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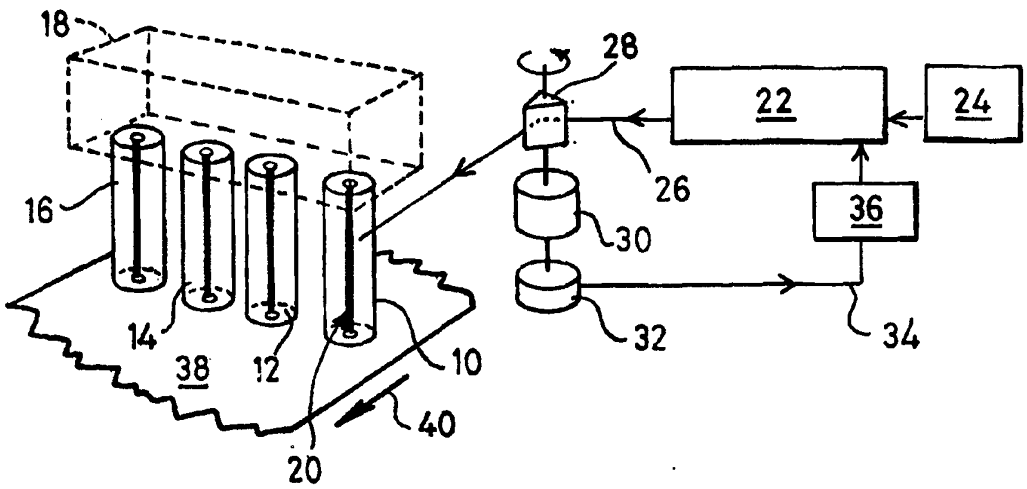

(57) Abstract

In a method and apparatus for expelling ink from an open ended capillary (20) to produce high resolution printing, a laser beam (26) causes the ink to vapourise, along the length of the capillary at a region spaced from the open end thereof. A small volume of ink is thereby expelled from the open end of the capillary tube onto the paper (38). The beam (26) is adjusted so as to increase or decrease the volume of ink expelled. A plurality of such capillaries can be used in a printing head, laser modulation being employed for scanning these arrays. Scanning is achieved by means of a moveable reflecting or refracting facet (28).

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METHOD AND APPARATUS FOR INK JET PRINTING

Field of invention

This invention concerns printing apparatus, particularly ink jet printers.

Background to the invention

It is known from US Patent 5,821,808 to vaporise ink from channels for deposition on paper or like surfaces. Such apparatus is not suited to high resolution printing nor is the apparatus as described suited to applications involving good registration from one image to the next.

It is an object of the present invention to provide an improved printing method and apparatus which does not suffer from the aforementioned disadvantages.

Summary of the invention

According to one aspect of the present invention, a method of expelling ink from an open ended capillary thereof, so as to deposit ink therefrom onto a selected region of a surface, comprises the step of positioning the open end of the capillary in registry with the selected region of the surface and projecting energy from a laser source onto a region of the capillary spaced from the open end thereof, the duration and intensity of the energy being such as to cause ink in the said region of the capillary to expand sufficiently to expel ink from the open end of the capillary towards the selected region of the said surface.

The intensity and/or duration of the pulse may be adjustable so as to increase or decrease the volume of ink expelled, thereby to create a larger or smaller spot on the said surface.

Since the distance over which the ink has to travel may determine the extent to which the ink spreads out before it intercepts the said surface, the distance between the open end of the capillary and the said surface may be made adjustable but will normally be maintained constant for any given printing operation.

In a preferred method where a plurality of equally spaced parallel capillaries of ink are arranged in array, a beam of energy from the laser may be scanned across the array so as to cause ink in some or all of the capillaries to be expanded and expelled as aforesaid during the scanning, so that one or more dots of ink will be deposited on the surface.

In a preferred method the laser may be modulated in synchronism with the scanning so as to be ON when the scanning registers with a capillary which is to print and be OFF when the scanning registers with a capillary which is not required to print. In this way a series of dots of ink at selected positions along a line can be deposited from the line of capillaries during a single pass of the laser beam.

In a method of printing in which a surface to be printed is moved relative to a line of capillaries containing ink, and a laser beam is caused to scan the array of capillaries and is modulated ON and OFF as required so as to cause dots of ink to be expelled from selected capillaries in the array onto the said surface as it moves relative to the array, the direction of movement is selected so as to subtend an angle relative to the capillary array which is greater than zero.

If the angle is maintained constant and the same one of the array of capillaries is fired during each scan thereof, then due to the movement of the surface relative to the array, a series of dots will be deposited thereon which define a straight line parallel to the direction of movement, each spaced from the last by a distance which is proportional to the rate at which the surface is moving relative to the array and the frequency of the scanning of the array.

If two capillaries in the array are fired during each scan, two lines of dots will be deposited on the surface, and if the same two capillaries are fired each time, then the two lines will be parallel and spaced by a distance related to the spacing in the array and the angle between the array and the direction of movement.

Since the dot size will be dependent on (a) the cross-section of the open end of the capillary and (b) the volume of ink expelled, by making both very small, the size of the dot can also be made very small. By moving the surface slowly for a given scan repetition rate (or employing a high scan repetition rate for any given speed of movement of the surface relative to the line of capillaries), so the dot spacing parallel to the direction of movement (ie along the line) can be controlled to any number of dots per unit length as is desired.

Since the angle between the array of capillaries and the direction of movement need not be 90° but can be much less if desired, so the spacing between two lines of dots deposited from adjacent capillaries can be made as small as required.

Thus by controlling the dot spacing parallel and perpendicular to the direction of movement so the dots per unit length parallel and perpendicular to the direction of movement can be controlled to any desired number limited only by the minimum dot size.

It is to be understood that whereas movement of the surface relative to the capillaries has been described, the important feature of the movement is that there is relative movement between the capillaries and the surface, and depending on the application so the surface may be stationary and the movement may be obtained by movement of the capillary or capillary assembly relative to the surface, or both may be moved so as to enable compound relative movement to be obtained. Thus for example the array of capillaries may be rotated and the surface moved linearly relative to either the centre of rotation of the array or some other point which may itself move relative to the surface so that the array either rotates about a point along a line parallel or inclined to the direction of movement or about points along a curve such as a sinusoid or more complex curve.

The dot spacing and size may be such that ink from adjacent capillaries forms dots which at least touch or partially overlap so as to produce a continuous line of ink on the surface (either parallel or inclined to the direction of movement).

Apparatus for performing the methods as aforesaid comprises:

means defining a capillary of ink having an open end,

means for effecting relative movement between the surface and the capillary defining means, and

laser source means adapted to project a beam of energy to intercept a region of the capillary spaced from the open end thereof so as to cause local expansion of the ink therein and expulsion of a droplet of ink from the open end thereof towards the said surface, to form a dot thereon.

Means may be provided for synchronously operating the laser in relation to relative movement of the surface and the capillary, so that droplets of ink are deposited at a constant spacing on the surface.

In a preferred embodiment a plurality of capillaries may be arranged in a side by side array, with constant spacing between the open ends thereof, the latter all lying in a plane which is parallel to the path of movement of the surface to be printed, and the laser source is adapted selectively to activate the capillaries so as to cause ink droplets to be expelled from selected ones thereof onto the said surface.

Typically means is provided to cause the laser energy to be scanned across the array of capillaries at a known rate so that by switching (modulating) the laser synchronously in relation to the said scanning so different ones of the capillaries can be fired or not, as desired.

The scanning may be achieved by means of a moving mirror or prism or other reflecting or refracting device. Typically the device rotates so as to effect the scanning.

Modulation may be effected by means of a shutter mechanically or electromechanically or by pulsing the laser so as to produce pulses of energy at desired points in time synchronised with the movement of the scanning device and relative movement of array and surface.

A multiple faceted device may be employed so that as one reflecting or refracting facet is moved out of registry with the laser beam, so the latter impinges on the next facet around the device, and by arranging that the path of each facet across the beam is similar to the preceding and following facet movements, so the beam can be made to describe a sweeping movement across the array of capillaries and then return quickly to the beginning of the sweep as one facet is replaced by the next.

If the capillary defining walls transmit laser energy, significantly move readily than the ink, then such an arrangement in combination with laser energy sensing means to the rear of the array may be used to generate a gating signal for controlling the pulsing of the laser source. Thus by scanning the array of capillaries using a first beam energy which is insufficient to heat up the ink by any significant amount, and locating an energy detector (eg an opto electrical detector) behind the array, so a first electrical signal will be generated by the detector when the beam registers with the capillary defining wall material (eg glass) and a second electrical signal will be generated by the detector when the beam registers with the more opaque ink.

By providing circuit means responsive to the first and second signals to generate a laser pulsing signal in response to a transition from a first to a second electrical signal, so the laser can be caused to change from a quiescent lower level mode to a high level mode whenever the beam intercepts an ink capillary.

In such an arrangement, each capillary will be fired during each scan, and the printing of selected dots can be achieved by synchronously generating a gating signal which either permits or inhibits the passage of the laser pulsing signals so that different ones of the array of capillaries will be fired as required.

Alternatively if the laser is set to operate at low power all the time, printing may be achieved by modulating the laser to operate at a higher power whenever a dot of ink is required on the surface.

The low power scan may be used to determine the timing-spacing if it is performed once (or infrequently on a regular basis) and the pattern of signals generated by the detector is stored in a suitable memory which is then addressed in synchronism with subsequent scanning of the array by the laser to provide synchronous signals for controlling when the laser beam register with a capillary, so that if a print controlling signal coincides with the scanning of that capillary so full power is momentarily applied to fire that capillary.

Since the volume of ink projected from a capillary and therefore the size of the dot of ink can be related to the energy in the laser beam and/or the energy pulse duration, so larger or smaller dots may be printed onto the surface by appropriately modulating the power and/or duration of the laser energy pulse.

If the array includes differently coloured inks. eg alternately triads of additive colours, such that equal depositions of each triad produces black and different proportions of each of the three additive colours produces a different overall colour effect, so colour printing can be achieved by simply controlling the energy and/or duration of each pulse of laser energy to each of the three capillaries of each triad, so as to deposit the required quantity of each different colour ink to obtain the desired overall effect.

The invention is of particular application in the field of so called ink jet printers in which no actual contact is made between the printing head and the surface to be printed. Very high speeds and very high resolutions are possible using the techniques described above.

Each capillary may be fed with ink from a reservoir of ink and projection of the ink from the open end of the capillary due to local heating and expansion of ink along the length of the capillary may be ensured by arranging for significantly greater resistance to ink flow towards the reservoir as opposed to through the open end of the capillary from the position at which the ink is heated. This may be achieved using valves, capillary design (cross section or relative lengths of capillary), or a combination of both, or a pressure head or local restriction in the capillary on the reservoir side.

Preferably the capillary size is chosen so as to prevent the flow of ink therefrom due to surface tension even when the capillary is mounted so that the open end is at the bottom of a column of ink.

The laser source may operate at any convenient wavelength, the latter being selected so as to produce heating of the ink in question, thus visible spectrum light lasers or infra red lasers may be employed for example.

Brief description of the drawings

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a single laser controlled ink jet printer embodying the invention;

Figure 2 shows in side elevation how a laser beam can be more conveniently conveyed to the capillaries of ink in a printing head such as shown in Figure 1;

Figure 3 shows diagramatically how a signal can be obtained during scanning of the capillaries for controlling the operation of the laser and/or for storage for subsequent use therefor;

Figure 4 shows the positioning of the reflecting surface behind the array of capillaries of Figure 3, and

Figures 5A and 5B show how three capillaries arranged in line can be wrapped around one another to define a triad of printing points at the open ends thereof, for colour printing.

Figure 6 is an end view of a linear array of capillaries for a printing head such as is shown in Figure 1;

Figure 7 is a corresponding view to Figure 6, and shows an array of capillaries for a colour printing head; and

Figure 8 is a diagrammatic cut away side view of a printer which incorporates a printing head embodying the present invention.

Detailed description of the drawings

In Figure 1 four glass tubes 10, 12, 14, 16 are arranged side by side in line below a reservoir 18 which keeps a capillary in each tube filled with ink. The capillary of tube 10 is denoted by reference numeral 20. The lower ends of the tubes 10-18 are open but surface tension prevents the ink from escaping.

A laser 22 is powered from a suitable supply 24 to produce a beam of light 26 (although IR or UV may be employed if preferred) which is deflected by a prism 28 rotated by motor 30 so as to cause the beam 26 to repetitively scan across the line of capillaries in the tubes 10, 12 etc. A transducer 32 produces a feedback signal along line 34 to indicate to a control centre 36 (preferably microprocessor controlled) the precise position of the beam at any instant, and therefore which of the capillaries in the tubes 10, 12 etc is being intercepted by the beam.

Below the open ends of the tubes 10, 12 etc is stretched a sheet of paper 38 (although any other material may be employed suitable for receiving ink) and although not shown means such as a platen is provided to move the sheet of paper 38 in the direction of the arrow 40.

As shown the arrow 40 extends substantially perpendicularly to the line of the capillaries.

The control centre 36 may generate control signals for causing the laser output to vary (typically to be pulsed) so that the beam energy when intercepting selected ones of the capillaries is sufficient to cause the ink therein in the path of the beam to vapourise and thereby expel a small volume of ink from the open end of the tube in question onto the paper, due to the rise in pressure in the capillary.

Figure 2 shows how a practical printing head may be constructed, contained within the dotted line 42. Here the laser 22 is mounted above the line of tubes, the end one 10 of which can be seen. Light from the laser is deflected by the rotating prism 44, and is then reflected downwardly by mirror 46 to a mirror 48 located in registry with the tube. By pulsing the laser 24 as previously described, synchronously with the rotation of the prism 44, so different ones of the capillaries can be fired during each scan as required. A substrate 50 such as a sheet of paper or card is moved below the head 42 in the direction of the arrow 52 so as to present successive regions of its surface to the head, for printing thereon.

Figure 3 shows a similar arrangement to that of Figure 2 but with the addition of a reflecting surface such as a plane mirror 54 located beyond the tubes such as 10 and angled so as to reflect light impinging thereon back towards the mirror 48 but at a slightly different angle to that of the light reflected from the mirror. By positioning a detector 56 so as to intercept the returning beam 58 and generate electrical signals in response to the intensity of the light received thereby, so an electrical signal can be generated for supply along line 60 to a control centre 62, whose waveform is similar to that shown at 64. Each downward excursion of the waveform such as 66 corresponds to the crossing of a capillary of ink (which is relatively opaque) whilst the remainder of the signal corresponds to the light transmitted by the transparent walls of the tubes and reflected by the mirror 54.

The positions of the excursions 66 relative to the beginning and ending of each scan of the beam due to a rotation of the prism 44 is stored in a memory 68 for synchronous readout during subsequent scans so as to enable the positions of the capillaries to be tracked during subsequent scans.

The signals such as 66 may be stored during each scan so that the memory 68 is continuously updated. However since in general the positions of the tubes and capillaries relative to the scanning devices and laser will not alter, the scanning to achieve registration signals for storing in the memory 68 may be performed only occasionally so as to monitor for example any change due for example to heating up of the tubes due to the laser beam interception or due to changes in ambient temperature.

Figure 4 shows how the mirror 54 can be mounted to the rear of an array of tubes such as 10, 12 14.

Figures 5A and 5B show how three tubes 70, 72, 74 may be twisted around one another so that at one end they are in line (as in Figure 4) and at the other end (their open ends as far as the capillaries are concerned) they occupy three parts of an equal sided triangle (Figure 5B). The tubes and capillaries can thus be addressed by a scanning beam as shown in Figures 1-3 at their upper end (as shown in Figure 5A) but the dots of ink deposited by them are posioned at the three points of a triangle (best seen in Figure 5B). By supplying the three tubes (70, 72, 74) with three differently coloured inks, so colour printing can be performed by appropriately energising each of the three tubes 70, 72, 74 in turn. Different quantities of each ink can be deposited by controlling the energy in the beam as it separately impinges on the three tubes in turn, as by suitable modulation of the laser output.

Figure 6 shows from beneath a linear array of eight capillary tubes 100a-100b for use in a monochrome printing head. As with the capillary tubes shown in Figures 1-4 the lower ends of the tubes 100 are open to allow ink to be expelled therefrom, onto an underlying surface (not shown), in response to being fired by a scanning beam from a laser source controlled in a similar fashion to beam from the laser source 22. The tubes 100 can be used in place of the tubes 10, 12, 14 and 16, so as to give greater printing resolution than can be achieved with 4 capillaries.

A similar array of capillaries is shown (from beneath) in Figure 7 , but instead of linear array of single capillaries there is provided a linear array of eight triads of tubes 110a-110h, each triad is as shown in Figure 5, and the members of each triad 110 contains differently coloured inks to unable colour printing to be performed.

The apparatuses shown in Figures 1 to 3, with the tubes 10, 12, 14 and 16 or the arrays shown in Figures 6 and 7 can be incorporated into a print head 112 of the printer shown in Figure 8.

The print head 112 is positioned downstream a first pair of pinch rollers 114 and 116, and upstream a second pair of rollers 118 and 120. The rollers 114 and 16 are operable to grip a sheet of paper such as the sheet 122 ffed into an inlet 124 and to draw the sheet into the printer, over a platter 126 positioned beneath the head 112, and to the rollers 118 to 120. The rollers 118 and 120 draw the sheet through the machine in the same direction through the machine as the rollers 114 and 116 and subsequently expell the sheet through an outlet 126, from which the sheet is deposited onto a tray 128.

As the sheet passes beneath the head 112, the latter scans across the sheet by being reciprocally moved in a direction perpendicular to the direction of progress of the sheet to enable ink to be deposited at appropriate places on the sheet.

Claims

1. A method of expelling ink from an open ended capillary so as to deposit ink therefrom onto a selected region of a surface, the method comprising the step of positioning the open end of the capillary in registry with the selected region of a surface and projecting electromagnetic radiation from a laser source onto a region of the capillary spaced from the open end thereof, so as to cause ink in the said region of the capillary to expand sufficiently to expel ink from the open end of the capillary towards the selected region of the said surface.

2. A method according to claim 1 in which the energy received by the ink from the laser source is adjustable so as to increase or decrease the volume of ink expelled, thereby to create a larger or smaller spot on the said surface.

3. A method according to claim 1 in which the capillary is one of an array of such capillaries and a beam of electromagnetic radiation from a laser is scanned across the array so as to cause ink in some or all of the capillaries to be expanded and expelled as aforesaid during the scanning, so that one or more dots of ink will be deposited on the surface.

4. A method in accordance with claim 1, or claim 2 wherein electromagnetic radiation from the laser is modulated in synchronism with the scanning so as to be ON

when the scanning registers with a capillary which is to print and be OFF when the scanning registers with a capillary which is not required to print.

5. A method of printing in which a surface to be printed is moved relative to a line of capillaries containing ink, and a laser beam is caused to scan the line of capillaries and is modulated ON and OFF as required so as to cause dots of ink to be expelled from selected capillaries in the array onto the said surface as it moves relative to the array, the direction of movement being selected so as to subtend an angle relative to the capillary array which is greater than zero.

6. A method of colour printing comprising expelling ink from an array of capillaries by a method according to any of claims 2 to 5, wherein surface to be printed is moved relative to the array of capillaries which are arranged in a plurality of groups, the capillaries in each respective group containing different colours of ink, the colour to be printed being controlled by controlling the amount of energy to be received by each capillary in each respective group relative to the other two capillaries in the group.

7. Apparatus for performing the methods as claimed in claims 1 to 6 comprising: means defining a capillary for containing ink the capillary having an open end, means for effecting relative movement between a surface and the capillary defining means, and laser source means adapted to project a beam of energy to intercept a region of a capillary spaced from the open end thereof so as to cause local expansion of the ink therein and expulsion of a droplet of ink from the open end thereof towards the said surface, to form a dot thereon.

8. Apparatus according to claim 7 in which means are provided for synchronously operating a laser in relation to relative movement of a surface and a capillary.

9. Apparatus according to claim 7 or claim 8, in which the capillary is one of a plurality of such capillaries arranged in a side by side array the and a laser source adapted selectively to activate the capillaries so as to cause ink droplets to be expelled from selected ones thereof onto the said surface.

10. Apparatus as claimed in claim 9 in which means is provided to cause a laser beam to be scanned across the array of capillaries at a known rate so that by modulating the laser source synchronously in relation to the said scanning different ones of the capillaries can be fired or not, as desired.

11. Apparatus as claimed in claim 10 in which the apparatus includes a shutter for modulating the laser source.

12. Apparatus according to any of claims 9 to 11 in which there is provided scanning means comprising moveable multiple faceted device so arranged that in use as one reflecting or refracting facet is moved out of registry with the laser beam, so the latter impinges on the next facet around the device, that the path of each facet across the beam being similar to the preceding and following facet movements, so that the beam is made to describe a sweeping movement across an array of capillaries and then return quickly to the beginning of the sweep as one facet is replaced by the next.

13. Apparatus according to any of claims 9 to 11 in which there is provided laser energy sensing means operable to generate a gating signal during one scan of the laser beam, wherein the gating signal is representative of the positions of the capillaries, and is used in the control of the pulsing of the laser source during subsequent scans.

14. Apparatus according to claim 13 in which circuit means, responsive to the gating signal, generates a laser pulsing signal such that the laser changes from a quiescent lower level mode to a high level mode whenever the beam intercepts an ink capillary, from which ink is to be expelled.

15. Apparatus according to any of claims 9 to 14 in which the array is composed of a plurality of triads of capillaries, the capillaries of each respective triad containing different colour inks the arrangement being such that colour printing is achieved by varying the amount of electromagnetic energy from the laser source that impinges on each of the capillaries in each respective triad relative to the energy received by the other capillaries in the triad.

16. Apparatus according to claims any of 9 to 15 wherein each capillary is fed with ink from a reservoir of ink and projection of the ink from the open end of each capillary is ensured by arranging for significantly greater resistance to ink flow in the capillary towards the reservoir than through an open end of the capillary from the position at which the ink is heated.

17. Apparatus according to any of claims 19-16 where the size of each capillary is such so as to prevent the flow of ink therefrom.

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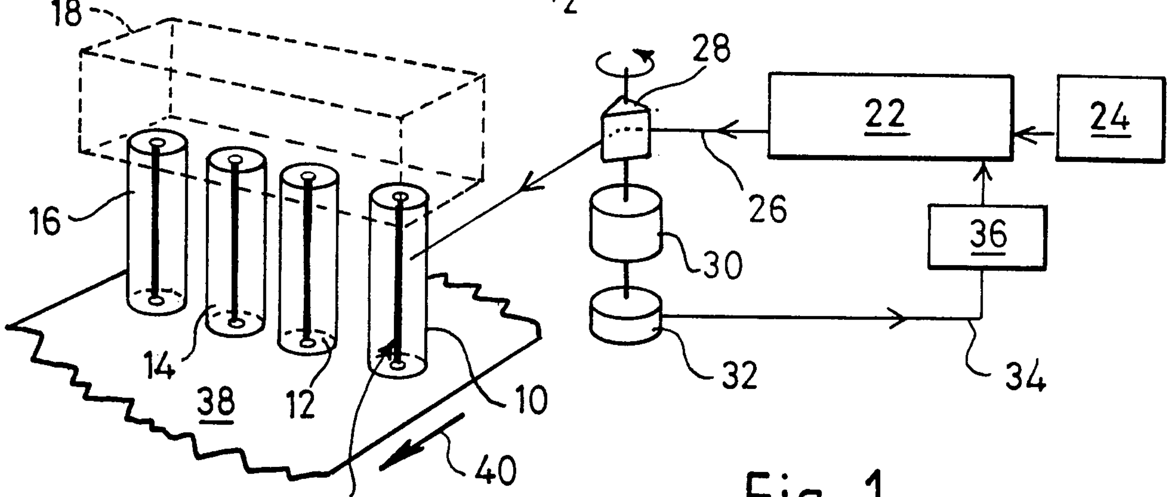

Fig. 1

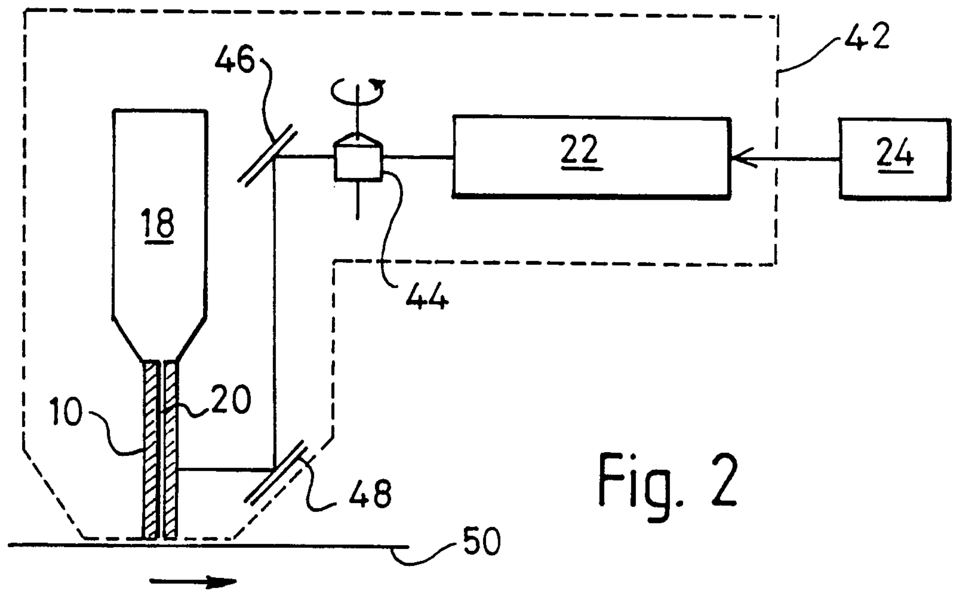

Fig. 2

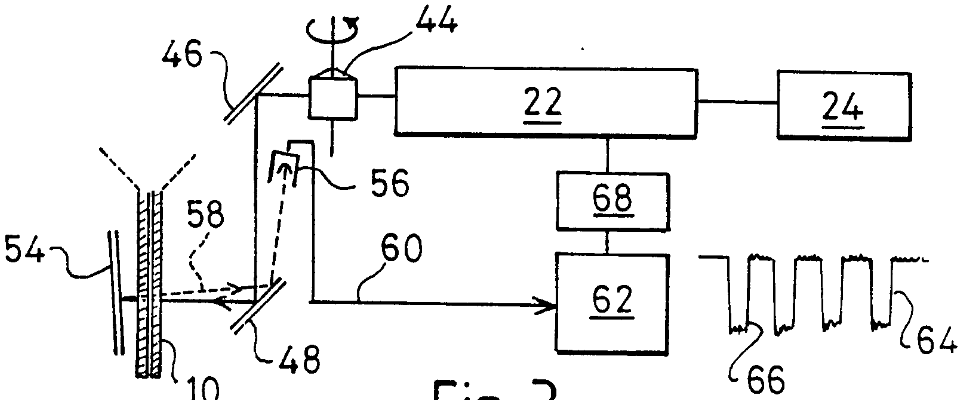

Fig. 3

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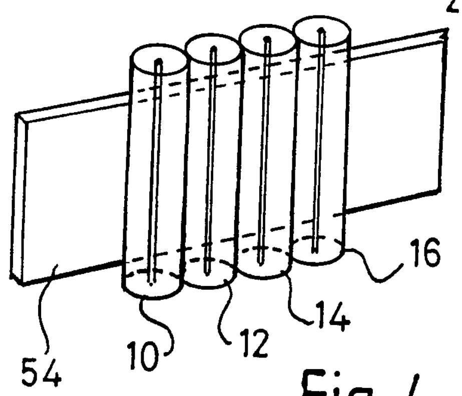

Fig. 4

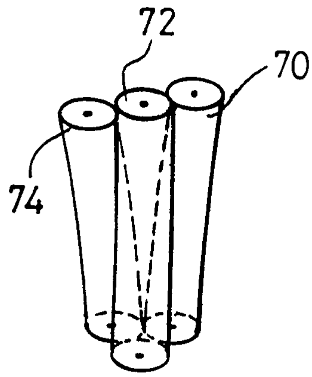

Fig. 5A

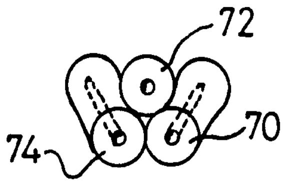

Fig. 5B

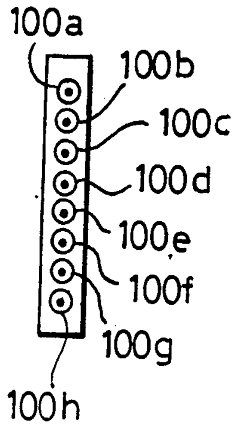

Fig. 6

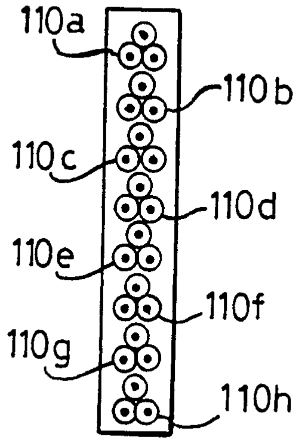

Fig. 7

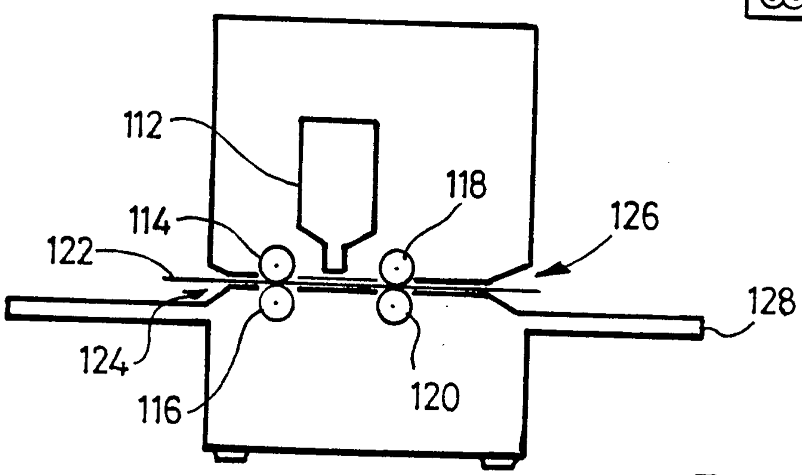

Fig. 8

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 93/02604

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 B41J2/05 B41J2/135

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 B41J

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 492 966 (M. SEKI) 8 January 1985	1-10,16
X	see column 2, line 28 - column 3, line 29 see column 5, line 5 - column 8, line 68 see figures 1,2,5-11 ---	17
X	EP,A,0 051 468 (XEROX CORPORATION) 12 May 1982	1,3-5
X	see page 3, paragraph 7 - page 10, paragraph 1 see figures 1-3 ---	7-14,16
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 567 (M-908) (3915) 15 December 1989 & JP,A,01 237 146 (K. ICHIKAWA) 21 September 1989 see abstract --- -/--	15

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

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29 March 1994	26. 04. 94

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US,A,4 312 009 (F. LANGE) 19 January 1982 ---	
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Information on patent family members

International Application No
PCT/GB 93/02604

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