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64 **Electrophotographic copier with variable original document to image size ratio.**

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50 References cited:

DE-A-2 120 727
DE-A-2 129 791
DE-A-2 154 809
DE-A-2 553 665
DE-A-2 738 301
DE-A-2 842 104
FR-A-1 097 439
GB-A-1 079 231
GB-A-1 525 218
US-A-4 057 342

IBM TECHNICAL DISCLOSURE BULLETIN, Vol. 17, No. 4, September 1974 New York G.L. SMITH "Variable-Aperture Stop for a Reciprocating Lens Copier Design" page 1111

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EP 0 022 175 B2

Description

The present invention is directed to electrophotographic copiers with variable original document to image size ratios.

5 One particularly desirable feature which has been introduced with commercial electrostatic copiers is the capability of varying the object image so that the copied image is varied in size with respect to the object image. The advent of copiers capable of this function required the solution of several problems, i.e., those particularly caused by changes induced as a result of the changes in the optical configuration required to reduce the image. While the solution of these problems in a laboratory environment may be
10 trivial, the constraints imposed by practical manufacture of these devices made the solution to these problems more difficult. In particular, the commercial device had to exhibit the same image sharpness and consistency of image intensity for all ratios of document and image sizes with desirably little or no increase in equipment size, cost or maintenance difficulty.

15 While a copier capable of varying an image satisfies more of the users' need than a machine which is not so capable, it is also desirable to increase the number of ratios and finally to provide for continuously variation of ratios within some specified range of ratios. As the number of ratios is increased until it becomes essentially continuous, the number of optical problems to be solved increases, and with the constraints imposed on commercial devices, the difficulty in solving these problems increases.

20 Desirably, the copied image produced by a copier is uniform in intensity, and the achievement of this requires careful design. Even if one assumed uniform object illumination (which is usually not actually the case due to size limitations), the presence of a lens in the optical path results in image intensity reduction for that portion of the image passed off the lens or optical centre line, i.e., so-called \cos^4 losses. In the prior art, solutions to this difficulty have been achieved by shaping the object illumination so as to compensate for the image intensity falloff, and similar shaping has been used to compensate for otherwise uneven
25 object illumination.

However, the introduction of a reduction capability caused further variations in the image intensity since, as reduction is introduced, image intensity at the image plane increases. The variations in intensity in a machine which included a single reduction mode (i.e., a reduction ratio other than 1) had been compensated for in the prior art by adding an aperture only in the reduction mode to limit image intensity
30 in that mode. This aperture, mask or light stop, could theoretically be located either adjacent the image plane or adjacent the object plane, and in the case of its location near the object plane, it could be located between the source of illumination and the object or between the object and the lens.

A further complication arises in some machines which are capable of variable ratio copying by reason of the relationship between the centre line of objects of different sizes. In one group of machines, the centre
35 line is not changed, i.e., the objects are centre-referenced; obviously, this causes no additional difficulties. However, in another group of machines, the objects to be copied are corner referenced, and as a result, as the object to be copied increases in size, and the ratio is correspondingly changed, the centre line moves or changes in position relative to centre line of a smaller object to be copied. This "corner-referencing" serves to increase the difficulties associated with \cos^4 losses and drum curvature distortions, since more of the
40 image to be reproduced falls in the edge areas whose intensity would be reduced absent some special attention.

In machines capable of a given small number of ratios, image intensity variations, in the prior art, were handled by arranging the illumination in a base mode to be relatively uniform, and then substituting a
45 different mask, light stop or aperture, for each different mode to maintain the uniformity of intensity. However, as can be realized, when the number of ratios is increased to such a point that they become essentially continuous the requirement to provide different masks, light stops or apertures, for each ratio, renders the system unmanageable in terms of equipment size, cost or maintainability.

A system capable of achieving some of these goals is shown in U.S. Patent Specification No. 4,057,342. This discloses a copying system with a pair of apertures located in the optical path and capable of operating
50 in a base mode and a reduction mode. The patentee recognized that additional reduction modes could be employed and, while image intensity variations would occur, the exposure system would provide a degree of correction. The patentee also indicates, however, that a slit appropriate for a base mode or non-reduction mode of operation would probably not be adequate for reduction mode of operation and correspondingly, a slit provided for uniform illumination in a reduction mode of operation would not
55 provide proper operation in a base of non-reduction mode or in a different reduction mode.

We have now discovered that, contrary to what has been said in the prior art, and particular in U.S. Patent Specification No. 4057342, a single, fixed, slit arrangement can be employed in a variable ratio copier to effect substantially uniform illumination for all of the ratios. We have done this by calculating the
60 width profile of the slit, with reference to a reference position therealong, for example, one end, to effect compensation for both light source variations and lens \cos^4 losses. This combination of factors in determining the slit profile has not, to our knowledge, been employed previously for variable ratio machines. In addition, it is by selecting a particular width at the reference position that variable ratio compensation can be achieved.

65 According to the present invention, therefore, there is provided an electrophotographic copier comprising an exposure station including a platen for supporting an original document to be copied, an

illumination source adapted to produce a line of light and to direct it towards the platen to scan a document thereon, an optical system adapted to direct a line of light reflected from a document on the platen on to an imaging element, said optical system including a lens for focussing the reflected light on to the imaging element and mounted for movement relative to the imaging element to effect variation of the ratio of original document to image size on the imaging element between one to one and one to a predetermined value less than one, and a single mask positioned adjacent the platen and having a fixed stop aperture in the form of an elongate slit therein to receive and pass said reflected light to said optical system, said slit having a length substantially equal to that of the reflected line of light, characterised in that said slit has a width profile defined by a predetermined width at a reference position and widths at points along the aperture calculated, relative to said predetermined width, to effect, at those points, compensation for light source intensity variations and lens \cos^4 losses at said one to one ratio, the predetermined width being selected such that said compensation is effective at all of said ratios.

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

15 Figure 1 shows an electrostatic copier, broken away to show essential components;

Figures 2 and 3 illustrate the optical path of the Figure 1 copier and the relation of several parameters related thereto;

Figure 4 is a typical illumination profile at the object plane; and

Figure 5 is a plan view of a mask employed to limit image intensity variations.

20 A preferred embodiment of the invention is illustrated in the accompanying drawings, in connection with an essentially continuously variable reducing copying machine which can be of the type shown in Figure 1, and in more detail in U.K. Patent Specification No. 152518. In that machine, a transparent platen or document support 50 is arranged to support a document to be copied. Illumination for the copying process is provided by the lamp 40, and reflectors 41, 44 are provided to reflect the illumination to impinge on the support 50. The source 40, the elliptical reflector 41 and the dichroic reflector 44 are arranged so that the illumination on the platen describes a focused line of light 45. Light reflected by the object to be copied, is directed to a mirror 46, and from thence to mirrors 47—48. Illumination reflected from the mirror 48 passes through a lens 9, is reflected by a further mirror 49, passes through a slit 51 in a wall of the machine and impinges on the surface of a drum 13. Thus, the image produced by the line of light 45 is reproduced on the surface of the drum 13 as a line of light 45'. In order to reproduce the image of an entire document, a first carriage supporting the light source 40, reflector 41 and mirrors 44, 46 and a second carriage supporting the mirrors 47—48 are moved parallel to the longer dimension of the platen 50. As the carriages are so moved, the line of light 45 scans the document to be copied and produces a corresponding image thereon the surface of the drum 13, as that drum rotates.

35 As is well known to those skilled in the art, a latent image of the object to be copied is produced on the drum 13, and this latent image is developed and the developed image later transferred to the copy paper so that the image which the object bears is reproduced on the copy paper.

As is disclosed in the aforementioned U.K. Patent Specification No. 1525218, reduction is achieved by selectively positioning the lens 9 and appropriately controlling the scanning of the first and second carriages in conjunction with the motion of the drum 13. The apparatus to position the lens 9 is shown in Figure 1 as a motor 15 operated under operator control 16. Motion of the first and second carriages is controlled by a motor 10 under the control of control apparatus 11.

45 For each discrete position of the lens 9 within its operating range, the electrophotographic copying machine shown in Figure 1 achieves a unique reduction ratio, and thus, the machine is capable of a range of reduction ratios or reduction modes within the range of movement of the lens 9. In a preferred embodiment of the invention, the machine is capable of reducing modes in the range 1:1 to 1:0.647.

The optical path of Figure 2 is useful in illustrating the problems which require solution. In Figure 2, the optical path has been straightened; those skilled in the art will understand that the following discussion will apply not only to optical paths of the type shown in Figure 2, but will also apply to folded optical paths such as that shown in Figure 1.

50 Figure 2 illustrates the illumination source including lamp 40, reflectors 41 and 44, in relation to the platen 50 and an image-bearing object 50' whose image is desired to be copied. The illumination from the illumination source is reflected by the document in accordance with the image on the document 50', and is coupled through the lens 9 to be focussed on the surface of the drum 13. If we assume that the distance along the optical centre line of the lens 9 from the object to the lens is equal to the distance from the lens to the surface of the drum 13, then the image at the drum 13 will be of the same size as is the image on the object 50', i.e., no reduction will be produced. With most practical illumination sources, the distribution of object light intensity is non-uniform. A typical profile is reproduced by the curve 52 in Figure 2. An incremental area of curve 52 labelled A will be "seen" by an incremental area on the drum 13. As the relative position of the illumination source and object 50' are changed during the scan, so the image produced at the surface of the drum 13 changes, and as the drum 13 rotates, this change produces on drum 13 a latent image of the entire document.

65 As explained in connection with Figure 1, reduction is achieved by repositioning the lens 9, so that for a particular reduction mode, the lens 9 will be located at the position 9'. This has the effect of increasing the effective illuminated area viewed by the drum from the portion A to the portion A' which increases the

image intensity at the drum 13, as compared with the intensity that would have been produced at the drum 13 had the lens been in the position 9. As a result, image intensity will be related to reduction mode, directly contrary to the desired goal of relatively constant image intensity regardless of reduction mode.

In order to evaluate the extent of this image intensity variation, we can refer to Figure 3, which is similar to Figure 2 except the illumination package has been eliminated as not being essential to this discussion. From the preceding discussion, it will be understood that the distances S and S' are varied in order to change the reduction mode. The irradiance produced at the plane of an image is given by $H = T\pi N \sin^2 \theta'$ (watt cm.⁻²), where T is the system transmittance, N is the object radiance (in units by watt STER⁻¹ cm.⁻²), and θ' is the half angle subtended by the exit pupil of the optical system from the image. For small angles, $\sin \theta'$, approximates to R/S'. In addition, $1/S' + 1/S = 1/f$, and $S' = mS$ where m is the magnification or reduction mode and f is the focal length of the lens. We can also write $S' = f(m + 1)$ and therefore, the irradiance H equals

$$\frac{T\pi NR^2}{f^2(m + 1)^2}$$

in units of watts per square centimetre, indicating that the irradiance varies in accordance with reduction mode m. To limit this variation, a mask, acting as a field stop, is located to limit the reflection from the object to a width h_o .

Other problems corrected by this mask are those caused when a flat object plane is imaged onto a curved surface, i.e., the photoconductor drum. One effect is velocity smear, where the image-plane component of the drum tangential velocity vector is less in magnitude than the image velocity vector. Another is an "edge effect" called elliptical side smear wherein a point of the object plane is not imaged continuously during exposure on the same point on the drum. Both these effects are overcome by providing a sufficiently narrow image height, h_i , controlled, in turn, by the height, h_o , of the object aperture.

In a copier, exposure energy density (joules per cm²) is the quantity of interest, and that is merely the irradiance multiplied by the exposure time. The exposure time is the height h_i of the illuminated image area divided by the drum tangential velocity v. However, for the paraxial optics, we can write $h_i = mh_o$. Thus, we can write that E (the exposure energy density) equals

$$\left(\frac{T\pi NR^2 h_o}{f^2 v} \right) \left(\frac{m}{(m + 1)^2} \right)$$

wherein the leftmost quantity is a constant, since we have limited the effective reflecting area of the object by aperture.

Accordingly, the energy exposure density can be written as

$$K \frac{m}{(m + 1)^2}$$

For two different reduction modes, the exposure energy density ratio E_1/E_2 is equal to

$$\frac{(m_2 + 1)^2}{m_1 (m_1 + 1)^2}$$

For the parameter of m equal to 0.647, this expression indicates a change in energy exposure density of about 5%, which is an acceptable variation. However, the preceding discussion is applicable only along the centre line, and does not treat edge effects or reduction in intensity off the optical centre line.

In general we can write that the image illumination E_i is equal to $TBW \cos^4 \phi$, where T is a function of the lens (and any mirror) transmittance and B is the object brightness, and ϕ is the angle between the image position and the lens centre line, and W (omega) is the solid angle subtended by the lens aperture to a given point in the image.

The average object brightness is a function of the light energy distribution illuminating the object and the attenuation of this light due, for example, to the aperture referred to above. That is, $B = KB_o$, where B_o is the object brightness. Therefore, $E_i = TWKB_o \cos^4 \phi$. However, we can write $K = K_A K_{III}$, where K is the brightness coefficient which is variable, K_A is the aperture width ratio and K_{III} is the object illumination intensity ratio. Thus, we can write that $E_i = TWK_A K_{III} B_o \cos^4 \phi$.

In order to ensure that E_i is a constant across the image plane, we set $K_A = 1/K_{III} \cos^4 \phi$.

Accordingly, by employing the fixed aperture of aperture width ratio K_A we can reduce image intensity variations as a function of reduction mode, $\cos^4 \phi$, and object illumination variations.

A practical copying machine will not have an object illumination footprint which is constant across the

object, and therefore, the aperture width ratio must also reflect shaping to reduce intensity variations as a result of object illumination variation caused by the particular illumination package employed. For example, Figure 4 is the object illumination profile for a practical illumination package. It can be seen that, for example, the illumination changes by a factor or more than two from the reference edge across the object width.

Table I reproduced below illustrates object illumination as a function of image positions or distance from the reference edge, with the first two columns of Table I merely reproducing the information shown in Figure 4. The third column illustrates relative illumination, K_{ill} , normalized to the reference edge. The next column corrects for \cos^4 losses by multiplying the factor K_{ill} by \cos^4 of the appropriate angle, depending upon image position. The factor K_A is the reciprocal of that product.

Finally, the last column shows the aperture width which is obtained by starting with an aperture width, for example, 10 m.m., and dividing that quantity by the associated factor K_A to determine a given factor, in this example, 9.017, that is used to multiply all K_A factors to obtain related widths along the aperture.

TABLE I

	Image position (m.m.fr.Ref.Edge)	Illumination (object)	K_{ill}	K_A	Aperture (m.m.)
20	0	7.76	1.000	1.109	10.00
	25	7.83	1.01	1.048	9.44
	50	7.56	.974	1.05	9.46
25	75	10.15	1.308	.768	6.93
	100	13.3	1.714	.583	5.26
30	125	15.87	2.045	.494	4.45
	150	17.098	2.203	.470	4.24
	175	17.45	2.247	.479	4.32
35	200	15.192	1.95	.581	5.24
	225	13.3	1.714	.686	6.19
	250	9.89	1.274	.936	8.44
40	275	7.64	.987	1.233	11.12
	300	6.68	.860	1.470	13.26

45

Figure 5 shows a field stop mask including an aperture having a configuration, from the reference edge up to 200 m.m. therefrom, which conforms to the width dimensions shown in Table 1. The chosen starting aperture width is selected to provide a consistent field angle for all ratios of the object to image size to be employed as explained above with reference to Figure 3. The K_A values correct for $\cos^4\phi$ losses when the lens remains on a constant axis. If, however, the lens axis is changed for different reduction modes, then the $\cos^4\phi$ values will also change somewhat. With the illumination package with the Figure 4 profile, it was found that the calculated aperture size from the reference edge up to 200 m.m. provided substantially even illumination throughout the reduction range. However, for 225 m.m. from the reference edge and greater, the calculated sizes had to be determined empirically to obtain good results throughout the reduction range. These determinations resulted in the following values:

- 225 m.m. from reference edge: 7.01 m.m.
 - 250 m.m. from reference edge: 9.5 m.m.
 - 275 m.m. from reference edge: 11.25 m.m.
 - 300 m.m. from reference edge: 14.94 m.m.
- These are the values shown in Figure 5.

In the machine shown in Figure 1, the mask must be mounted to avoid the illuminating rays from source 40, via mirror 44, towards the document glass, and to intercept the reflected light passing between the document glass and mirror 46. It must, therefore, be mounted for movement with mirrors 44 and 46 in a direction along the document glass.

Claims

1. An electrophotographic copier comprising an exposure station including a platen (50) for supporting an original document to be copied, an illumination source (40, 41) adapted to produce a line of light and to direct it towards the platen to scan a document thereon, an optical system adapted to direct a line of light reflected from a document on the platen on to an imaging element (13), said optical system including a lens (9) for focussing the reflected light on to the imaging element and mounted for movement relative to the imaging element to effect variation of the ratio of original document to image size on the imaging element between one to one and one to a predetermined value less than one, and a single mask (Figure 5) positioned adjacent the platen and having a fixed stop aperture in the form of an elongate slit therein to receive and pass said reflected light to said optical system, said slit having a length substantially equal to that of the reflected line of light, characterised in that said slit has a width profile defined by a predetermined width at a reference position and widths at points along the aperture calculated, relative to said predetermined width, to effect, at those points, compensation for light source intensity variations and lens \cos^4 losses at said one to one ratio, the predetermined width being selected such that said compensation is effective at all of said ratios.

2. A copier as claimed in claim 1 including means for side aligning a document on the platen, further characterized in that said reference position is an end of the slit corresponding to the aligned side of a document on the platen.

Patentansprüche

1. Elektrophotographisches Kopiergerät mit einer Belichtungsstation, in der eine Auflagefläche (50) für das zu kopierende Originaldokument vorgesehen ist, mit einer Belichtungsquelle (40, 41) die ein Lichtband erzeugt und es auf die Auflagefläche richtet, um das dort aufliegende Dokument abzutasten, mit einem optischen System, das ein von dem Dokument auf der Auflagefläche reflektiertes Lichtband auf ein Abbildungselement (13) richtet und eine Linse (9) zum Fokussieren des reflektierten Lichts auf das abbildende Element enthält, die relativ dazu beweglich montiert ist, so daß das Verhältnis des Originaldokuments zur Bildgröße auf dem abbildenden Element zwischen Eins und einem vorbestimmten Wert kleiner Eins geändert werden kann und mit einer einzelnen Maske (Fig. 5), die benachbart zur Auflagefläche angebracht ist und eine feste Blende in Form eines länglichen Schlitzes aufweist, um das reflektierte Licht aufzunehmen und an das optische System weiterzuleiten, wobei der Schlitz eine Länge aufweist, die im wesentlichen gleich der des reflektierten Lichtbandes ist, dadurch gekennzeichnet, daß der Schlitz in Breitenrichtung ein Profil aufweist, das durch eine vorbestimmte Breite bei einer Bezugsposition und Breiten an Punkten längs der Öffnung bestimmt ist, die relativ zur vorbestimmten Breite so berechnet sind, daß an diesen Punkten eine Kompensation der Intensitätsänderungen der Lichtquelle und der Kosinus⁴-Verluste der Linse beim Eins-zu-Eins-Verhältnis erfolgt und daß die vorbestimmte Breite so gewählt ist, daß die Kompensation bei allen Verhältnissen wirksam ist.

2. Kopiergerät nach Anspruch 1 mit Vorrichtungen zur seitlichen Ausrichtung eines Dokuments auf der Auflagefläche, dadurch gekennzeichnet, daß die Bezugsposition ein Ende des Schlitzes darstellt, das der ausgerichteten Seite eines Dokuments auf der Auflagefläche entspricht.

Revendications

1. Copier électrophotographique comportant une station d'exposition qui comprend une platine (50) sur laquelle est déposé le document original à reproduire, une source de lumière (40, 41) permettant de produire une ligne lumineuse et de la diriger vers la platine afin de balayer le document déposé sur celle-ci, un système optique permettant de diriger une ligne de lumière réfléchie par un document disposé sur la platine vers un élément de formation d'image (13), ledit système optique comprenant une lentille (9) servant à focaliser la lumière réfléchie vers l'élément de formation d'image et montée de manière à pouvoir se déplacer relativement à l'élément de formation d'image pour effectuer des variations du rapport des dimensions du document original à celles de l'image formée sur l'élément de formation d'image, lesquelles variations se situent entre 1 et une valeur supérieure à l'unité, et un unique masque (figure 5) disposé à proximité immédiate de la platine et comportant une pupille fixe présentant la forme d'une ouverture de forme allongée destinée à recevoir ladite lumière réfléchie et à la transmettre audit système optique, ladite ouverture présentant une longueur pratiquement égale à celle de la ligne de lumière réfléchie, caractérisé en ce que ladite ouverture présente un profil de largeur défini par une largeur prédéterminée à une position de référence et des largeurs en différents points de l'ouverture calculées, relativement à ladite largeur prédéterminée, de manière à compenser, à ces points, les variations de l'intensité de la source lumineuse et les pertes en \cos^4 pour ledit rapport 1, la largeur prédéterminée étant choisie de telle sorte que ladite compensation soit obtenue pour tous lesdits rapports.

2. Copier selon la revendication 1, comportant des moyens pour effectuer un alignement latéral du document à reproduire sur la platine, caractérisé en outre en ce que ladite position de référence se trouve à une extrémité de l'ouverture correspondant au côté aligné d'un document disposé sur la platine.

FIG. 2

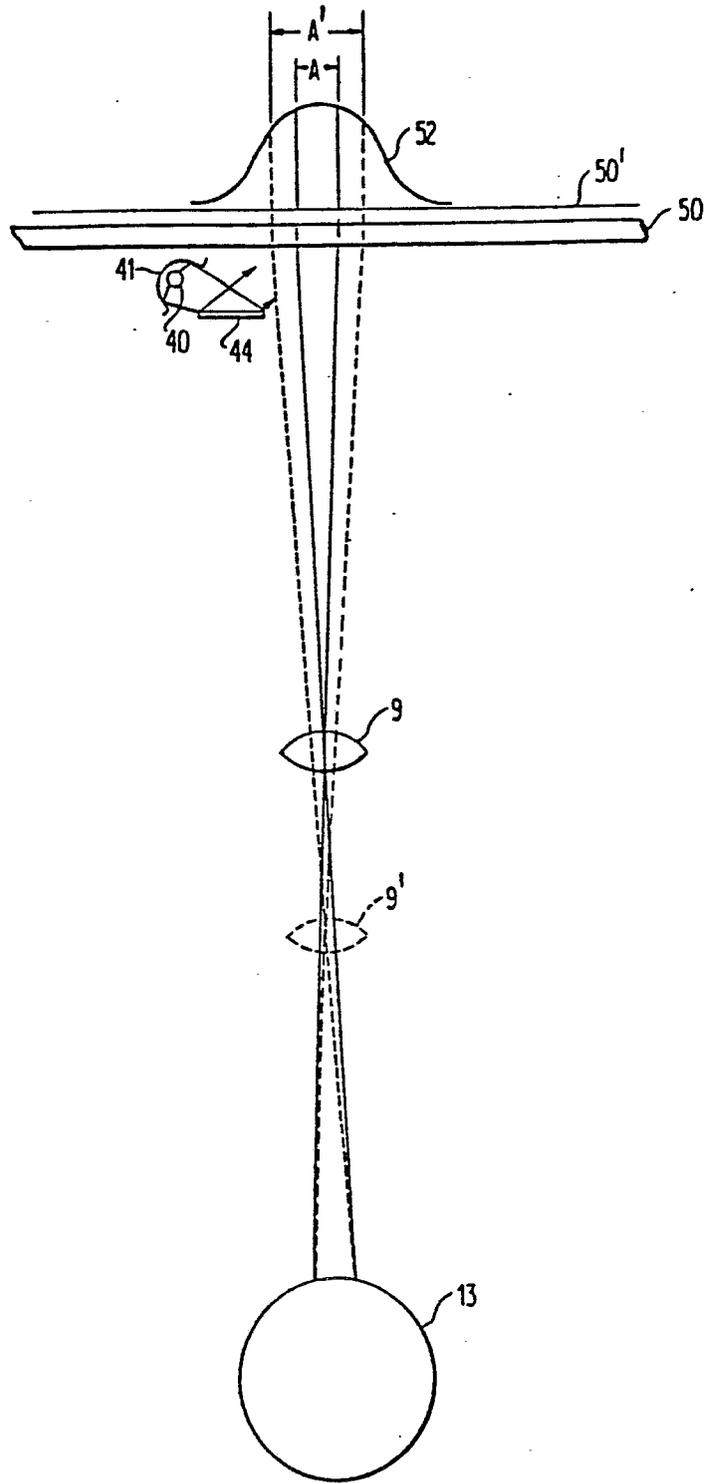


FIG. 3

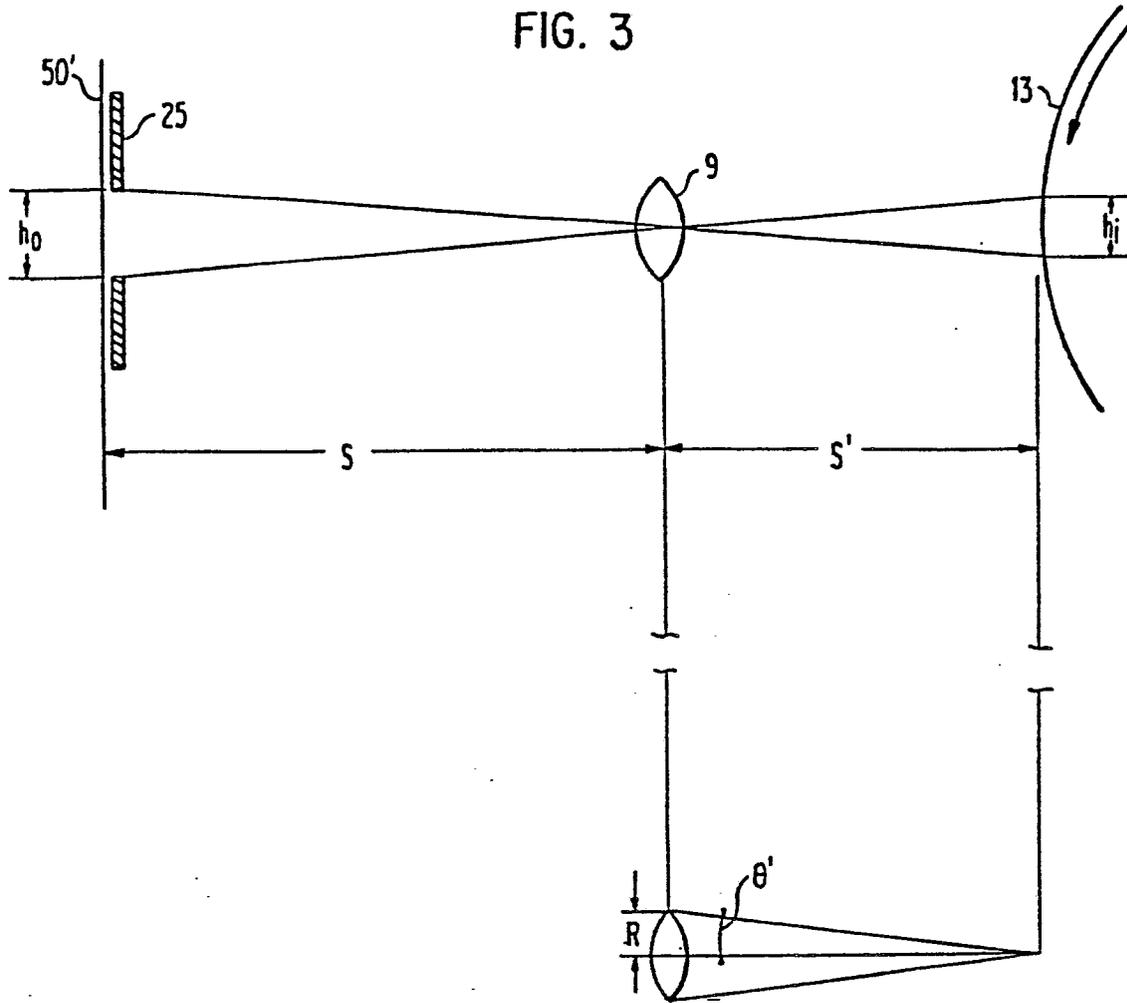


FIG. 5

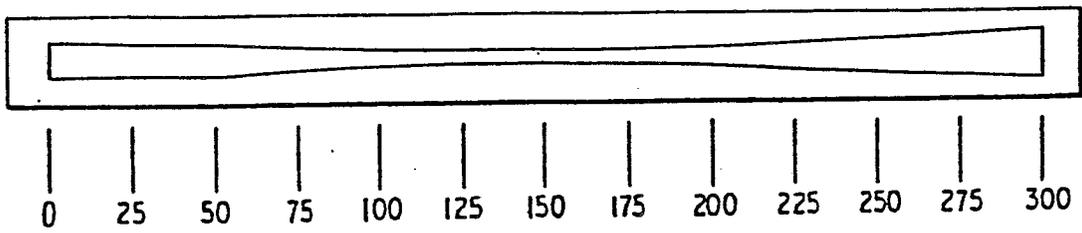


FIG. 4

