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(71) Applicant
Pitney Bowes Inc.,
Walter H. Wheeler Jr. Drive,
Stamford,
Connecticut 06904,
United States of America

(72) Inventors
Frank Thomas Check,
Ronald Philip Sansone

(74) Agents
D. Young and Co.,
10 Staple Inn,
London,
WC1V 7RD

(54) **Light-scanning**

(57) In a method of producing an image on a rotating photoconductive drum 32 using modulated laser light and light-scanning, the resulting image being made of up dots, intermeshing dots of different sizes are produced so as to create an image having a smooth outline. Dot size may be controlled by varying the intensity of an intensity modulator 64 for a single laser source 10 or by using two laser sources producing beams of different diameter.

Fig. 1

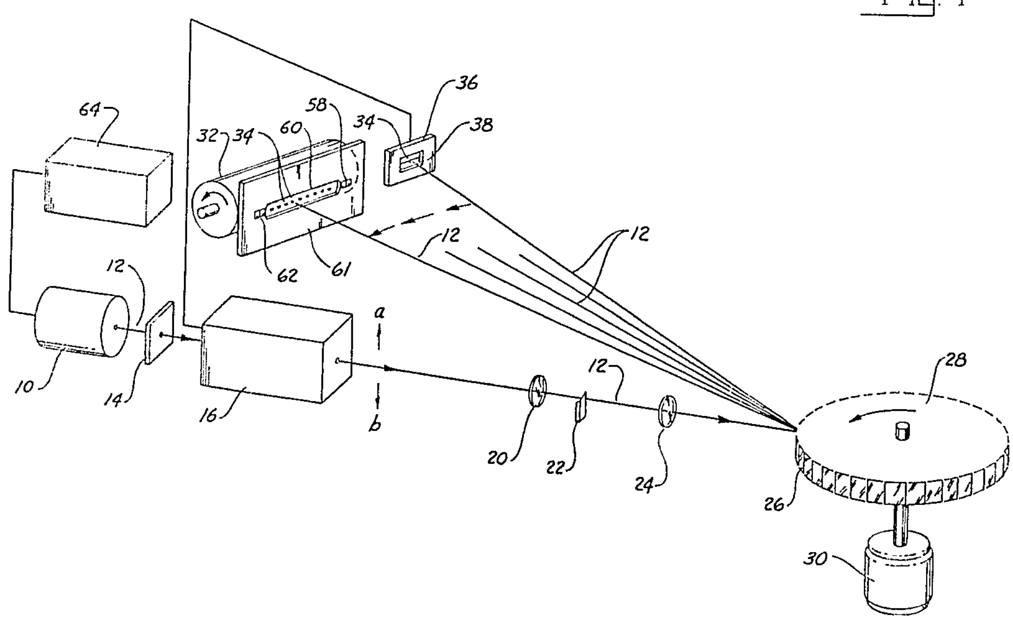

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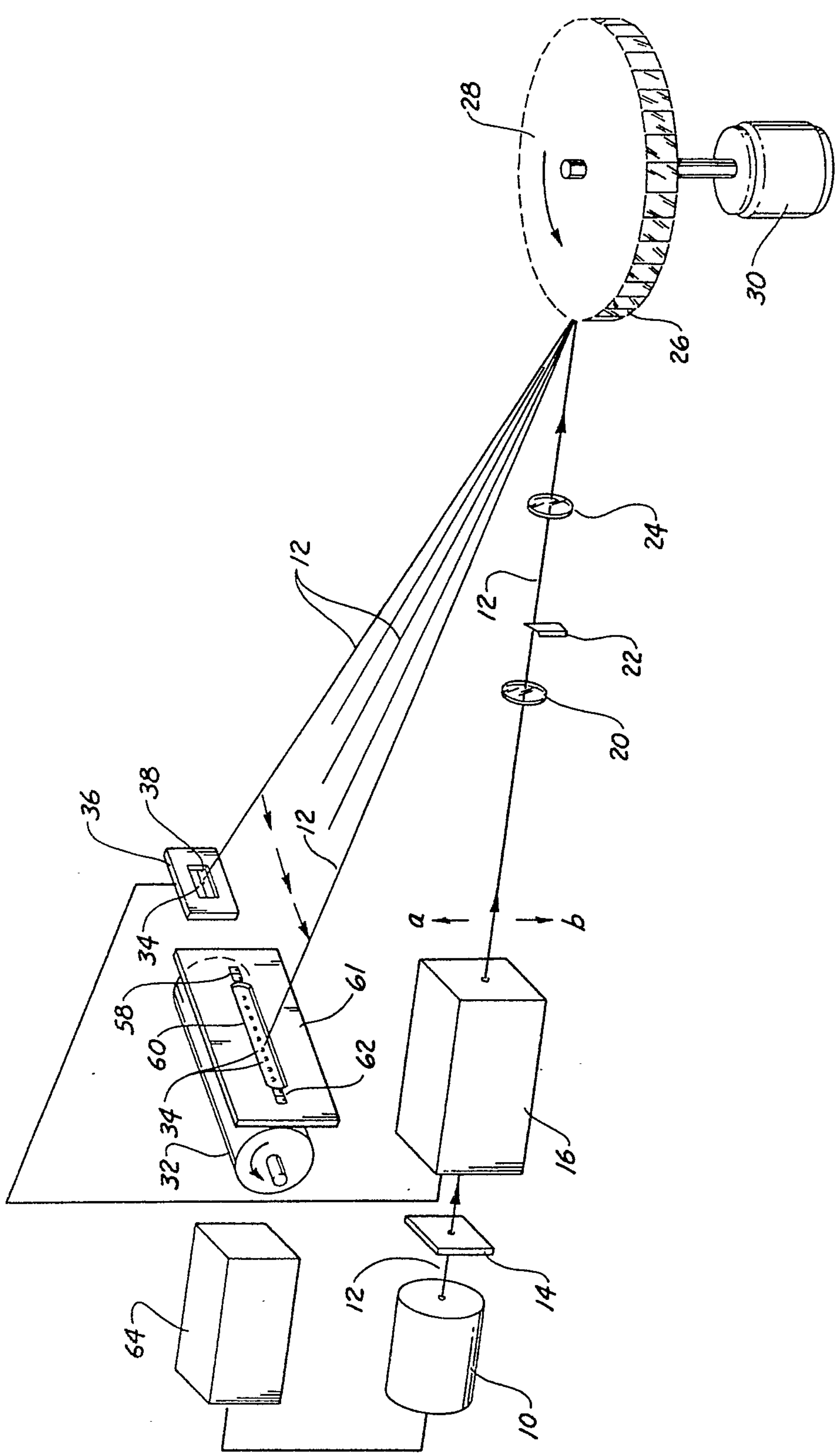
Fig. 1



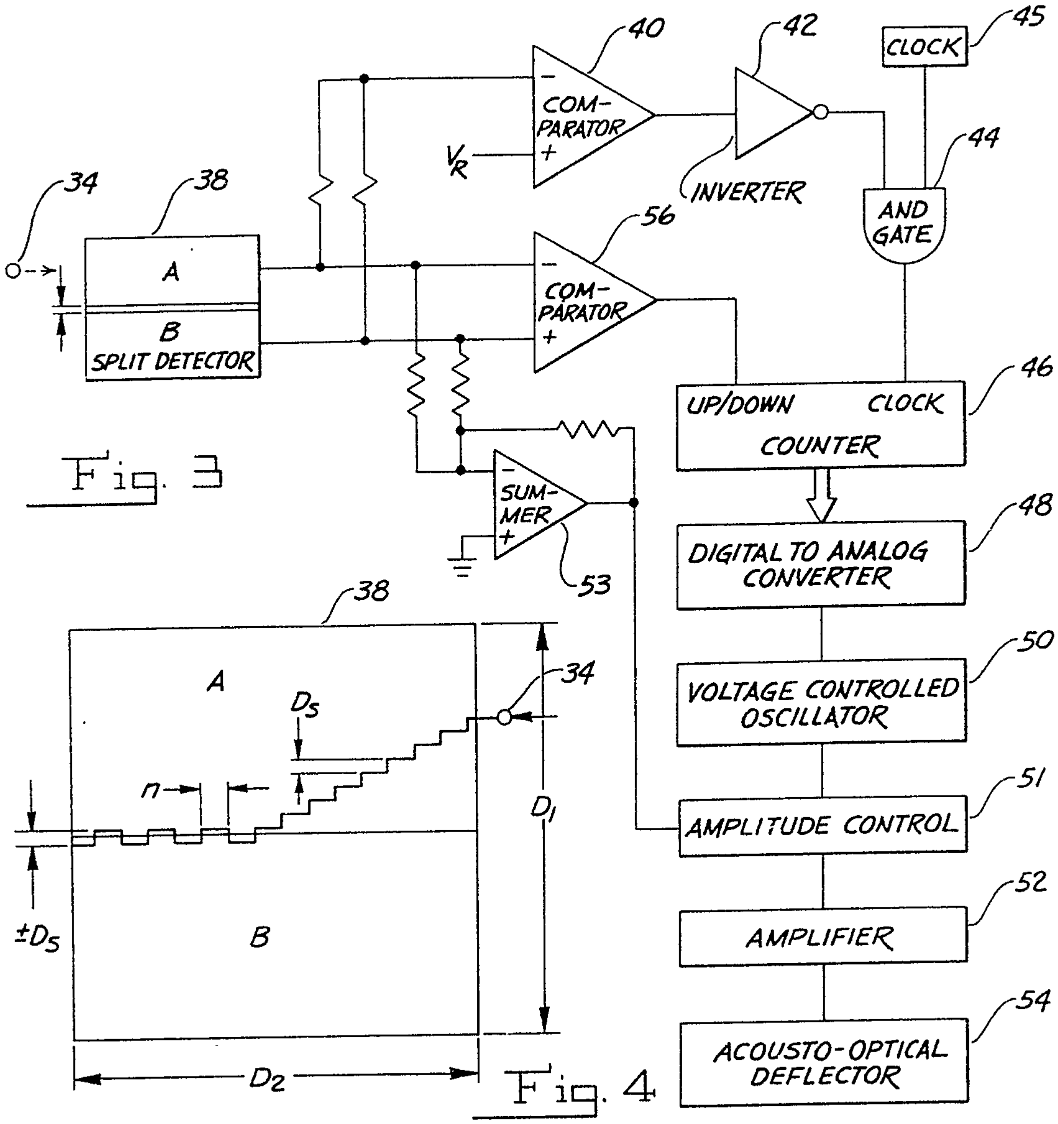


Fig. 3

Fig. 4

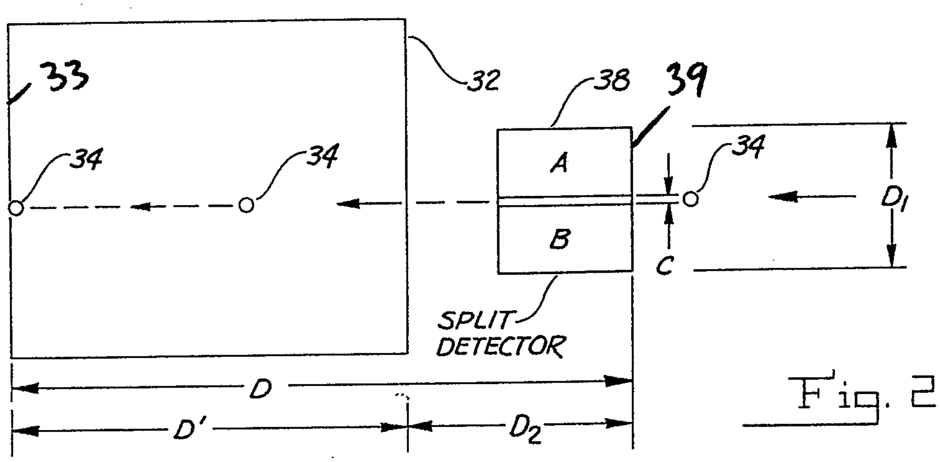


Fig. 2

SPECIFICATION

Producing generated shapes on a photoreceptor

This invention relates to a method of producing on a photoreceptor an image of generated shapes made up of spots.

This application is divided out of Patent Application No. 79 23509, Publication Serial No. 2 027 950.

According to the present invention, there is provided a method of producing on a photoreceptor an image of generated shapes made up of spots, comprising directing a plurality of beams of light toward a photoreceptor, each beam of light generating a spot on the photoreceptor and controlling a parameter of the light beams to produce spots of different sizes whereby the appearance of smoothed edges are given to the generated shapes.

In a preferred embodiment of the invention, the parameter controlled is light beam intensity.

The invention will be better understood from the following non-limiting description of an example thereof given with reference to the accompanying drawings in which:—

Figure 1 is a diagrammatic representation of the major components of one example of an optical scanning device according to the present invention, the angle of reflection of the beam being distorted for purposes of illustration;

Figure 2 is a schematic representation of the longitudinal travel of a modulated laser beam approaching and crossing a spot detector and photoreceptor;

Figure 3 is a schematic diagram of the spot correction logic; and

Figure 4 is a diagrammatic illustration of spot displacement during corrective modulation.

Referring now to the drawing, Figure 1 illustrates an overall view of the scanning system of this invention. The light source, such as a laser 10, which may be a 3 mw helium-neon laser, generates a collimuted beam 12 of monochromatic light which is directed through a neutral density filter 14 to control the light intensity. The beam 12 then passes through a modulator 16, such as an acousto-optical modulator. The beam 12 is next directed through a first lens 20 and intercepted by a knife edge 22 placed at the focal point of the first lens 20. The knife edge 22 is employed for stopping the zero order Bragg beam. The first order beam is thus separated and passes the knife edge 22 unattentuated. An example of a commercially available acousto-optic modulator is Model 1209 by Isomet Corp. Springfield, VA., which provides a built-in Bragg angle adjustment. The modulator 16 can typically be operated by a digital driver, such as Model No. 220 available from Isomet Corp, wherein transistor-transistor logic compatible digital input controls an RF switch for on-off gating of the modulator 16. Another acousto-optical modulator is Model 304 manufactured by Coherent Associates, Danbury, Connecticut, U.S.A.

It is desirable to use the first order beam to produce a spot because the position of the spot can be displaced in accordance with frequency modulation applied to the modulator which will selectively deflect the beam 12 in a desired direction such as indicated by the arrows a, b. The first order beam 12 is then directed toward a second lens 24 which directs a converging beam onto a reflecting face of facet 26 of a rotating polygonal mirror, herein referred to as a polygon 28. the polygon 28 is continuously driven by a motor drive 30 and preferably is maintained at a constant velocity. In the preferred embodiment as shown, the polygon 28 has thirty facets 26 and is designed for generating approximately 240 scan lines per second. A moderate spot velocity is preferred for implementing the optical sensing and closed loop feedback correction circuitry.

The beam 12 is thus reflected successively from each of the facets 26 of the rotating polygon 28 and onto a photoreceptor 32. The reflection of the beam 12 from the polygon 28 is distorted for purposes of illustration as it will be appreciated that the incident beam and reflecting beam will be in the same plane rather than at an angle to one another as indicated by Figure 1. The modulated beam 12 may appear as a succession of dots 34 which will generate a scan line forming a raster across the moving photoreceptor 32. The photoreceptor 32 may be any image plane and can be mounted on a rotating drum such as for use with an electrophotographic copier.

It should thus be apparent that the light scanning system of the present invention can be readily interfaced with an electrophotographic copier having panchromatic photoreceptors and can thus function as a high quality nonimpact printer.

It is well known that various types of errors are inherent in the geometric fidelity of a commercially available rotatable polygon. In particular, deviation in parallelism of each facet relative to the axis of rotation introduces a fact-to-axis error and the resulting scan lines will correspondingly contain these inaccuracies which manifest themselves as alignment deviations from a desired scan line travel axis, i.e. line to line spacing variation. A spot correction assembly 36 is used for optically detecting and correcting for these facet-to-axis errors. The spot correction assembly 36 in the preferred embodiment, is provided with an optical detector in the form of a split detector 38 optically positioned in the scan format plane and divided in half to form cells A, B (Figure 3) with a common electrode. A division C (Figure 2) formed between the two cells A, B is registered with the desired scan path axis and has a dimension substantially less than the diameter of the spot 34. A signal will thus be generated from either or both cells A, B when the spot 34 sweeps the split detector 38. Since the alignment of division C is parallel to the scan direction, the division C provides a reference for indicating deviations of spot 34 from the desired travel axis on the photoreceptor 32.

Referring now to Figure 2, maximum allowable uncorrected face-to-axis angular error may cause the spot 34 to fall anywhere within a transverse zone, within the light sensitive area of split detector 38. Successive scans, as determined by the rotating polygon 28, travel a distance D that extends from the outside edge 33 of the photoreceptor 32 to the outside edge 39 of the split detector 38. The distance D is greater than the width D′ by a distance D2 which is at least equal to the distance a spot 34 will travel as a result of the greatest facet-to-facet deviation it should thus be evident that the correction of each successive spot 34 is achieved during a "dead" time, i.e., the period of travel prior to transversing the photoreceptor 32.

A typical logic circuit implementing the present invention for control of an acousto-optical deflector to provide compensating deflection of the laser beam such that the spot 34 will exit the split detector 38 in registration with the division C between the individual cells A and B is shown in Figure 3. When an uncorrected spot 34 of the laser beam enters the detector 38, a comparator 40 compares the signal generated at either photocell A or B with a reference voltage V_r and provides a low output signal to an inverter 42 to generate a high enabling signal at an AND gate 44. A system clock 45 provides correction count pulses as a second input to the AND gate 44. The presence of the spot 34 at either cell segment A or B thus provides a high signal at the AND gate 44 enabling clock pulses to pass through the AND gate 44 and register at a counter 46. The instantaneous count of the counter 46 drives a digital to analog converter 48 which in turn provides an analog correction signal *via* a voltage controlled oscillator 50, an amplitude control 51, and an amplifier 52 to an acousto-optical deflector 54 which is incorporated into the modulator 16. The beam 12 will thus be displaced in the appropriate direction a or b. The amplitude control 51 is connected to a summer 53 that measures the amount of light falling on A and B of the split detector 38 to maintain the light output constant to the acousto-optical deflector 54.

It should be appreciated that the direction of count of the counter 46 determines the direction of corrective deflection applied by the deflector 54. In order to control the direction of count, a second comparator 56 compares the output of cell A with respect to the output of cell B. If the terminal spot 34 of the laser beam enters cell A, the output of cell A will be greater than that of cell B, and the comparator 56 will provide a low output. The low output of comparator 56 determines the count direction of the counter 46. As the deflecting correction is applied, the spot 34 progresses towards cell B while translating across the detector 38. As soon as the spot 34 crosses into cell B, the signal of cell B will be greater than the signal of cell A which causes the comparator 56 to switch to a high output. The high output of the comparator 56 reverses the direction of the counter 46 and thus provides an opposite direction of corrective deflection of the laser beam such that the laser beam will progress towards cell A. Thus, the spot 34 will track the division C until it exits from the detector 38 at which time the clock 45 is disabled and the correction value for the particular facet 26 is digitally stored in counter 46 until the next uncorrected spot enters the detector.

The control process is further detailed in Figure 4. The spot 34 is shown entering the split detector 38 at cell A. The displacement of the spot 34 resulting from an incremental change in the counter is reflected through the closed loop control circuitry through a deflection in either direction a or b. The uncertainty of the exit point of spot 34 is $\pm D_s$ due to the digitization of the signal. The amount D_s is less than the tolerable error. With a given voltage controlled oscillator and acousto-optical modulator, D_s can be varied by changing the scaling factor of the digital to analog converter. Since the most extreme error would be equivalent to

$$\frac{D1}{2},$$

the number of correction steps to bring the spot 34 to the division C is a maximum of

$$n=\frac{D1}{2D_s}.$$

Assuming it takes a given time (t_s) to perform a corrective step, the total time is

$$(n)(t_s)=\frac{D_1t_s}{2D_s}.$$

If the spot velocity is V_s, then the minimum, length of photocell required is

$$D_2=\frac{D_1t_s}{2D_s}(V_s).$$

A typical value for V_s is 2200 inches per second.

Other alternate closed loop means of control include a successive approximation technique which converges more rapidly than the above described counter system.

A further method capable of converging more rapidly in the use of a precision sensing detector such as United Detector Technology PIN-SC/10D, which senses the centroid of a light spot and gives analog output proportional to spot position. These outputs can be digitized directly and coupled to a voltage controlled oscillator without intervening conversions.

Scan line spot detection will now be discussed with reference to Figure 1. Since the modulator 16 is controllable by internal logic which determines exposure on the scan formate 32, an edge detector 58 is positioned adjacent the leading edge of an exposure slot 60 formed in an opaque shield 61 for indicating when the spot 34 is at the precise location. The edge detector 58 and a logic circuit can thus be used as an implement to synchronize the internal logic with the location of the scan line. It should therefore be clear that each sweep of the scan line is independently referenced and will thus negate any facet-to-facet polygon error which will manifest itself as jitter in the time that successive scans cross a geometric reference point.

The edge detector 58 of the preferred embodiment utilizes a split photocell similar in construction to detector 38 except for orientation of the division perpendicular to the scan path. Each half of the split photocell forming detector 58 is essentially identical in area, location, material and temperature. Thus, the use of split photocell has advantages over a single cell edge detector in that it will be relatively insensitive to laser light intensity change, temperature changes and ambient light.

A second edge detector 62 of similar construction to the edge detector 58 is located at a trailing edge of the exposure slot 60. The edge detector 62 will indicate when spot 34 has passed a fixed terminal point beyond the scan path. The time differential as detected between the first edge detector 58 and the second detector 62 can be interpreted through logic circuitry to indicate the flight time for spot 34 to cover a fixed length scan path. Thus, the speed of the spot can be computed. Variations in speed for different scan lines can be detected, and a feedback loop can then be utilized for speed control of the motor drive 30.

With regard to the aforementioned, it has been found that as a beam 12 is deflected or detuned from the Bragg angle, the efficiency will change. The efficiency of the scanning apparatus disclosed herein, however, can be improved by introducing an intensity modulator 64 for applying an amplitude modulated correction signal for maintaining laser illumination at a constant level. The intensity modulator 64 could also be used for control of spot size by either varying the intensity. The use of different spot sizes can effectively be employed as letters or numbers are created so as to avoid roughened edges and improve character formation. The system of this invention can also employ two power sources using parallel laser beams with each of the beams being of a different diameter and corresponding spot size. This will provide a matrix of dots having different sizes for forming a single generated character. The different size dot will intermesh to create letters and numerals having a smoother appearance.

It will be seen that the laser scanning apparatus illustrated herein is well suited to meet conditions of practical use.

As various changes may be made in the apparatus as above particularly described, it is to be understood that the matter shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Claims

1. A method of producing on a photoreceptor an image of generated shapes made up of spots, comprising directing a plurality of beams of light toward a photoreceptor, each beam of light generating a spot on the photoreceptor and controlling a parameter of the light beams to produce spots of different sizes whereby the appearance of smoothed edges are given to the generated shapes.

2. A method according to claim 1 wherein the parameter controlled is light beam intensity.

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