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Gundlach et al.

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[54] **IMAGING SYSTEM**

[75] Inventors: **Robert W. Gundlach,** Victor; **Lloyd F. Bean,** Rochester, both of N.Y.

[73] Assignee: **Xerox Corporation,** Stamford, Conn.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 1,591, Jan. 9, 1970, abandoned.

[52] **U.S. Cl.** **354/110**

[51] **Int. Cl.** **G03b 35/08**

[58] **Field of Search** 95/12.21, 18; 355/4; 354/110

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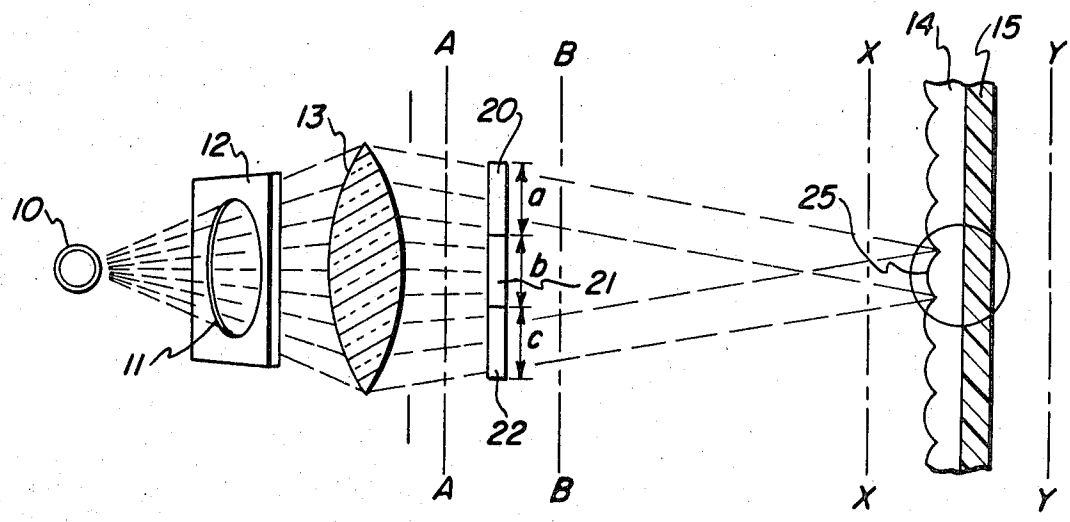
Primary Examiner—John M. Horan

Attorney, Agent, or Firm—James J. Ralabate; David C. Petre; Gaetano D. Maccarone

[57] **ABSTRACT**

A photographic system for exposing a photoreceptor to a light image of an object and including a plurality of light filters, each having a predetermined light-transmission density different from that of the others, for differentially attenuating the light in contiguous sections of the light image, and a transparent element having one surface formed with a plurality of adjacent lenticules, each lenticule focusing the differentially attenuated light image sections onto contiguous segments of the photoreceptor, whereby high light medium tone and shadow information of the object are recorded in the image produced on the photoreceptor.

13 Claims, 8 Drawing Figures



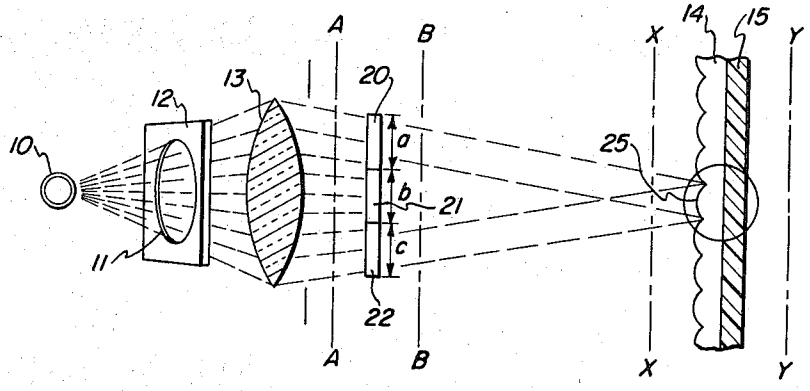


FIG. 1A

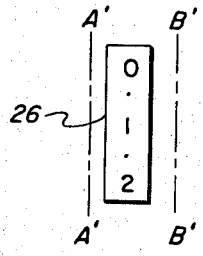


FIG. 1B

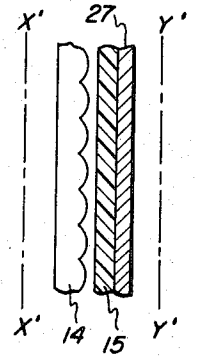


FIG. 1C

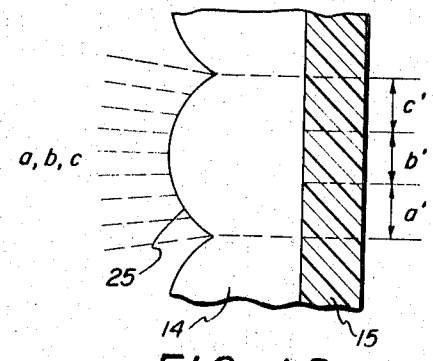


FIG. 1D

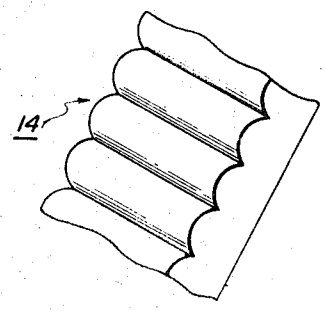


FIG. 2

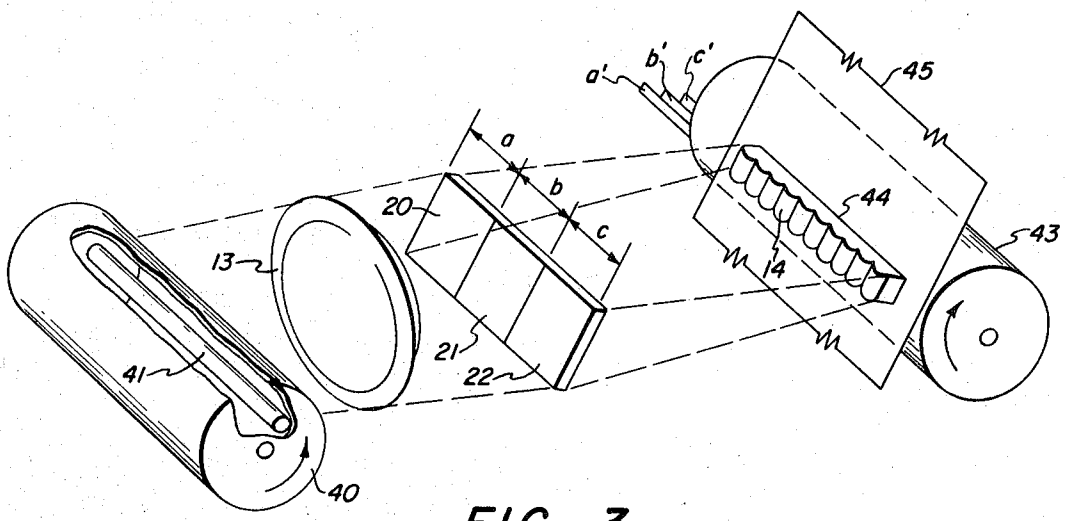


FIG. 3

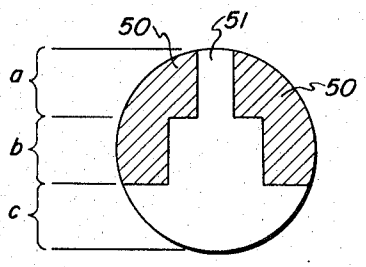


FIG. 4A

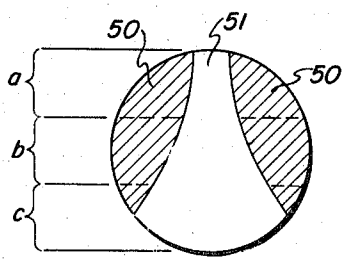


FIG. 4B

IMAGING SYSTEM

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of prior copending application Ser. No. 1,591, filed Jan. 9, 1970 now abandoned.

This invention relates to a method of, and photographic system for, exposing a photoreceptor to a light image. More specifically the invention relates to such a system which includes a plurality of light filters having different light transmission densities and a lenticulated element for controlling light contrasts on contiguous segments of the photoreceptor behind each lenticule.

The prior art is aware of multi-color photographing systems in which a plurality of discrete color filters is employed to transmit three color separations (blue, red and green, for example) via a lenticulated surface onto a photoreceptor for subsequent blending of the separated colors thereon. One such system is disclosed, for example, in U.S. Pat. No. 3,322,034 issued to D. S. Cary on May 30, 1967. It is noted, however, that the patented color-blending system does not disclose the use of a plurality of filters varying in light-transmission density at all wavelengths equally and a lenticulated element for recording highlight, medium tone and shadow information on the photoreceptor regarding light contrasts of an object whose image is produced thereon.

It is known in the art that various photoreceptors have a dynamic range which is not adequate to provide quality tone reproduction with a reasonably full latitude of contrast when the photoreceptors are used to reproduce certain types of continuous tone and/or high contrast original images. For example, amorphous selenium photoconductors, while producing line copy and other high contrast in excellent fashion have a relatively short dynamic range of about 0.6 density units when used in combination with conventional xerographic development processes such as cascade development. The dynamic range of a photoreceptor, as used herein, is intended to mean that range of original image densities which will produce a viewable change in the density of the reproduction produced by the photoreceptor where density $= D = \log 1/R$ and R represents the ratio of reflected light to incident light. For example, in a very dense area of an original or reproduction where only one-tenth of the incident light is reflected back to the eye of a viewer, $R = 1/10$ and the log of $1/R$ i.e., density of the area, is 1. A density of 1.3 is where about one-twentieth of the incident light is reflected back to the viewer. Generally speaking, reflection densities of anywhere from about 1.2 to 1.5 or above appear to the human eye as a very dense black. Therefore it is generally considered that the photoreceptor in a given imaging system should have a dynamic range of about 1.2 to 1.5 or above to produce a quality tone reproduction with a reasonably full latitude of contrast for contiuous tone and/or high contrast originals. As aforesaid, it is recognized that various photoreceptors do not meet this requirement. Thus there exists continuing need for methods and apparatus to improve the dynamic range of photoreceptors.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide the above-described desirable characteristics.

It is another object of the invention to provide a photographic system capable of providing improved light contrast in an image formed on a photoreceptor.

It is a further object of the invention to provide such a photographic system which provides improved light contrast is monochromatic and/or polychromatic images formed on a photoreceptor.

Still another object of the invention is to provide controllable amounts of light in adjacent sections of a light image at the image plane of a photoreceptor.

A still further object of the invention is to lenticularly focus differentially attenuated contiguous sections of a light image on contiguous sections of a photoreceptor at the image plane thereof.

Yet another object of the invention is to extend the dynamic range of a photoreceptor.

Another object of the invention is to extend the dynamic range of a xerographic plate.

A further object of the invention is to improve the highlight segment of an image formed on a photoreceptor.

Yet another object of the invention is to improve the medium tone segment of an image formed on a photoreceptor.

Still a further object of the invention is to improve the shadow segment of an image produced on a photoreceptor.

These and other objects and advantages are accomplished in accordance with the present invention by providing a photographic system which includes light attenuation means varying in light-transmission density at all wavelengths equally for differentially attenuating light in contiguous sections of a light image; and a transparent lenticulated element in which each lenticule focuses the differentially attenuated contiguous light image sections on contiguous segments of a photoreceptor thereby resulting in improved light contrast in the latter segments. The novel photographic system is operable with respect to the formation of both monochromatic and/or polychromatic images on a photoreceptor.

Generally speaking, the present novel photographic system provides the above-described advantageous results by "overexposing" some areas of the original image in order to properly reproduce the shadow areas, while "underexposing" other areas of the original image in order to properly reproduce the highlight areas. In this manner some portions of the photoreceptor receive a great deal more light than other portions thereof.

The invention will be more readily understood from the following detailed description of various preferred embodiments thereof particularly when read in conjunction with the accompanying drawings wherein:

FIG. 1A is a partially schematic, cross-sectional view of one embodiment of the photographic system of the invention;

FIG. 1B illustrates a portion of the system shown between vertical lines A'–A' and B'—B' and substitutive for the portion of the system included between lines A—A and B—B in FIG. 1A;

FIG. 1C illustrates a portion of the system illustrated between vertical lines X'—X' and Y'—Y' and substitu-

tive for the portion of the system included between the vertical lines X—X and Y—Y in FIG. 1A;

FIG. 1D illustrates, greatly magnified, contiguous light-controlled segments of the image formed on the photoreceptor shown in FIG. 1A;

FIG. 2 is a fragmentary perspective view of a component (shown encircled) of the embodiment shown in FIG. 1A;

FIG. 3 is a partially schematic illustration of another embodiment of the photographic system of the invention; and

FIGS. 4A and 4B illustrate typical light filters which may be used in the photographic system of the invention.

As aforesaid, the novel photographic system is operable with respect to the formation of both monochromatic and polychromatic images on a photoreceptor. Thus it should be recognized that both monochromatic imaging systems and polychromatic imaging systems are encompassed within the scope of the present invention. It should be understood that by "a monochromatic imaging system" is meant one in which the visible image formed is monochromatic, e.g., black and white; and that by a "polychromatic imaging system" is meant one in which the visible image formed is polychromatic, i.e., contains a plurality of the various individual colors present in the visible spectrum. The particular photoreceptor utilized in the photographic system may be one which itself forms the visible image such as, for example, photographic film; or one on which a latent image is formed and a developer material is added to develop the latent image. In the latter embodiment the developer material makes up the visible image.

Of course it will be understood by those skilled in the art that many embodiments of monochromatic and polychromatic imaging systems are possible according to the novel photographic system of the invention. For example, consider monochromatic imaging systems. In such systems the original object which is to be reproduced on a photoreceptor may be monochromatic or polychromatic. Of course, where the original object is monochromatic the photoreceptor employed in any particular embodiment may be monochromatic, e.g., black and white photographic film, or polychromatic, e.g., multicolor photographic film, and the image formed on the photorecptor will always be monochromatic. However there are instances where the original image is polychromatic and it is desired to form a monochromatic image on the photoreceptor. One technique by which this result may be accomplished is through the use of any monochromatic photoreceptor, i.e., one which is capable of forming only monochromatic images such as, for example, black and white photographic film. Another technique for achieving this results resides in the use of a photoreceptor which is not itself the image material such as, for example, a conventional xerographic imaging member. In this instance a panchromatic photoconductive insulating material, i.e., one which responds about equally to all wavelengths of the visible spectrum or at least wavelengths well distributed across the visible spectrum, may be used, an electrostatic latent image formed thereon according to the well known xerographic imaging process and the latent image developed with a monochromatic developer material which may be any color.

Many various embodiments of polychromatic imaging systems are possible according to the photographic system of the invention. Of course in the polychromatic imaging systems the original object desired to be reproduced will be a multicolor object; and the photoreceptor may be, for example, a polychromatic photoreceptor which itself forms the visible image or a panchromatic photoconductive insulating material. It will be understood that the embodiments of the invention described above are not intended to be exhaustive of all the embodiments which are possible according to the novel photographic system. Rather, these embodiments are intended to be illustrative and are set forth to better aid those skilled in the art to understand and appreciate the invention.

In combination with an optical photographic system including an object, a source of light for providing a light image of the object, a photoreceptor and an optical lens for focusing the light image onto the photoreceptor, a specific embodiment of the invention comprises light filter means disposed in proximity of the lens and varying in predetermined light-transmission density at all wavelengths equally for differentially attenuating light in contiguous sections of the light image as focused by the lens; and a lenticulated element positioned ahead of the photoreceptor whereby each lenticule of the lenticulated element focuses the differentially attenuated contiguous light sections on contiguous segments of the photoreceptor for extending the dynamic range thereof.

Referring now to FIG. 1A there is seen a light source **10**, which may be any suitable photographic light source, directing light upon a transparent object **11** carried by a suitable material **12** to provide a light image of the object. Although the object is shown as a transparency exposed by transmission this is intended to be illustrative only and it will be clearly apparent that any type or original image may be employed such as, for example, an opaque original which is exposed by reflection. Furthermore although the object is shown in inanimate form for the purpose of illustration, it may also comprise a three dimensional and movable form such as, for example, an animal or a person posed in a stationary position at the moment. Of course, the object may be monochromatic or polychromatic.

Optical lens **13** transmits the light image therethrough and at the same time focuses the light image onto a suitable photoreceptor which may be any suitable monochromatic or polychromatic photoreceptor. By the term "monochromatic photoreceptor" as used herein is meant one which is capable of forming only a monochromatic image. Typical suitable monochromatic photoreceptors which may be used in accordance with the invention include, for example, black and white photographic film; and monochromatic photoelectrophoretic imaging suspensions such as are described in U.S. Pat. No. 3,384,566.

By the term "polychromatic photoreceptor" as used herein is meant one which is capable of forming a multicolor image in accordance with the photographic system of the invention. Typical suitable polychromatic photoreceptors which may be utilized in the photographic system include, for example, any of the commercially available polychromatic photographic films; polychromatic photoelectrophoretic imaging suspensions such as are described in U.S. Pat. No. 3,384,488; panchromatic photoconductive insulating plates such

as are described in copending application Ser. No. 50,265, filed June 26, 1970; and any of the many photoconductive insulating materials known for use in the xerographic reproduction process which are not panchromatic photoconductors but which respond to wavelengths of more than one color of the visible spectrum.

In accordance with the specific embodiment of the invention shown in FIG. 1A, a light filter means comprising a plurality of discrete light filters **20, 21** and **22,** each provided with a predetermined neutral light-transmission density different from that of the other filters, is disposed in proximity of the lens **13**, i.e., intermediate the optical lens **13** and the photoreceptor **15,** in a direction perpendicular to the plane of the paper and at least coextensive with the width of the photoreceptor. Although the light filters have been shown positioned between the lens **13** and photoreceptor **15,** this is for the purpose of illustration only and it should be recognized that the light filters may be alternatively arranged between the object **11** and the lens **13** without impairing the operation of the inventive photographic system. Moreover, although the light filter means is shown as being comprised of three discrete filters it should be understood that other types of structures may be utilized as the light filter means in accordance with the invention. For example, the light filter means may be made up of any plurality of discrete filters (two or more) of the type described above. In addition the light filter means may comprise a unitary structure **26,** such as is illustated in FIG. 1B, continuously varying in light transmission density between two preselected different integral numerical values (0 and 2 for example) to constitute discrete zones in the manner of filters **20, 21** and **22.**

The light filters themselves may be made up of a developed silver halide emulsion, partially metallized glass or even a screen or other pattern comprised of opaque areas and light-transmitting windows. A single shaped aperture could also selectively limit the amount of light transmitted by each portion of the lens **13.** Typical suitable shaped apertures which may be utilized are illustrated in FIGS. 4A and 4B having light-transmitting areas **50** and opaque areas **51.** Light filters **20, 21** and **22** are provided with the respective predetermined light-transmission densities at all wavelengths equally for differentially attenuating the light in three contiguous sections of the light image transmitted through the optical lens **13** and focused on the photoreceptor **15** for a purpose that is explained below.

Lenticulated element **14** is disposed immediately ahead of the photoreceptor so as to focus the light image on the photoreceptor. The lenticulated element **14** may be arranged in contact with the photoreceptor **15** with the individually contiguous lenticules facing in the direction of the light filters as is illustrated in FIG. 1A. Where such an embodiment is employed the lenticulated element may be permanently or detachably affixed to the photoreceptor as desired depending upon the particular circumstances surrounding the practice of the novel photographic reproduction system. Alternatively the lenticulated element may also be positioned with the individual lenticules in a direction facing the photoreceptor but fixedly secured in spaced relation therewith as is illustrated in FIG. 1C. The individual lenticules are disposed in a direction perpendicular to the plane of the paper and at least in coextensive relation to the light filter means and the photoreceptor. The individual lenticules are arranged in side-by-side relation as is illustrated in FIGS. 1A and 2.

In the operation of the specific embodiment of the invention as shown in FIGS. 1A, 1B and 1C the differentially attenuated light transmitted via the filters **20, 21** and **22** through the contiguous sections of the optical lens **13** is now focused, for example, on lenticule **25.** Lenticule **25** then focuses the differentially attenuated light image sections *a*, *b*, and *c*, for example, to produce corresponding contiguous light-controlled segments *a'*, *b'*, and *c'* of the image (not shown) formed on the photoreceptor as indicated in FIGS. 1A and 1D. As a consequence, the image formed on the photoreceptor due to a low filter density section *a* is represented as a shadow recording segment *a'*, a medium filter density section *b* is represented as a medium tone recording segment *b'* and the greatest filter density section *c* is represented as segment *c'* wherein image highlights are reproduced.

It is therefore to be understood that the filter **20** attenuates a large fraction of light in the image at all wavelengths equally to produce an underexposed image which differentiates only the image highlights, filter **21** attenuates approximately one-half the light in the light image to provide optimum exposure for the medium tones of the image and filter **22** attenuates none or a small amount of the light in the light image to effect optimum exposure of the shadow, or high density portions of the image. It is obvious that the focusing action of lenticule **25** is duplicated by the remaining lenticules included in lenticulated element **14.** Accordingly the entire image produced on the photoreceptor is a result of the integration of the shadow, medium tone and highlight segments provided thereon, thereby effectively accomplishing an extension of the dynamic range of the photoreceptor.

As aforesaid, the lenticulated element may be manually detached from the photoreceptor and discarded, thereby leaving the photoreceptor with the image thereon as the final product of the embodiment illustrated in FIG. 1A. Of course where a reuseable photoreceptor is employed, e.g., a reuseable xerographic plate, the lenticulated element is preferably made an integral part of the photoreceptor. When this mode of operation of the invention is practiced the lenticulated element could be part of the transparent substrate for a photoconductive insulating layer with the charging, development, transfer and cleaning steps taking place on the photoconductive insulating surface of the xerographic plate.

On the other hand the lenticulated element may be arranged with the individual lenticules facing the photoreceptor but in spaced relation thereto, typically separated therefrom by a distance equal to the focal length of the lenticule, to constitute a fixed component in the system as is illustrated in FIG. 1C. In FIG. 1C the photoreceptor is shown attached to a supporting member **27.** Where an expendable photoreceptor is utilized in the practice of the invention, e.g., Polaroid film, conventional silver halide film or single use xerographic members, this embodiment is preferred since the lenticulated element may be used with many different individual photoreceptors.

From the foregoing discussion it can be seen that each of filters **20, 21** and **22** in FIG. 1A attenuates the light in the light image transmitted through one of three

continguous sections of the optical means, and each lenticule focuses the outputs of all three filters onto contiguous sections of the photoreceptor to provide the light contrasts in the reproduced image. As aforesaid, any plurality of discrete filters may be used in place of the three discrete light filters shown in FIG. 1A. In such an instance each of the plurality of filters is provided with a predetermined light transmission density different from that of the others. Each discrete filter attenuates the light in the light image transmitted through a corresponding portion of the optical means. Therefore each lenticule will focus the attenuated light image received from the plurality of filters onto a corresponding number of adjacent segments of the photoreceptor to provide light contrast therebetween in the manner described above.

Where the novel photographic system is employed in the monochromatic imaging mode with any photoreceptor, or in the polychromatic imaging mode in conjunction with a photoreceptor such as a multicolor photographic film or a polychromatic photoelectrophoretic imaging suspension then only one exposure of the original object is required. It should be understood that where the invention is practiced in the polychromatic mode with a photoreceptor such as a panchromatic xerographic plate a plurality of color separations, typically three, are made and then combined in registration on a final receiver member. Of course in this embodiment the same light source, e.g., a white light source, may be used for each exposure with appropriate color filters being utilized to obtain the proper wavelengths of light for each color separation.

According to another embodiment of the invention wherein it is practiced in a continuous process, the object and photoreceptor may be positioned on oppositely rotating drums while at the same time the light filter means and lenticulated element are maintained in a fixed position between the rotating drums. Referring now to FIG. **3** there is seen a photographic system including a drum **40** rotating in a counterclockwise direction, for example, as indicated by the arrow and carrying on a peripheral surface thereof a transparent object (not shown) illuminated by a light source **41** of suitable light mounted in a fixed position interiorly of the drum. Of course in this embodiment the drum surface may be opaque except in the vicinity of the object area. Of course the object to be reproduced could be opaque in which case it would be carried by the peripheral surface of drum **40** and exposed by reflection.

A light image of the object is focused via lens **13** onto a photoreceptor mounted on the peripheral surface of drum **43** rotating in a clockwise direction, for example, as indicated by the arrow. The operation of a photographic system having this basic structure is well known in the art.

Light filters **20, 21** and **22** are mounted in proximity of the lens **13** in a fixed position between the lens and the drum **43.** Of course, the light filters could be alternatively mounted in a fixed position between drum **40** and lens **13.** The transparent lenticulated element **14** is suitably mounted over an elongated aperture **44** formed in a plate **45** fixed in a position in front of drum **43.** The operation of the photographic system illustrated in FIG. **3** is identical with that of FIGS. **1A–1D** as previously described.

While the invention has been described in detail with respect to certain preferred embodiments thereof it is not intended to be limited thereto but rather it will be appreciated by those skilled in the art that modifications and variations are possible which are within the spirit of the invention and the scope of the claims.

What is claimed is:

1. A photographic apparatus comprising:

a. optical means for producing a light image;

b. a photoreceptor;

c. light attenuation means varying in light transmission density equally at all light wavelengths in preselected different light density ranges for differentially attenuating said light image in corresponding different light density ranges as said light image is transmitted through said light attenuation means; and

d. lenticulated means comprising a surface having a plurality of cylindrically shaped segments for receiving a portion of said differentially attenuated light image and for focusing that portion of the differentially attenuated light image onto a corresponding segment of the photoreceptor in preselected contiguous areas,

wherein said apparatus is capable of forming a reproduction of an original image which when viewed in its entirety will show more of the image information present in the original image than a reproduction of the original image which was recorded on the photoreceptor without using the light attenuation means and the lenticulated means.

2. The apparatus as defined in claim **1** wherein said photoreceptor is polychromatic.

3. The apparatus as defined in claim **2** wherein said photoreceptor comprises a polychromatic photographic film.

4. The apparatus as defined in claim **2** wherein said photoreceptor comprises a polychromatic photoelectrophoretic imaging suspension.

5. The apparatus as defined in claim **2** wherein said photoreceptor comprises a panchromatic photoconductive insulating material.

6. The apparatus as defined in claim **1** wherein said photoreceptor is monochromatic.

7. The apparatus as defined in claim **6** wherein said photoreceptor comprises black and white photographic film.

8. The apparatus as defined in claim **6** wherein said photoreceptor comprises a monochromatic photoelectrophoretic imaging suspension.

9. The apparatus as defined in claim **1** wherein said photoreceptor comprises a photoconductive insulating material.

10. The apparatus as defined in claim **1** wherein said light attenuation means comprises at least two discrete light filter means, each provided with one of said preselected different light transmission density ranges.

11. The apparatus as defined in claim **1** wherein said light attenuation means comprises three discrete light filter means, each provided with one of said preselected different light transmission density range.

12. The apparatus as defined in claim **1** wherein said light attenuation means comprises a unitary light filter means continuously varying in light transmission density between two preselected different integral numerical values.

13. The apparatus as defined in claim **1** wherein said photoreceptor is mounted on the peripheral surface of a rotating drum and said light attenuation means and said lenticulated means are mounted in fixed positions with respect to said rotating drum.

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