

12

EUROPEAN PATENT APPLICATION

21 Application number: 80103074.3

51 Int. Cl.³: **G 03 G 15/052**
G 03 B 27/50

22 Date of filing: 03.06.80

30 Priority: 21.06.79 US 50849

43 Date of publication of application:
14.01.81 Bulletin 81/2

84 Designated Contracting States:
DE FR GB

71 Applicant: International Business Machines Corporation

Armonk, N.Y. 10504(US)

72 Inventor: Libby, Edwin Langford
6074 Brigadoon Drive
Longmont Colorado 80501(US)

72 Inventor: Maddox, Randall Adrian
416 Woodview Drive
Lexington Kentucky 40509(US)

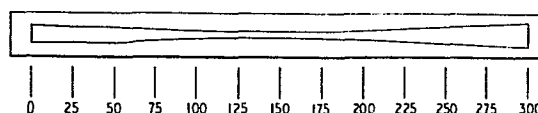
72 Inventor: Roberts, Douglas James
1426 Brookfield Drive
Longmont Colorado 80501(US)

74 Representative: Hawkins, Anthony George Frederick
IBM United Kingdom Patent Operations Hursley Park
Winchester Hants S021 2JN(GB)

54 Electrophotographic copier with variable original document to image size ratio.

57 An electrophotographic copier, of the type in which a line of light scans the original document and in which the lens is movable to effect variations in the ratio of original document to image size, has a field stop mask positioned to intercept light from a document being scanned before it is passed to the lens. The mask has an aperture configured to minimise image intensity variations caused by changes in the ratio, to correct for lens $\cos^4$ losses and to compensate for uneven intensity along the line of light scanning the document.

FIG. 5



- 1 -

ELECTROPHOTOGRAPHIC COPIER WITH VARIABLE
ORIGINAL DOCUMENT TO IMAGE SIZE RATIO

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

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 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.

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.

- 2 -

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 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 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 line is not changed, i.e., the objects are centre-referenced; obviously, this causes no additional

- 3 -

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 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 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 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

- 4 -

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 provide proper operation in a base of non-reduction mode or in a different reduction mode.

According to the present invention, 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 and an optical system adapted to direct a line of light reflect 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, characterised by a mask positioned adjacent the platen and having a field stop aperture therein to receive and pass reflected light to said optical system, said aperture having a length substantially equal to that of the reflected line of light and a width profile configured to minimise image intensity variations caused by changes in said ratio and to correct for lens $\cos^4$ losses.

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

- 5 -

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.

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 52 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

- 6 -

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 on the surface of the drum 13, as that drum rotates.

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.

For each discrete position of the lens 9 within its in 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.

- 7 -

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.

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 focused 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 a 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.

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

- 8 -

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 that 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 of 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, $1/S' = 1/\tilde{S} + 1/f$, 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 25, acting as a field stop, is located to limit the reflection from the object 50' to a width h_0 .

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

- 9 -

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 cm^2) 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 paraxial optics, we can write $h_i = mh_o$. Thus, we can write that E (the exposure energy density) equals

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

wherein the leftmost quantity is a constant, since we have limited the effective reflecting area of the object by aperture 25.

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

- 10 -

In general we can write that the image illumination E_i is equal to $TBW\cos^4\theta$, where T is a function of the lens (and any mirror) transmittance and B is the object brightness, and θ 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 25 referred to above. That is, $B = KB_o$, where B_o is the object brightness. Therefore, $E_i = TWKB_o\cos^4\theta$. However, we can write $K = K_A \times K_{ill}$, where K is the brightness coefficient which is variable, K_A is the aperture width ratio and K_{ill} is the object illumination intensity ratio. Thus, we can write that $E_i = TWK_A K_{ill} B_o \cos^4\theta$.

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

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

- 11 -

illumination package. It can be seen that, for example, the illumination changes by a factor of more than two to one from the reference edge across the object width.

Table I reproduced below illustrates object illumination as a function of image position 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.

- 12 -

TABLE I

Image Position (m.m.fr.Ref.Edge)	Illumination (Object)	K_{ill}	K_A	Aperture (m.m.)
0	7.76	1.000	1.109	.10
25	7.83	1.01	1.048	9.44
50	7.56	.974	1.05	9.46
75	10.15	1.308	.768	6.93
100	13.3	1.714	.583	5.26
125	15.87	2.045	.494	4.45
150	17.098	2.203	.470	4.24
175	17.45	2.247	.479	4.32
200	15.192	1.95	.581	5.24
225	13.3	1.714	.686	6.19
275	9.89	1.274	.936	8.44
275	7.64	.987	1.233	11.12
300	6.68	.860	1.470	13.26

Figure 5 shows a field stop mask including an aperture having a configuration, from the reference edge up to 400 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 $\cos^4 \theta$ losses when the lens remains on a constant axis. If, however, the lens axis is changed for different reduction modes, then the $\cos^4 \theta$ 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 400m.m. provided substantially even illumination throughout the reduction range. However, for 225 m.m. from the reference edge and greater, the calculated sizes

- 13 -

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 40, 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.

- 14 -

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 and an optical system (46, 47, 48, 49) adapted to direct a line of light reflect 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, characterised by a mask (Figure 5) positioned adjacent the platen and having a field stop aperture therein to receive and pass reflected light to said optical system, said aperture having a length substantially equal to that of the reflected line of light and a width profile configured to minimise image intensity variations caused by changes in said ratio and to correct for lens $\cos^4$ losses.

2. An electrophotographic copier as claimed in claim 1 further characterised in that said width profile is further configured to compensate for uneven intensity along the line of light from the source.

3. An electrophotographic copier as claimed in claim 1 or claim 2 in which said illumination source is mounted for movement along the platen to effect document scanning, characterised in that said mask is mounted for movement therewith.

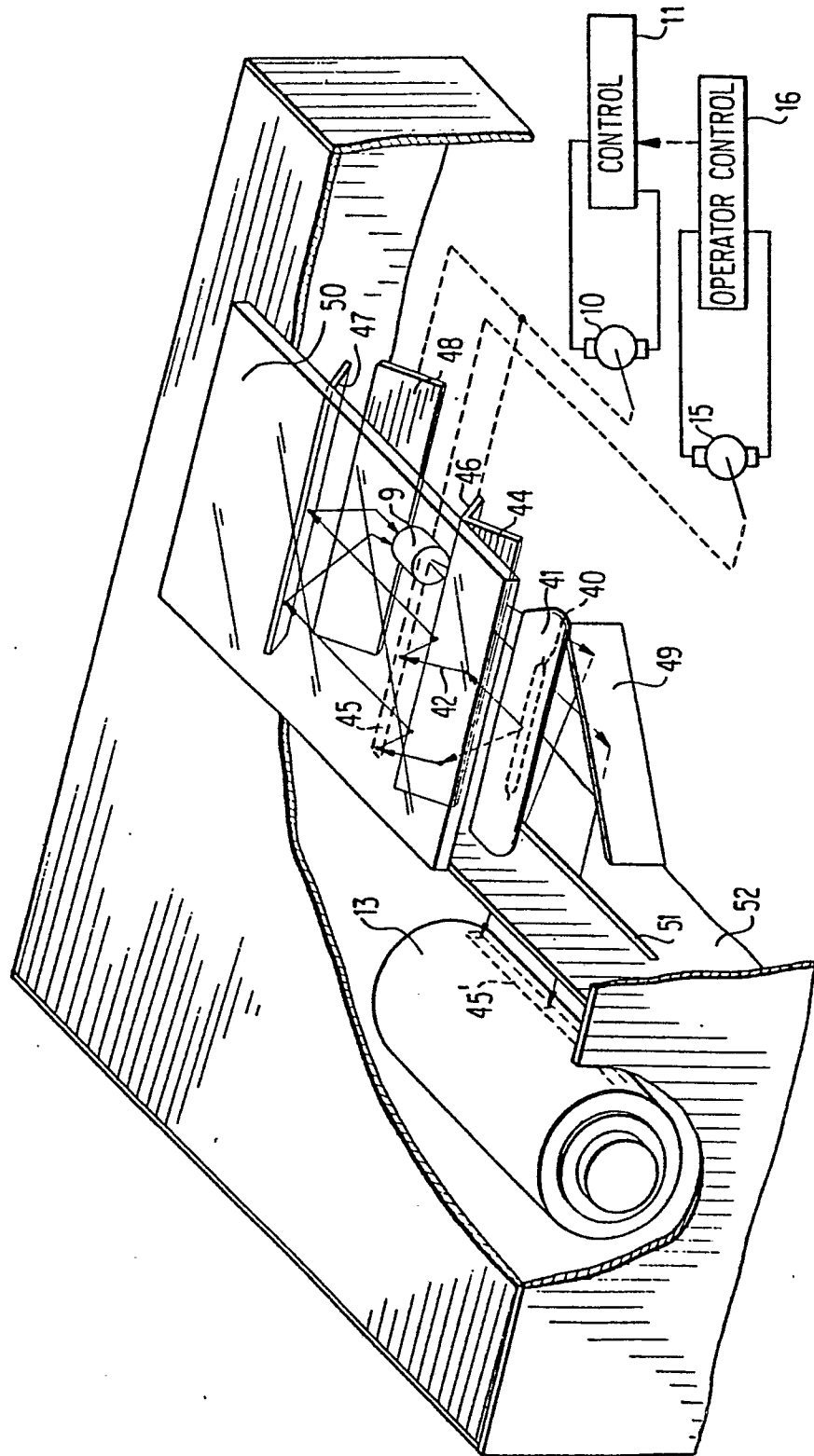
- 15 -

4. An electrophotographic copier as claimed in any of the previous claims further characterised in that said field stop aperture has a compound dogbone shape.

5. An electrophotographic copier as claimed in claim 4 further characterised in that said aperture has a configuration varying from a first width at one end to a minimum width substantially at the centre to a second width, greater than said first width, at the end opposite to said one end.

6. An electrophotographic copier as claimed in claim 5 further characterised in that from the first width, the width of the aperture decreases to a first intermediate minimum width and then increases to a first intermediate maximum width before decreasing to said minimum width.

FIG. 1



2/4

FIG. 2

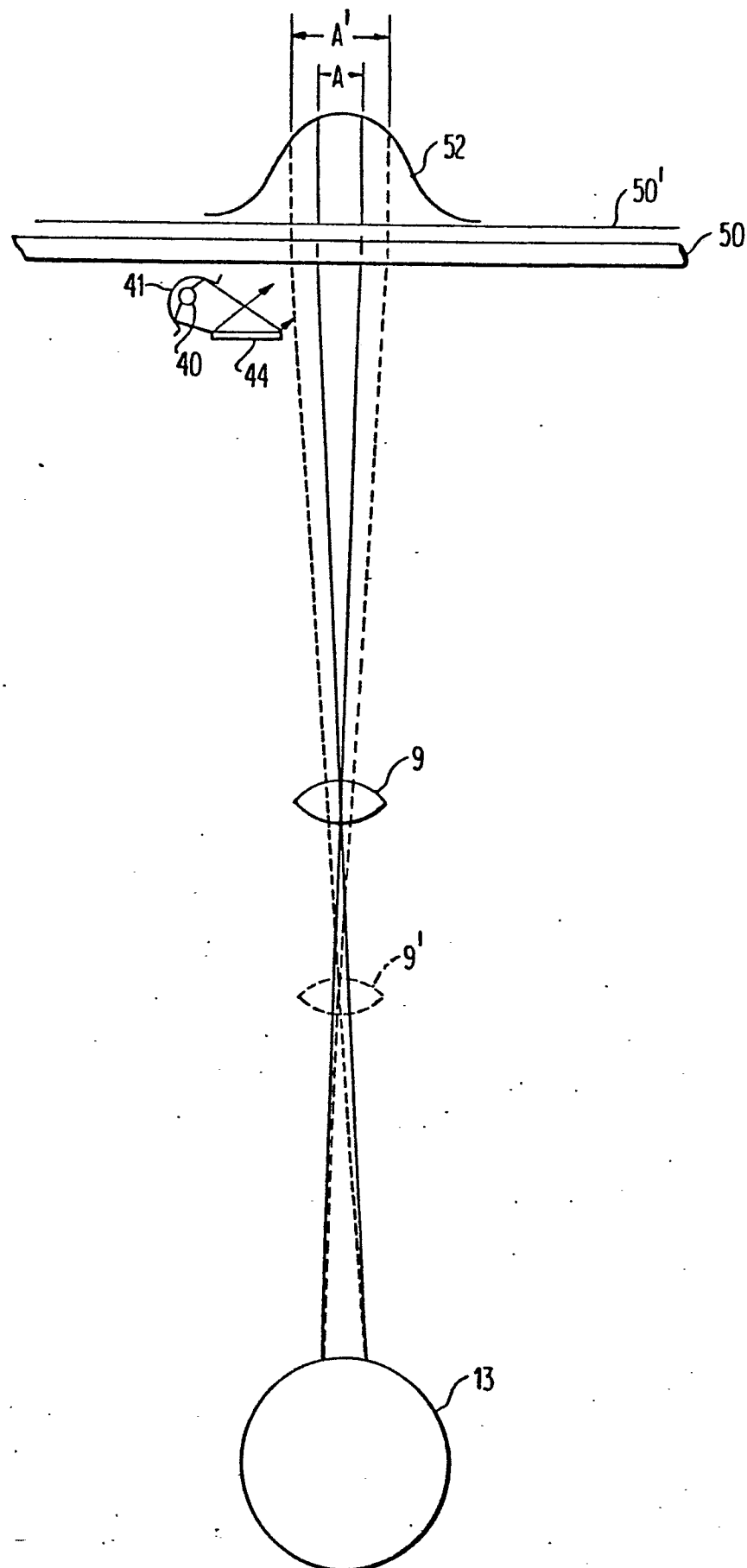


FIG. 3

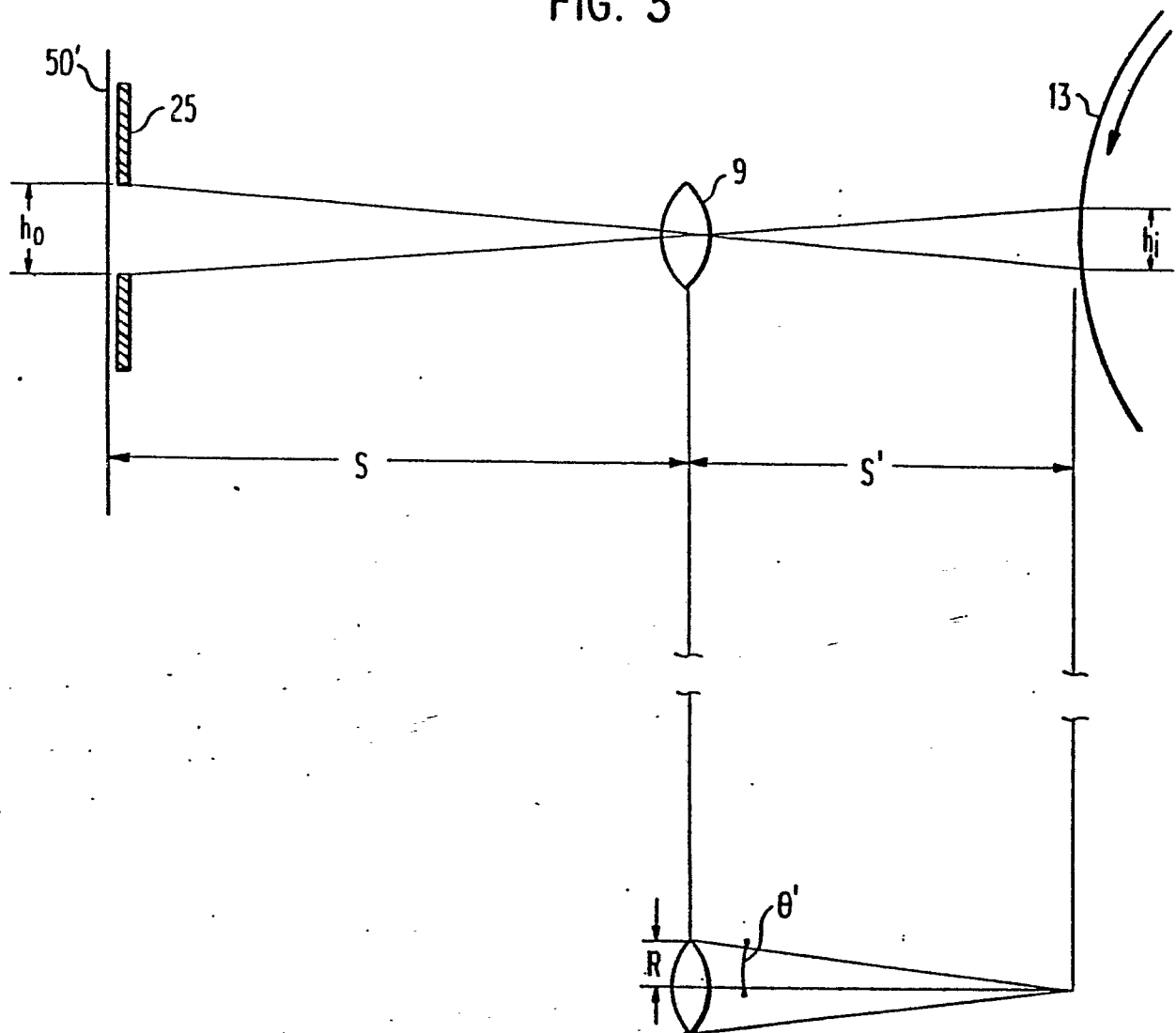
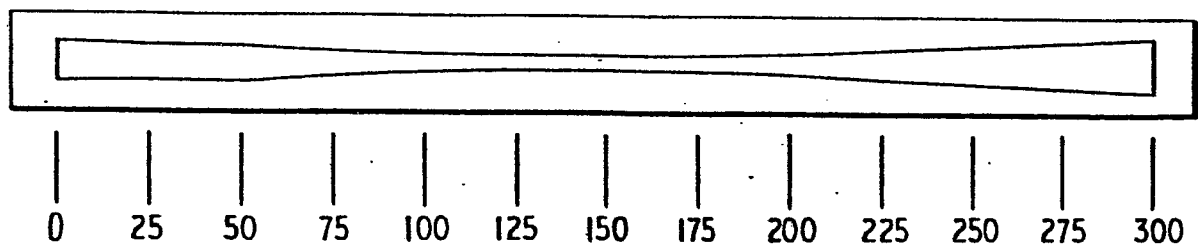
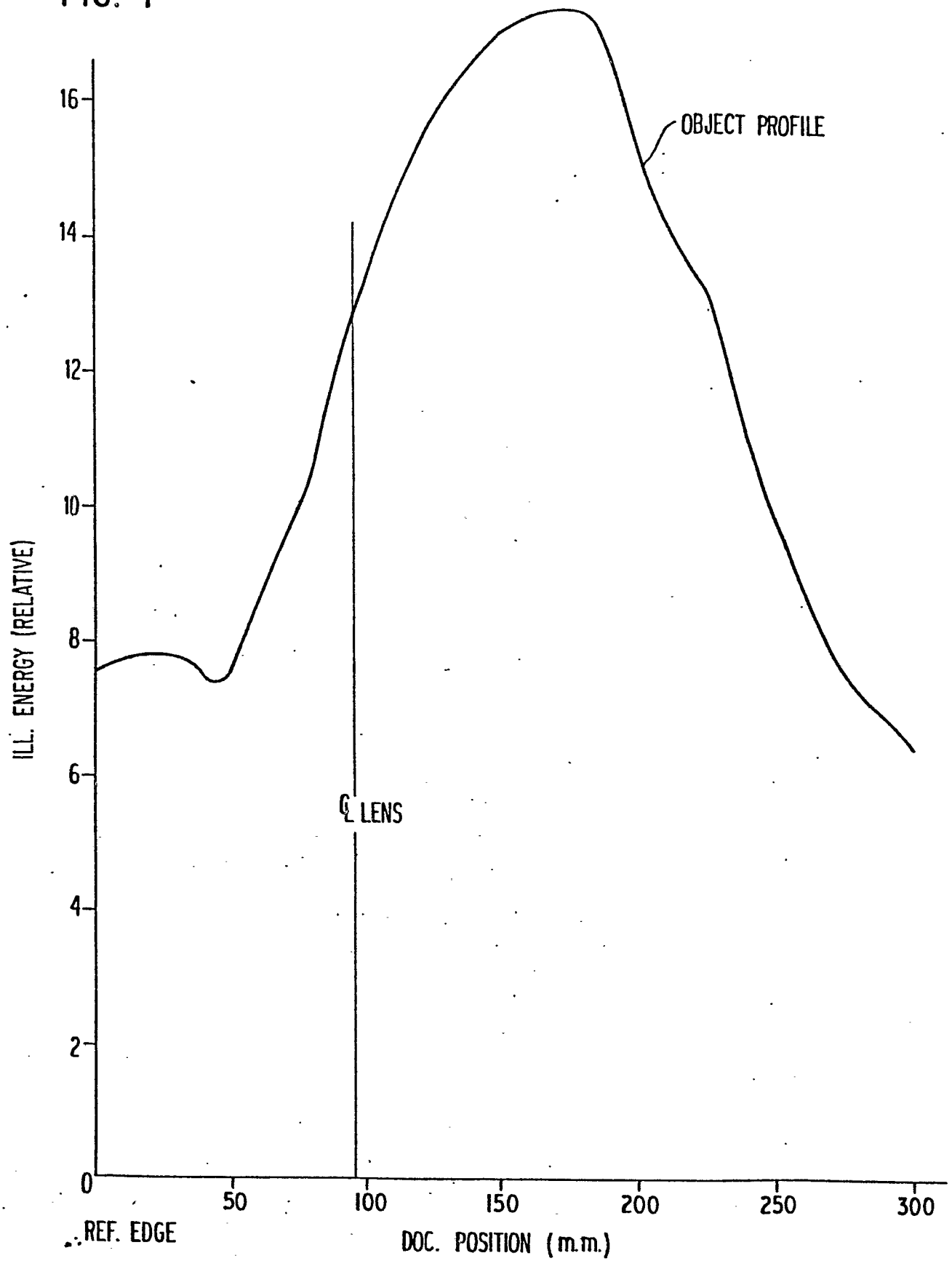


FIG. 5



4/4

FIG. 4





European Patent
Office

EUROPEAN SEARCH REPORT

0022175

Application number

EP 80 10 3074..3

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. CL ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
D	<u>DE - A1 - 2 842 104</u> (TOKYO SHIBAURA DENKI) * pages 3, 4; fig. 2 * --	1,2	G 03 G 15/052 G 03 B 27/50
	<u>GB - A - 1 079 231</u> (HALL HARDING) * claims 7 to 10; fig. 1, 6 * --	1-3	
	<u>DE - A1 - 2 553 665</u> (AGFA-GEVAERT) * fig. 1, 5 * --	1-3	
	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 --	1	TECHNICAL FIELDS SEARCHED (Int. CL ³) G 02 B 27/17 G 03 B 27/00 G 03 G 15/00
	<u>FR - A - 1 097 439</u> (LA VERRERIE SCIENTIFIQUE) * fig. 1, 2 * --	1	
	<u>DE - A1 - 2 738 301</u> (IBM) * fig. 3 * --	1	CATEGORY OF CITED DOCUMENTS X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
	<u>US - A - 4 057 342</u> (R.F. ALLIS) * claims 1 to 3; fig. 1, 9 to 13 * -- ./..	1	
X The present search report has been drawn up for all claims		&: member of the same patent family, corresponding document	
Place of search Berlin		Date of completion of the search 23-10-1980	Examiner HOPPE



EUROPEAN SEARCH REPORT

EP 80 10 3074.3

- page 2 -

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>DE - A - 2 129 791</u> (IBM) * claims * --		
A	<u>DE - A - 2 154 809</u> (IBM) * fig. 7 * ----		TECHNICAL FIELDS SEARCHED (Int. Cl.3)