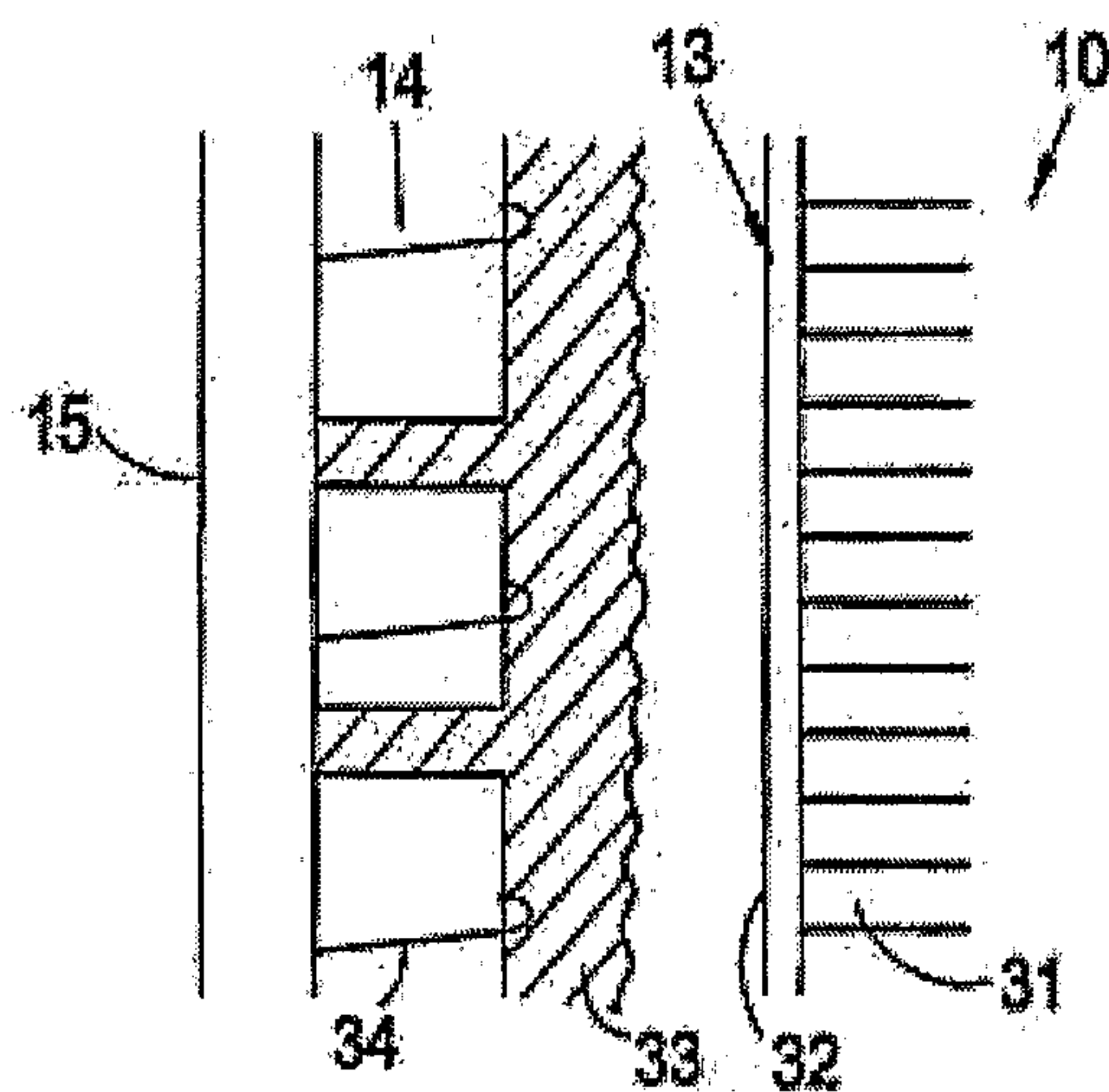
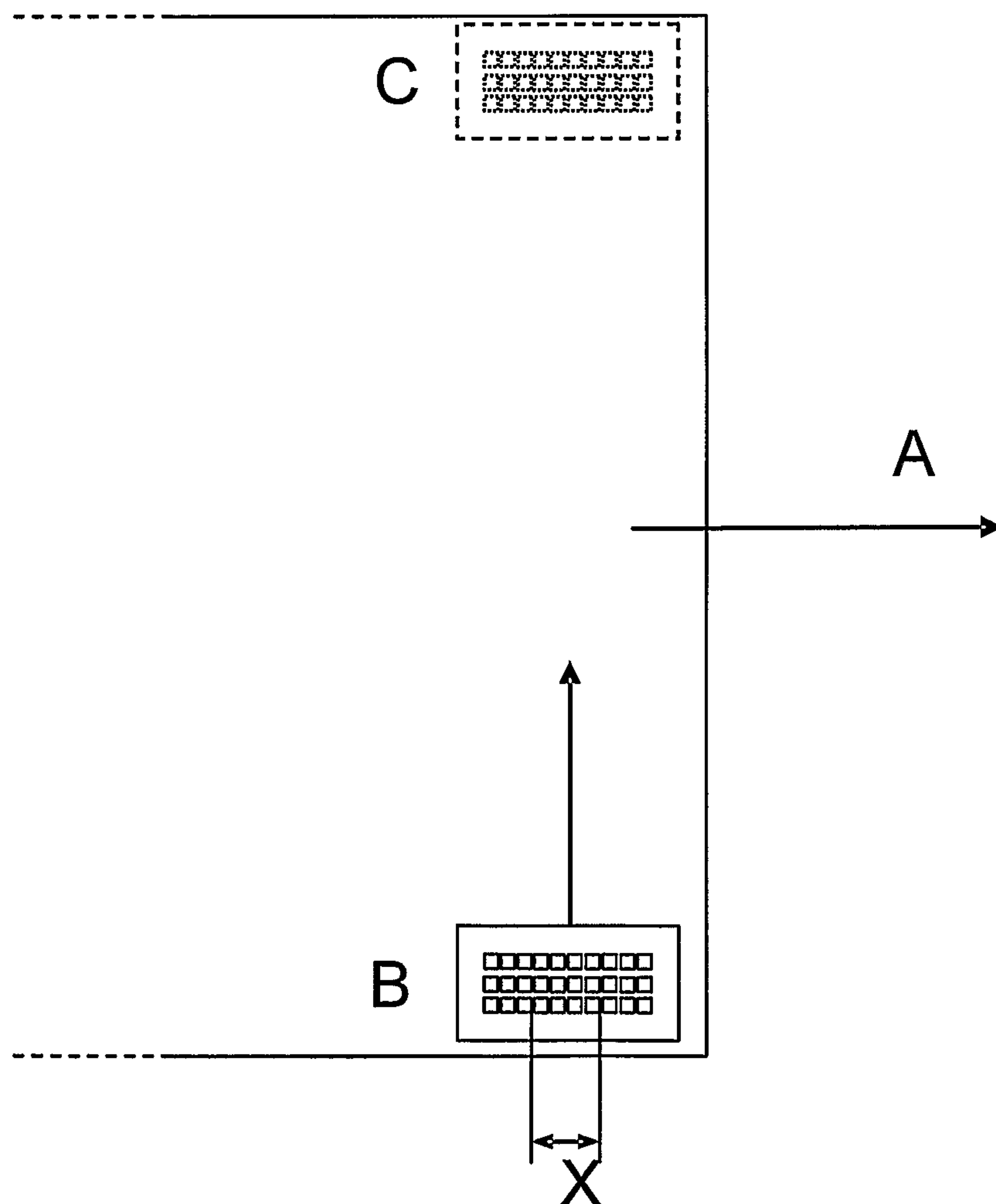


Fig. 2(c)



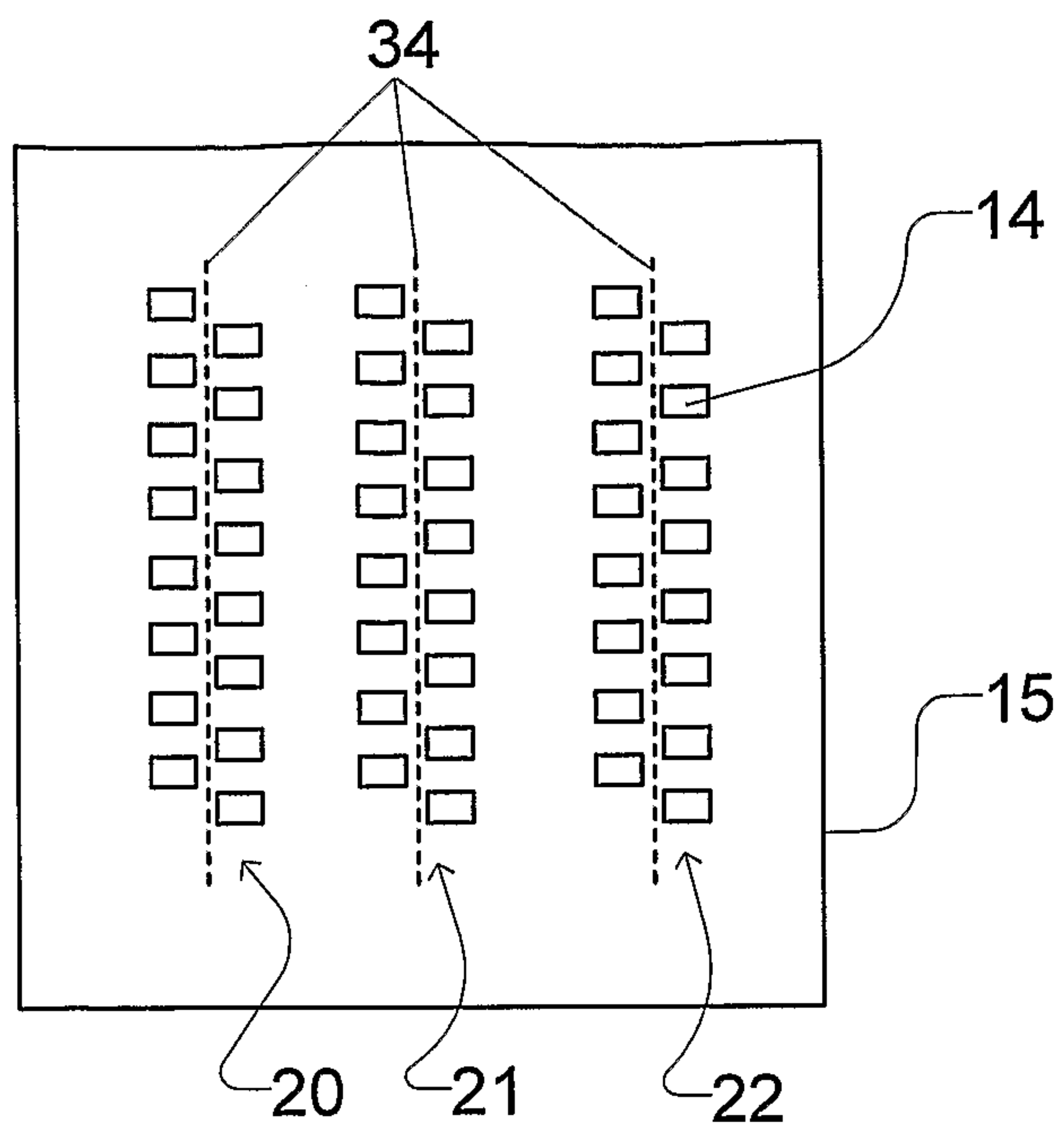


Fig. 3

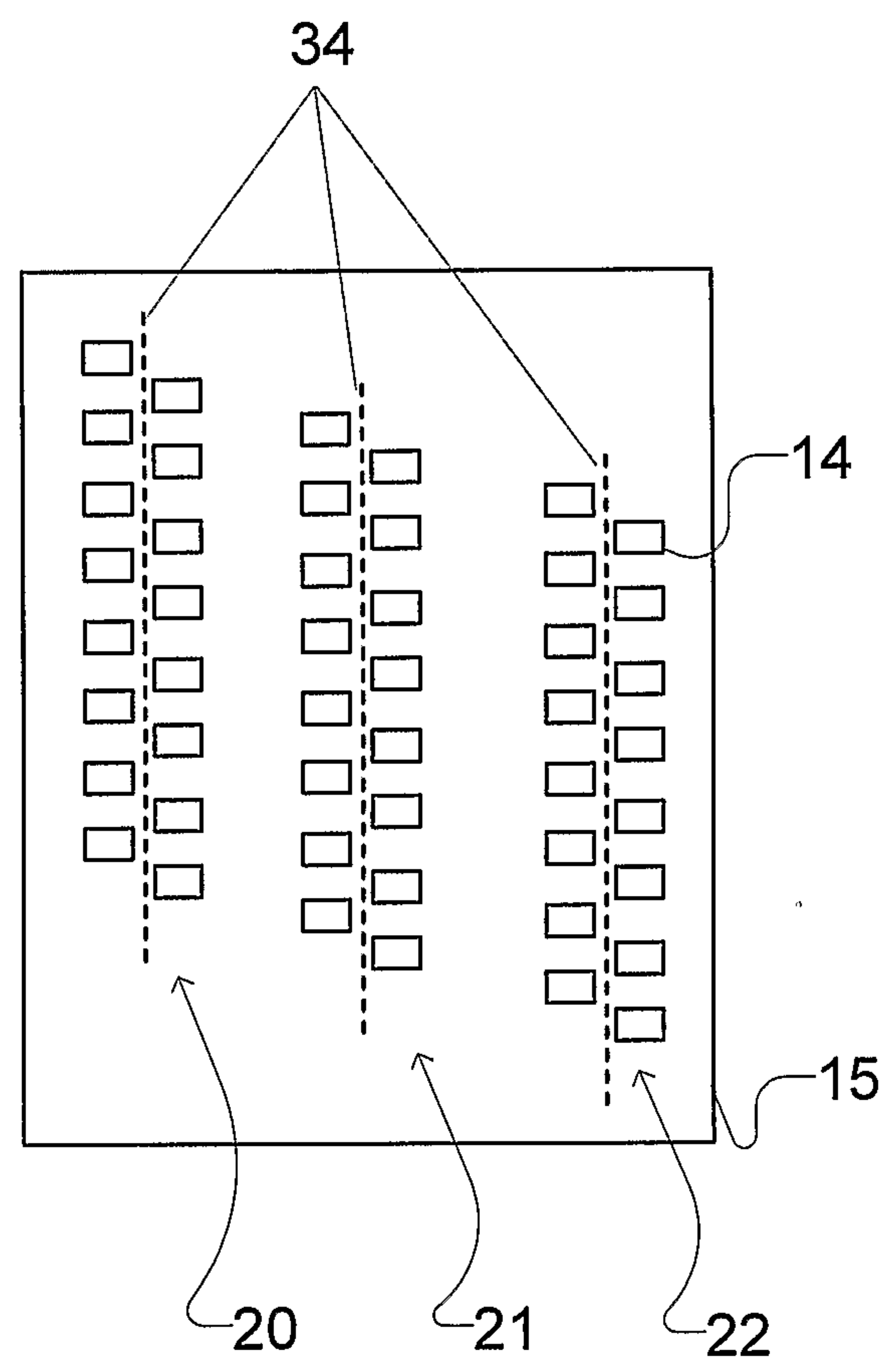


Fig. 4

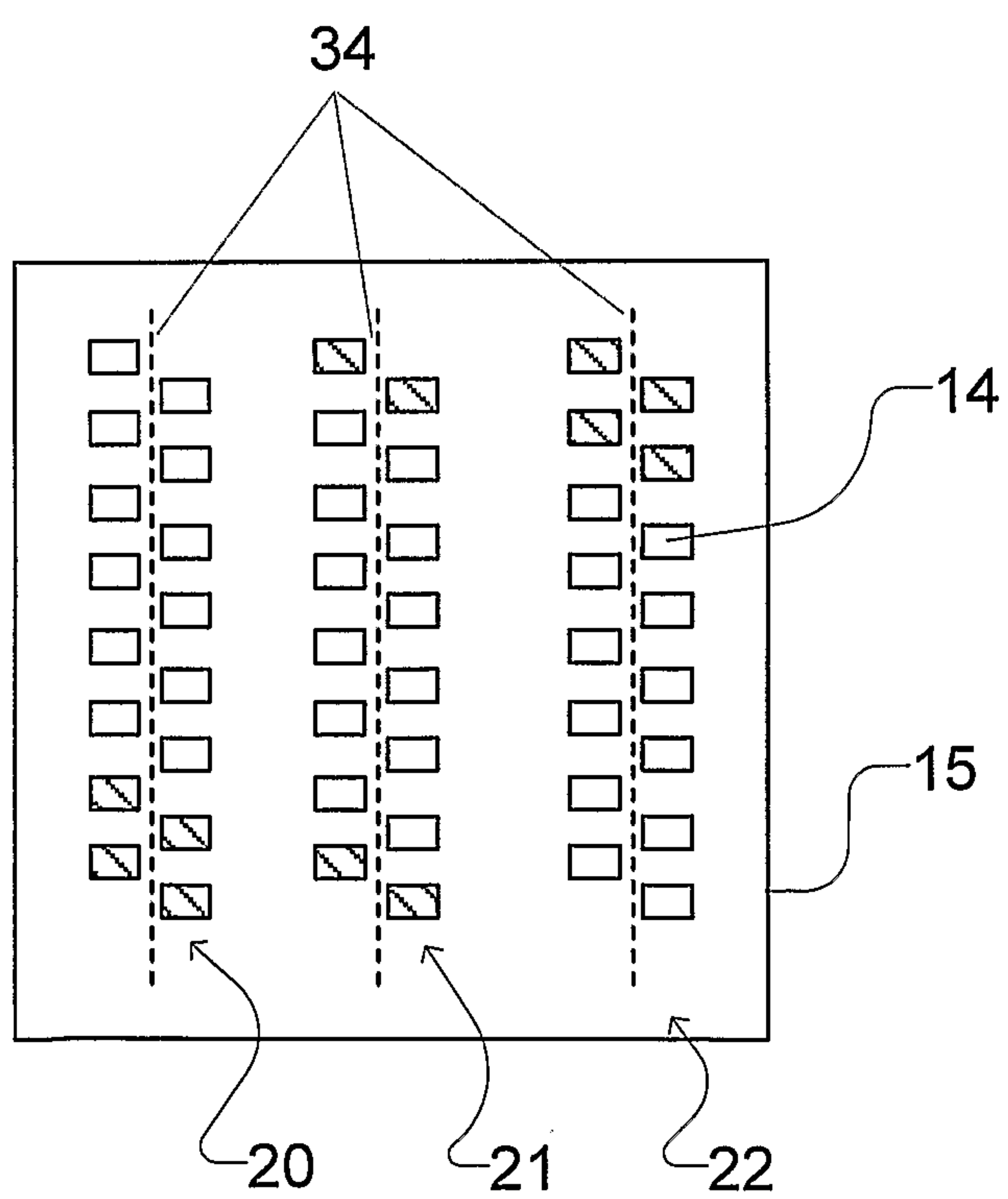
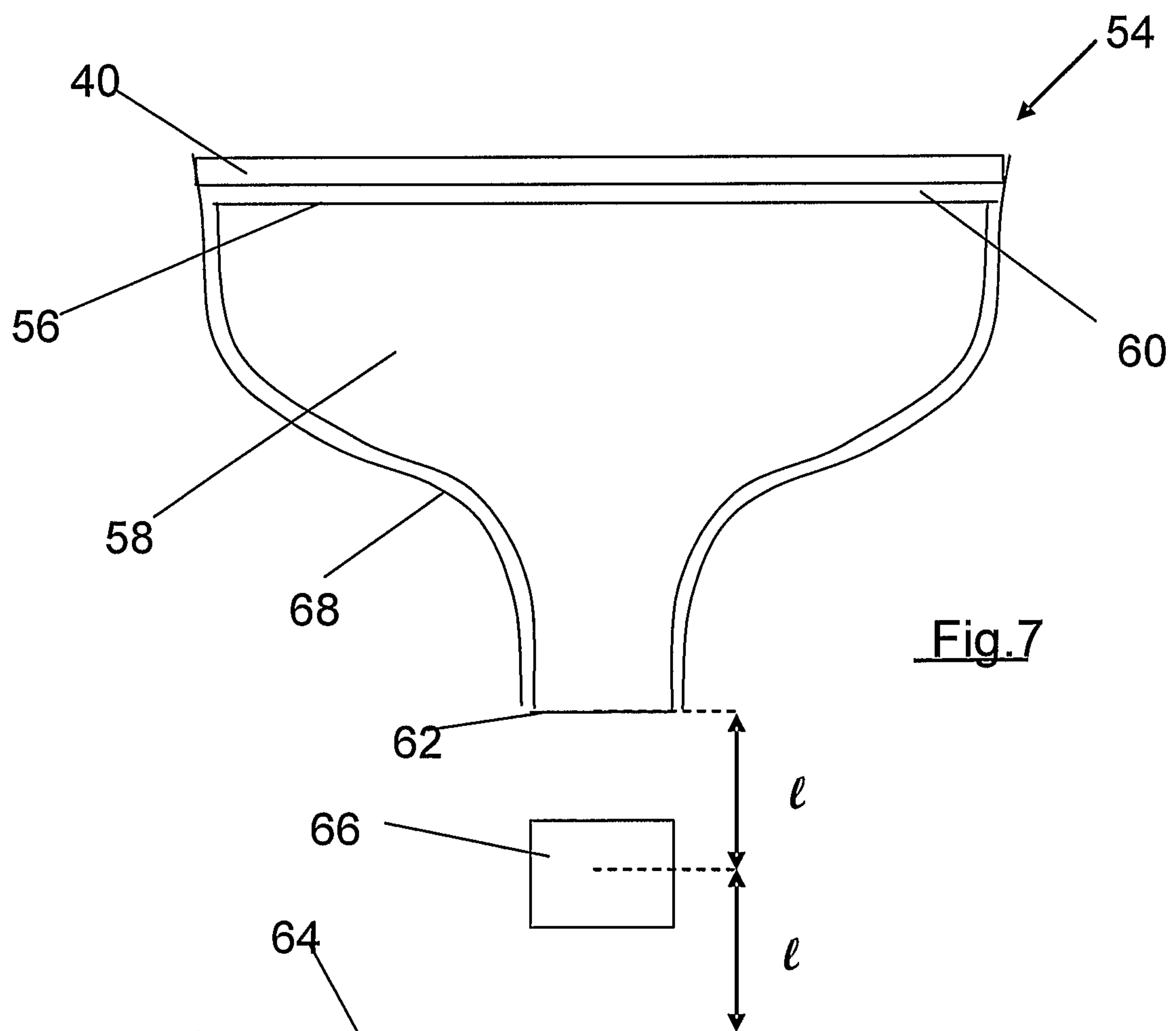
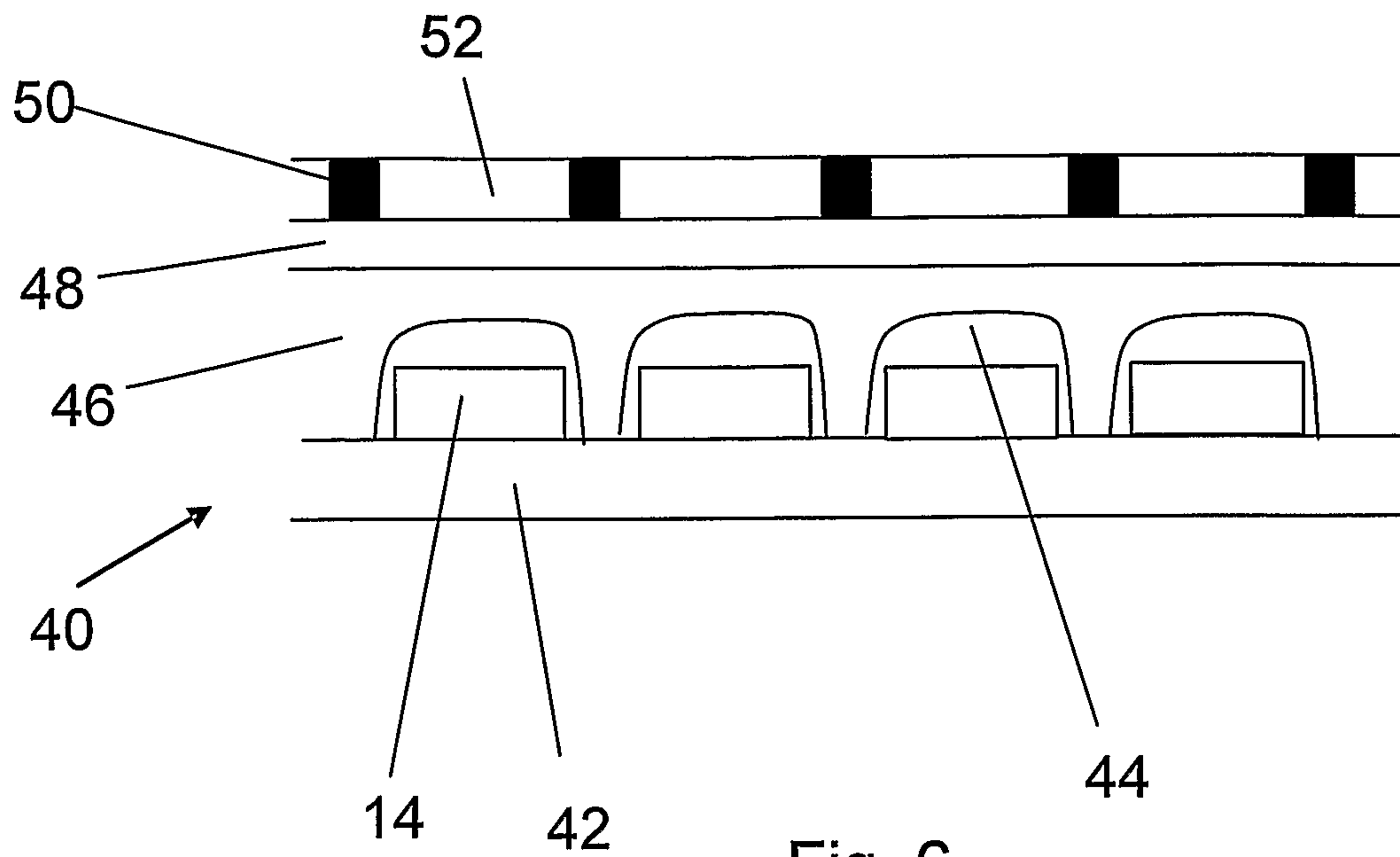
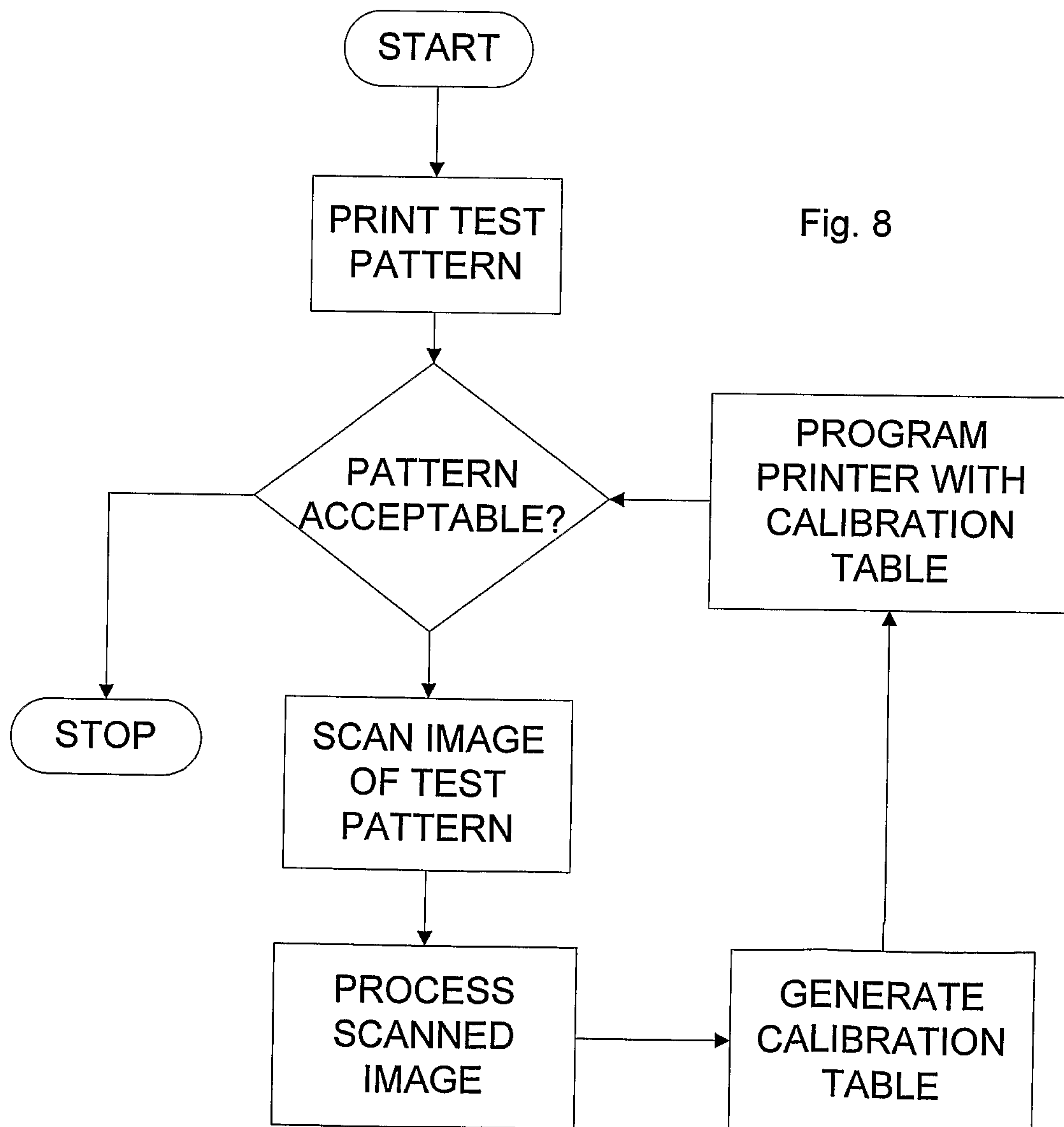
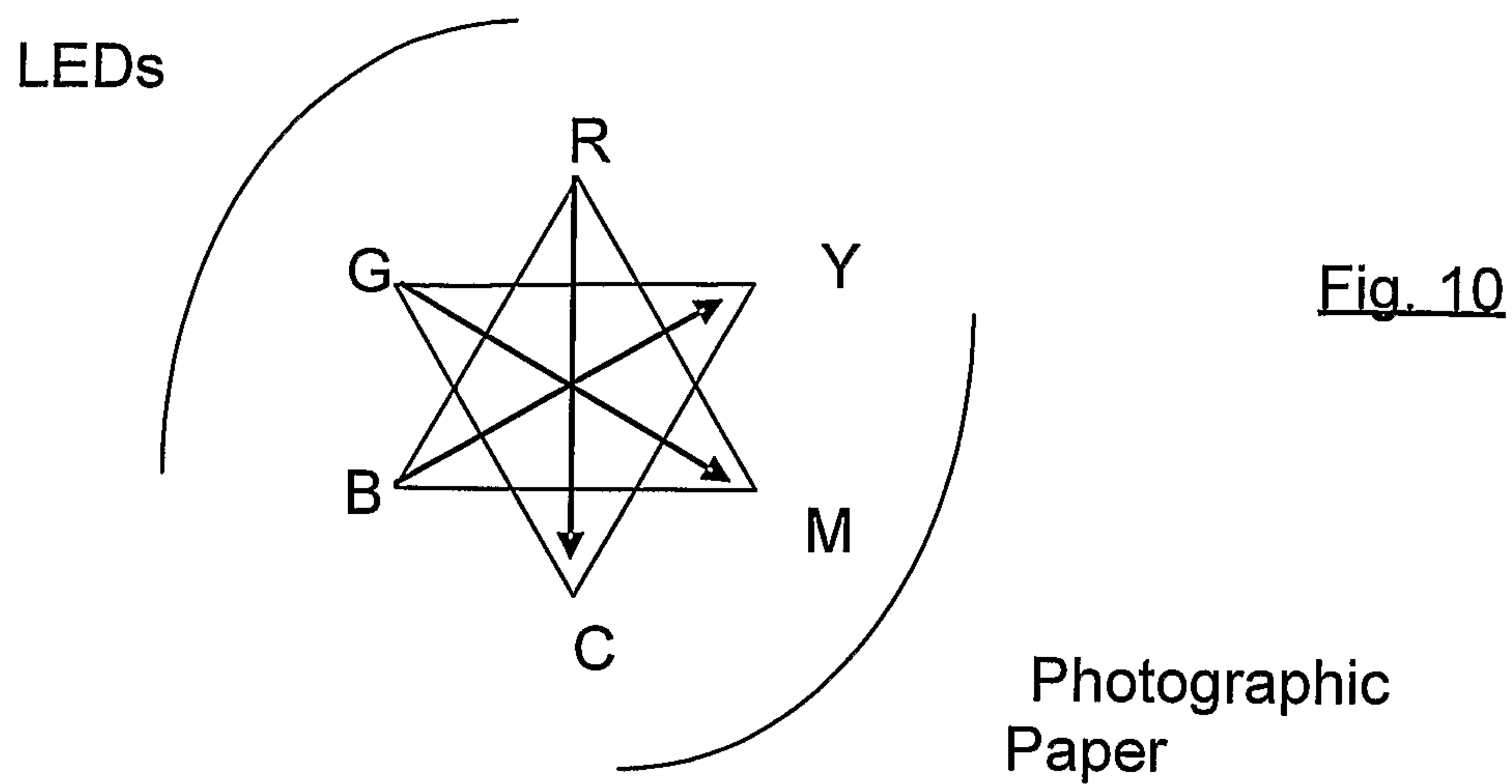


Fig. 5





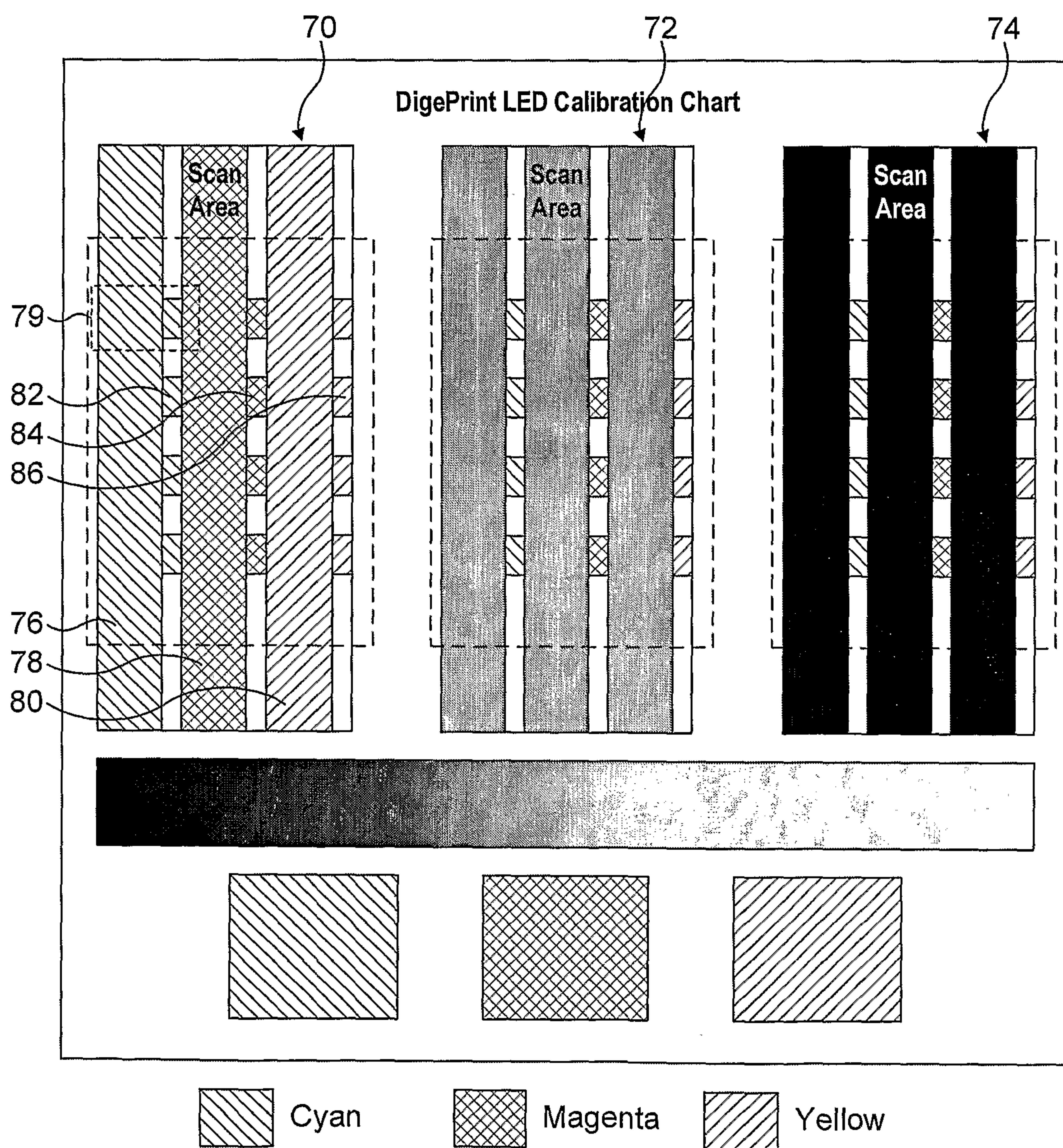


FIG. 9a

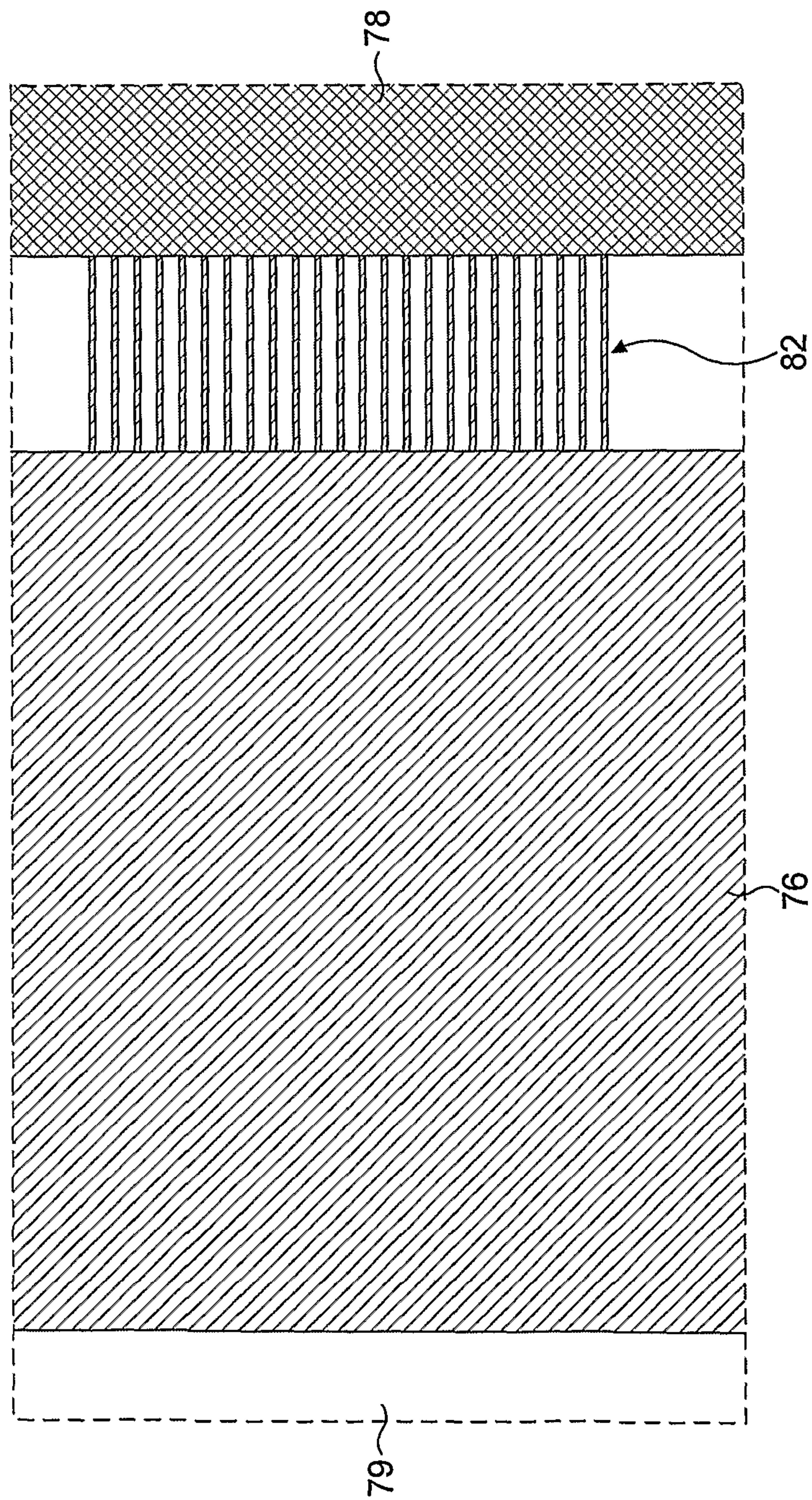
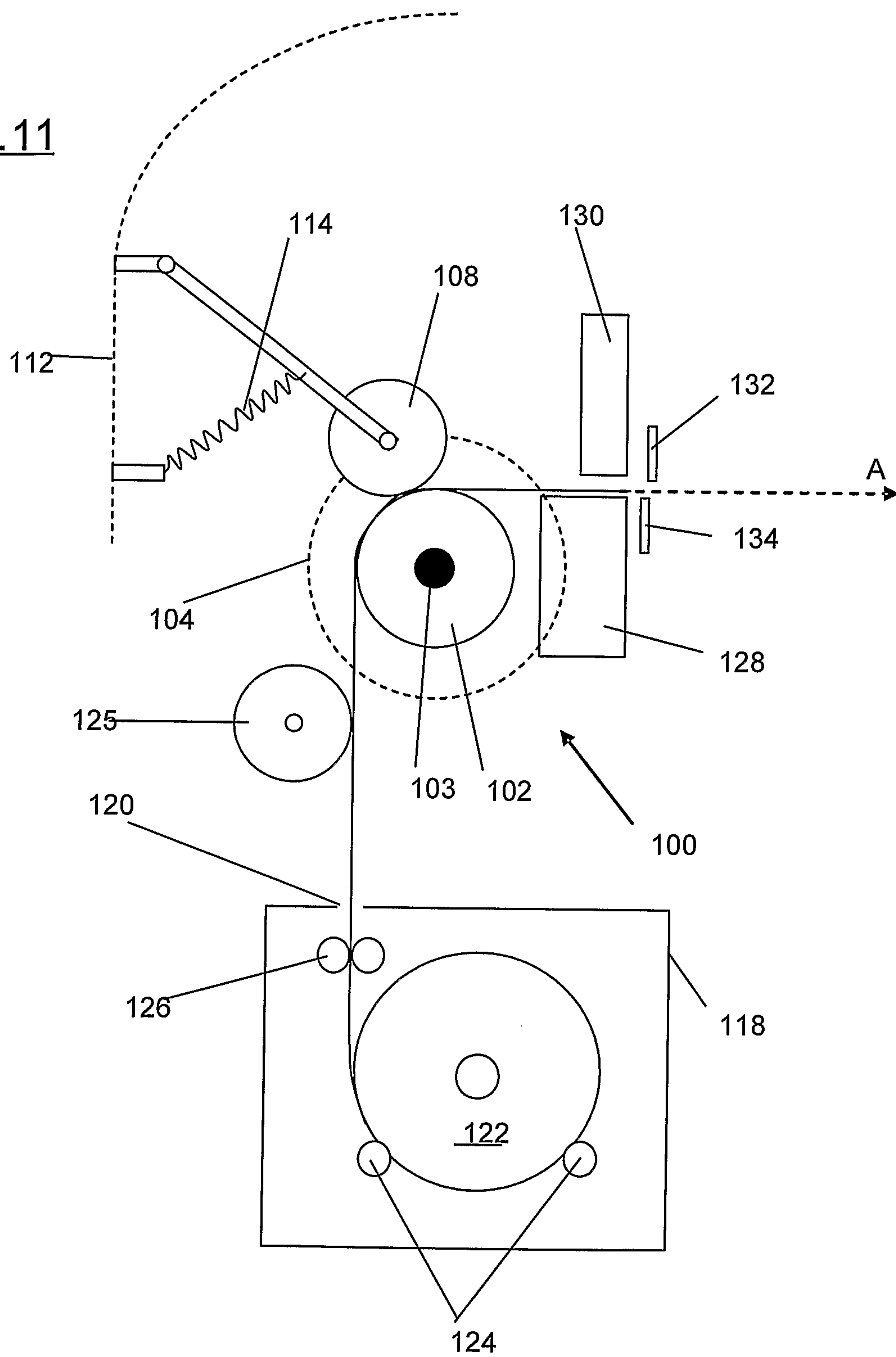
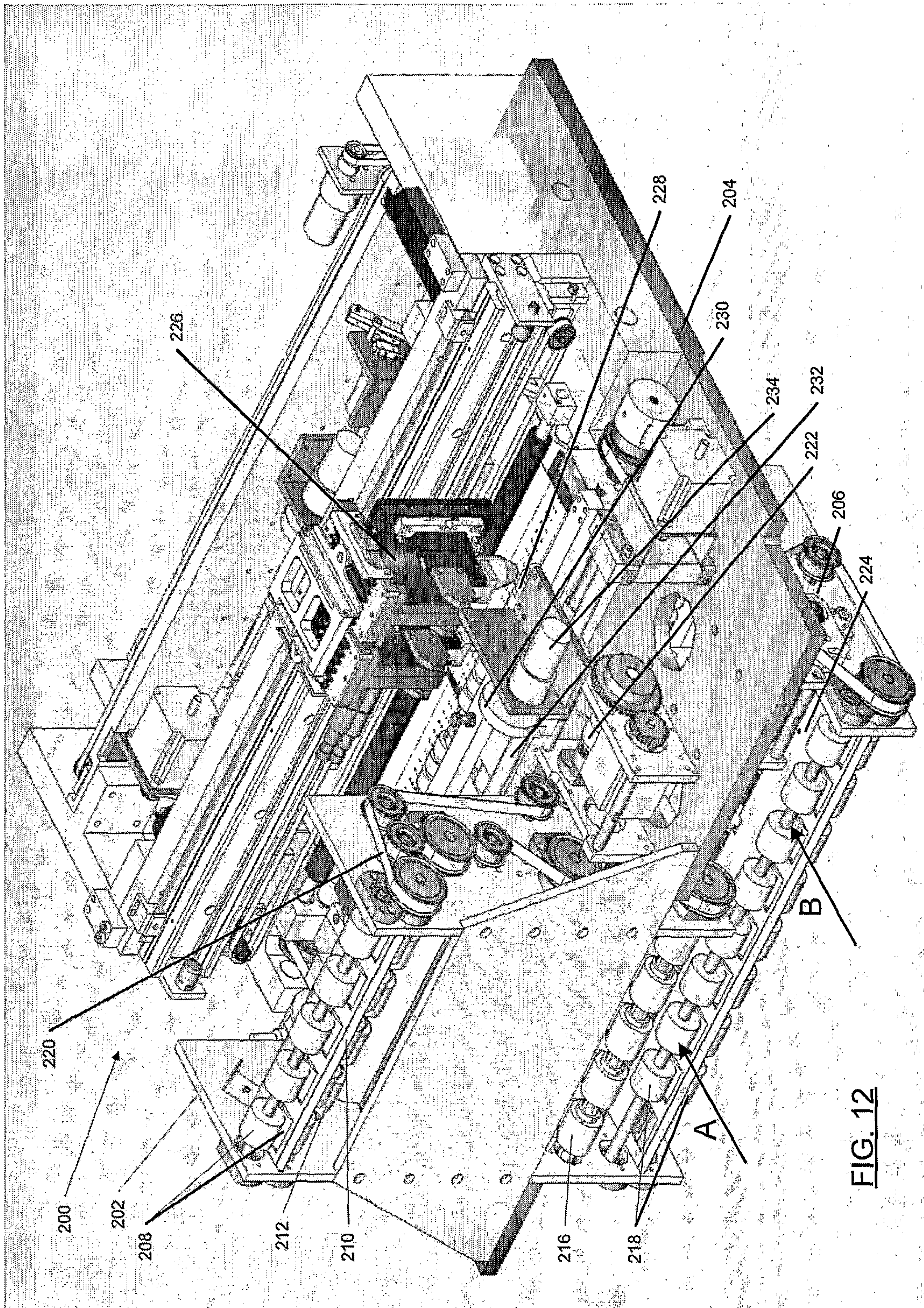
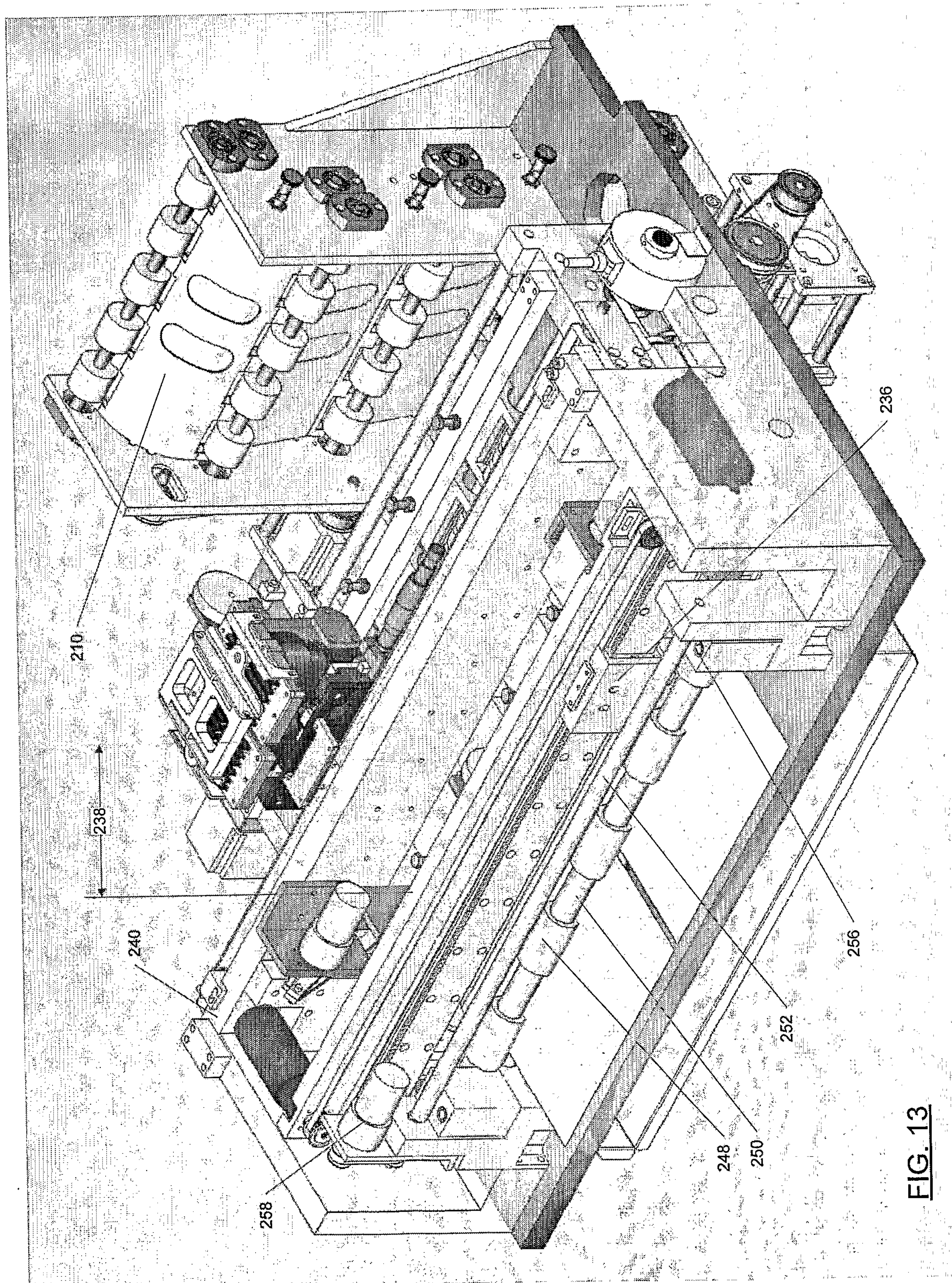
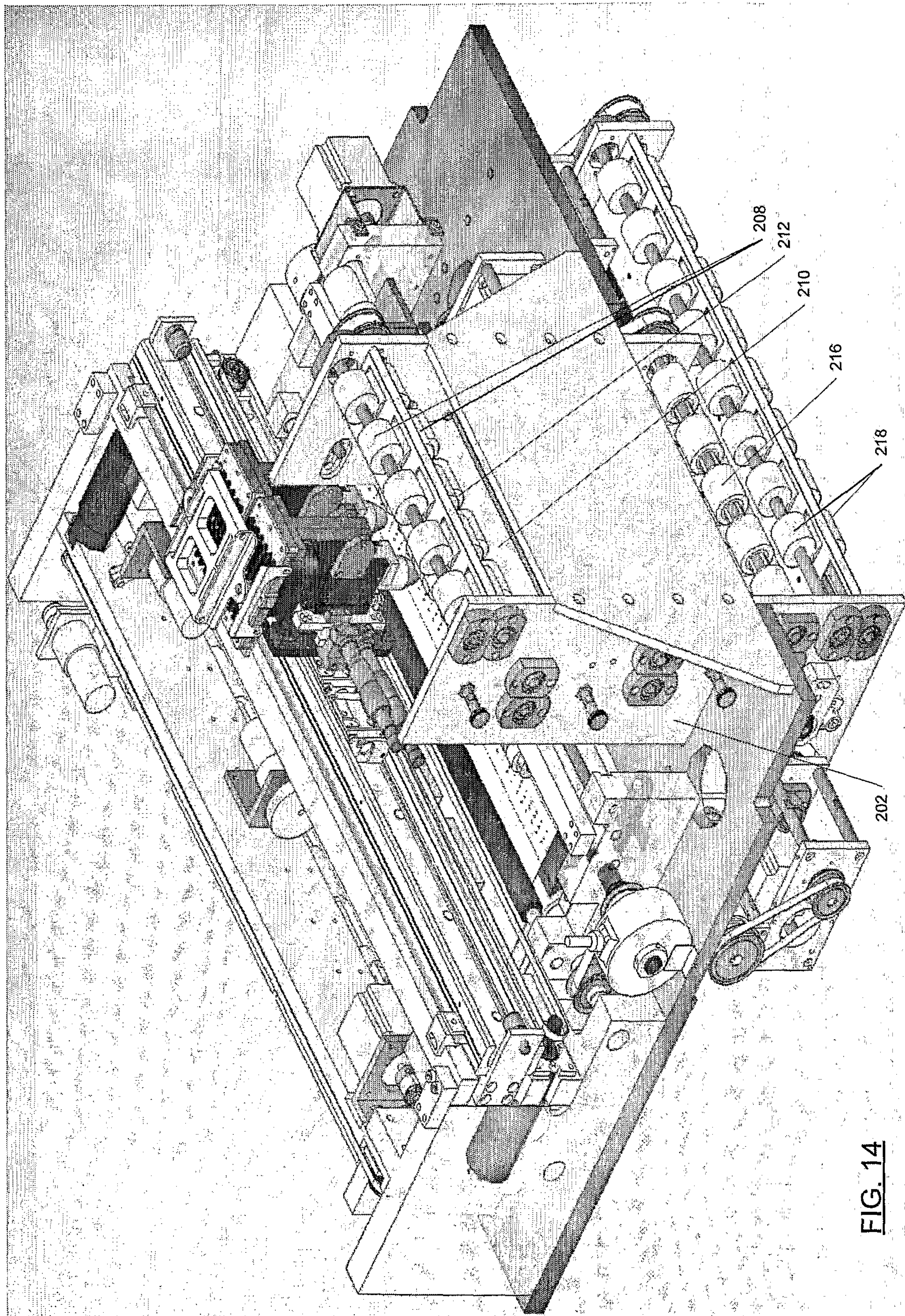


FIG. 9b

Fig. 11



**FIG. 13**

**FIG. 14**

