United States Patent

Young

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[54] COLOR PRINTING SYSTEM

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[73] Assignee: Xerox Corporation, Rochester, N.Y.

[22] Filed: Dec. 2, 1969

[21] Appl. No.: 789,090

[52] U.S. Cl. 355/88, 355/38, 355/83, 355/103

[51] Int. Cl. G03b 27/04

[58] Field of Search 355/88, 84, 83, 95, 99, 103, 355/35, 36, 37, 38

[56] References Cited

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Primary Examiner—John M. Horan

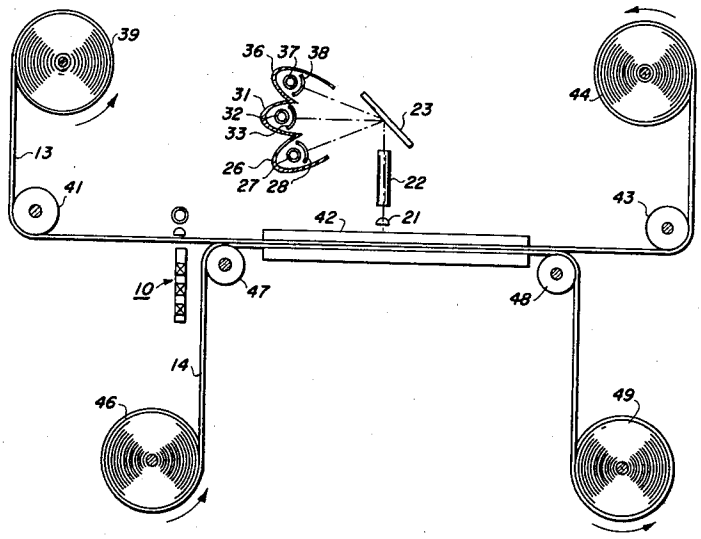
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[57] ABSTRACT

An exposure control system having application in a color contact printer wherein the master film is sampled on a line at a time basis by a detecting head. The detecting head may comprise a continuous light source, a cylindrical lens, a light pipe and a plurality of photodetectors. Each photodetector furnishes an output representing the sensed light which has been modulated in color and intensity as the result of its passage through the master film. This detected or sensed light is thereafter applied to an analog computer for processing. The computer furnishes control data to a plurality of phosphor-excited printing light sources which are modulated in color and intensity thereby. Concurrently, the printing light sources expose duplicating material or film while in contact with the master film.

9 Claims, 8 Drawing Figures



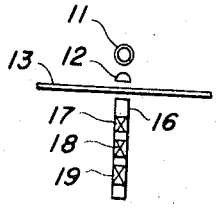


FIG. 1b

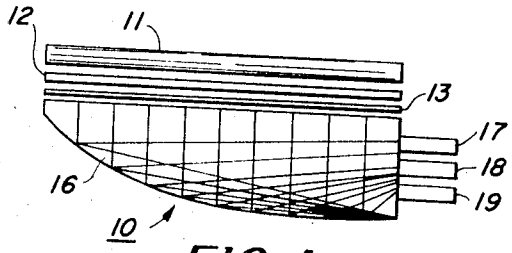


FIG. 1a

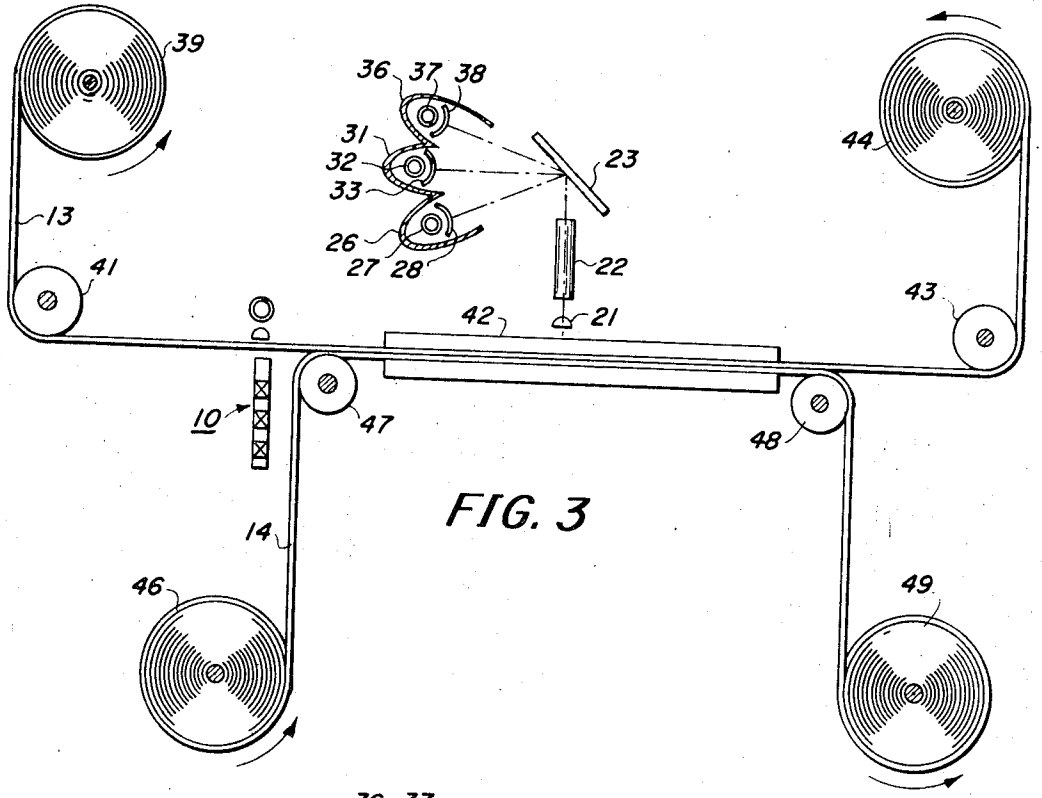


FIG. 3

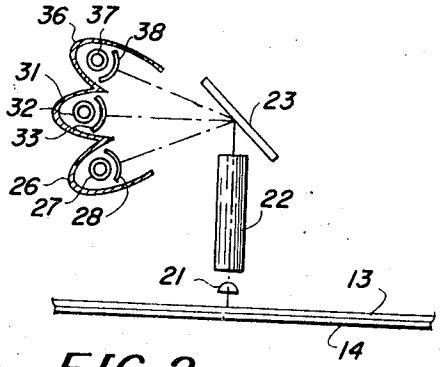


FIG. 2

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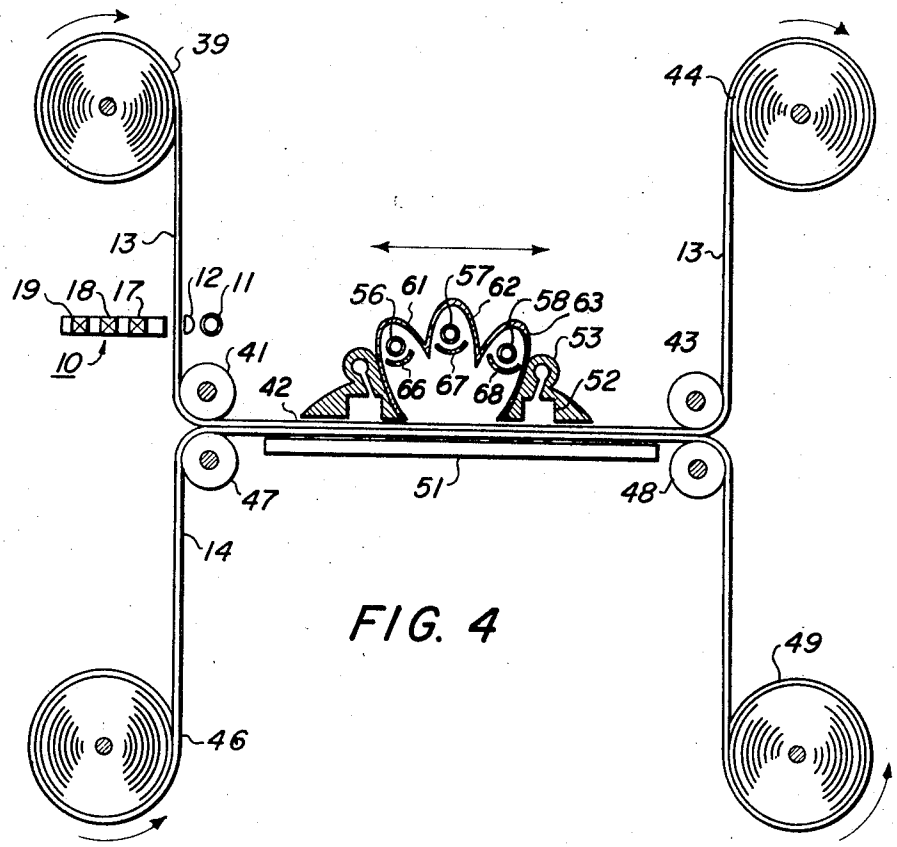

39
44
13
13
19
18
17
12
11
56
61
57
62
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43
41
42
66
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68
52
10
47
51
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14
49
46

FIG. 4

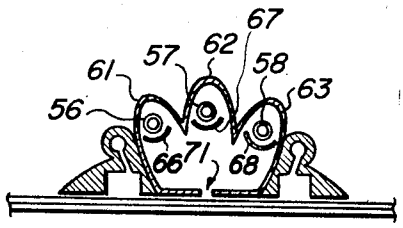

67
62
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61
58
63
56
66
71
68

FIG. 5

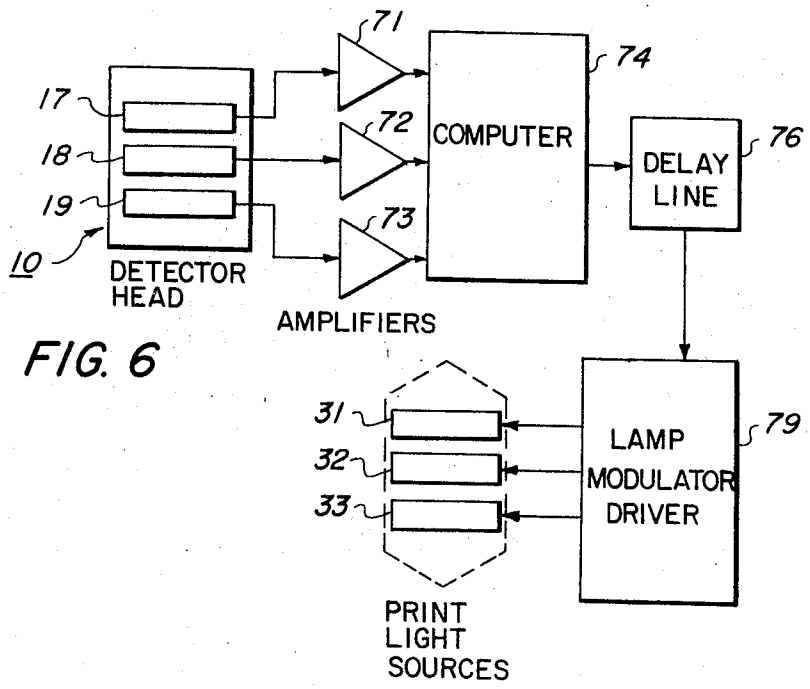

71
74
17
72
COMPUTER
76
18
DELAY
LINE
19
73
10
DETECTOR
HEAD
AMPLIFIERS
31
LAMP
79
32
MODULATOR
DRIVER
33
PRINT
LIGHT
SOURCES

FIG. 6

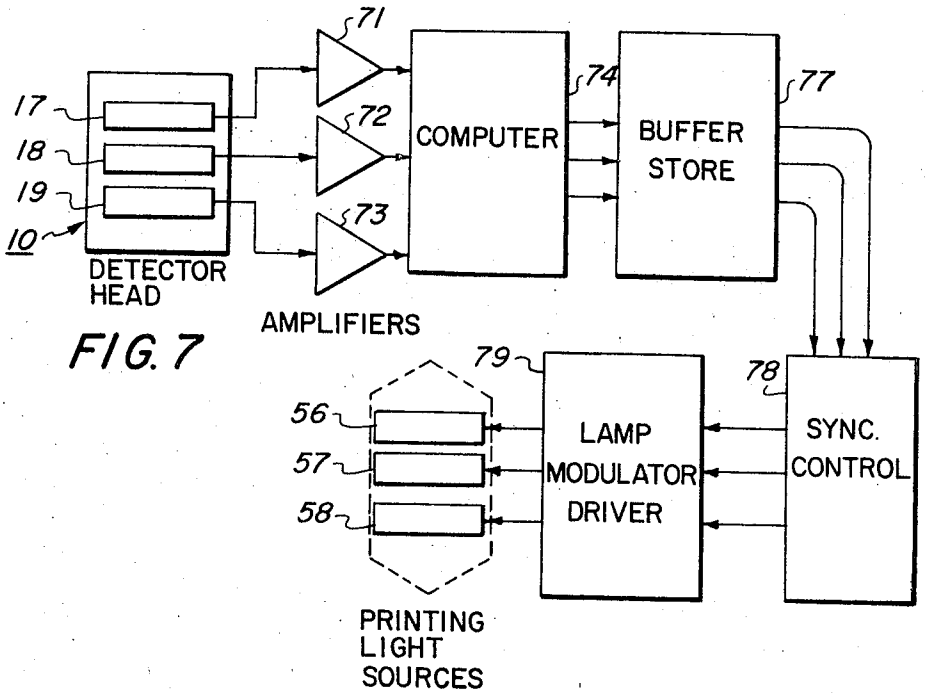

71
17
74
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COMPUTER
BUFFER
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DETECTOR
HEAD
AMPLIFIERS
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LAMP
SYNC.
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MODULATOR
CONTROL
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DRIVER
PRINTING
LIGHT
SOURCES

FIG. 7

COLOR PRINTING SYSTEM

This invention relates to photography. More particularly, this invention relates to an automatic exposure control system for contact exposure of undeveloped photographic stock from photographic color negatives or transparencies.

The exposure control device referred to controls the exposure of light in three regions of the spectra to color-sensitive material. The three regions of the spectra are for example the three primary colors, red, green and blue.

BACKGROUND OF THE INVENTION

For some time workers in color photography have been interested in color contact printers. Contact printing is the process of exposing a photographic sensitive duplicating film, paper or the like while in physical contact with a negative or transparency to be reproduced. The problems of achieving color contact printing have been many fold. First of all it was necessary to achieve control over contact printing in black and white photography. In the past it was a matter of trial and error and reliance upon the experience and competence of the technician, to obtain a good print from a negative in black and white contact photography. The problems of inspecting the negative and attempting to obtain an exposure which corresponded to the average density of the transmission characteristics of the image transparency were exceedingly difficult and the results were not always consistent. The technique of balancing the exposure is referred to as "dodging." That is, the negative is selectively illuminated through means of an optical system and thereby the print achieves a balanced exposure. The difficulties attendant with black and white photographic contact printers are increased when color photographic contact printers are attempted. Not only is there concern over the problem of obtaining a print which corresponds to the average density of the transmission characteristics of the image transparency, but there is also the problem of obtaining faithful color reproduction.

It is known in the prior art to expose color-sensitive film to red, green and blue light sources so as to achieve color balance on the print. These devices are represented by U.S. Pat. No. 3,341,441. However, these devices were principally employed in full frame printing or exposure and they had the drawback of requiring mechanical insertion of color filters over a white light source. In addition, adaptation of color correction on a gross full frame basis in continuous or step and repeat printers would be inadequate since they do not achieve the point to point color balance desired.

BRIEF DESCRIPTION OF THE INVENTION

The present invention is adapted to control the exposure of a photosensitive emulsion by detecting the light modulated in color and intensity as it passes through a color negative, transparency or the like. This modulated light is detected and sent to printing light sources of red, green and blue which in turn modulate the photosensitive color material while in contact with the color negative to achieve a print which has high color fidelity and color compensation to the original negative. It is also a feature of this invention that the exposure proceeds a line at a time as opposed to the full frame exposure of the prior art. The line at a time exposure permits increased control over color balance throughout the print since smaller areas are sampled and controlled as opposed to gross control over full frame areas. Another important feature of the present invention is the provision of three light sources each enclosed within a phosphor-coated elliptical mirror. These light sources are so arrayed that the focal line of each is common. The phosphors employed in the elliptical mirrors have the property of supplying the desired colored light and of concentrating the scattered light. The present invention is capable of use with either a continuous printer, a step and repeat printer, or any other color development process. In a continuous printer embodiment the detected color and intensity-modulated light is amplified and fed to a computer. The computer processes these signals and sends them to a delay line. At the proper time the delayed signals are supplied to the exposure area. In the step and repeat printer the signals processed by the computer are stored in a buffer stage and are retrieved when the respective area of the negative has reached the exposure area. At that time the signals modulate the printing light sources to expose the duplicating material.

It is an object of this invention to provide a color contact printer exposure control which scans and samples a negative or transparency on a line-at-a-time basis.

It is another object of this invention to provide a color contact printer wherein the individual controllable printing light sources are modulated by the detected light passing through a negative or transparency.

It is another object of this invention to employ hydrostatic bearing techniques to maintain the separation between the printing head containing the individually controllable light sources and the film to be exposed.

It is still a further object of this invention to control the exposure of color photosensitive material or film employing a computer which processes the detected color and intensity signals and delays or stores them before applying them to printing light sources.

These and other objects of the invention are achieved by means of an exposure control device which modulates the color and intensity of light from printing light sources in a color contact printer.

In order to gain a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description of the invention to be read in conjunction with the accompanying drawings wherein:

FIG. 1*a* shows an elevational view of the sampling detector head;

FIG. 1*b* is a side view of the sampling detector head;

FIG. 2 is a diagrammatic presentation of the printing light sources;

FIG. 3 is a diagrammatic presentation of the continuous motion color film contact printer;

FIG. 4 is a diagrammatic presentation of the step and repeat open gate color film contact printer;

FIG. 5 is a diagrammatic presentation of the air bearing color variable printing light sources;

FIG. 6 is a block diagram of a continuous color contact printer employing computer processing of the detected color and intensity; and

FIG. 7 is a block diagram showing a step and repeat color contact printer also employing computer processing.

Referring to FIGS. 1*a* and 1*b* there is a sampling detector head shown generally at **10** having a light source **11**. The light source **11** may be a quartz iodide lamp or any suitable source of continuous white light. In one embodiment of the invention the light source is a fluorescent lamp having the desired spectral characteristics.

It should be noted that in the preferred embodiment of the invention a lighttight enclosure is provided for the light sources and optics in order to prevent scattering of light. It is also understood that suitable support is provided for the light sources, the optics and other components to be disclosed hereinafter.

Spaced from the light source **11** is a cylindrical lens **12** having its convex surface facing light source **11**. The purpose of lens **12** is to focus the light emanating from the light source **11** into a line light source. An alternate means of obtaining a line light source would be to furnish an exposure gate at the detector head just above light pipe **16** and eliminate lens **12**. The master film or negative **13** is situated below the flat surface of cylindrical lens **12** and held in place by suitable supports. The negative may be a continuous web or separate film sheets. The light passing through the negative having been color and intensity modulated by its passage through the film is collected by a light pipe **16**. The light pipe **16** is formed of a suitable plastic such as an acrylic and is shaped so that most of the incident light falling on its curved surface is reflected uniformly

toward the three photodetectors, red **17**, blue **18** and green **19**. The light pipe **16** shown in elevation has a horizontal flat surface and a vertical flat surface which intersect to form an L. The two legs of the L are joined by a generally arcuate surface. The long leg of the L of the light pipe is situated so that the incident light is normal to it and the arcuate surface reflects the collected light on to the short leg of the L wherein are located the photodectors **17**, **18** and **19**. With proper design, the light which is collected by the light pipe **16** will be uniformly reflected over the photodetector area and provide an integrated sample of the impinging light. Although a light pipe is shown it is understood that any suitable arrangement which concentrates the light on to the photodetectors would suffice. The photodetectors **17**, **18** and **19** receive an integrated sample of the light passing through the master film or negative on a strip or slit scan basis.

The samples obtained by the three photodetectors **17**, **18** and **19** are amplified with the appropriate gain correction factors to compensate for the relative response of each cell. The gain factor correction or scaling can be made adjustable thereby by providing variation of the color balance of the output duplicates for image enhancement. This amplified and scaled output from the photodetectors is through analog computer means applied to modulate the printing light sources to be discussed hereinafter.

Referring to FIG. **2**, the printing light sources red **27**, blue **32** and green **37** may be standard ultraviolet lamps of 2,537 A. However, any other suitable light sources could be employed. The light sources chosen herein are preferred because they lend themselves to the desired control of exposure. Each light source **27**, **32** and **37** is enclosed within an elliptical mirror **26**, **31** and **36**. The elliptical mirrors are phosphor coated. For example, elliptical mirror **26** is coated with a red phosphor, elliptical mirror **31** is coated with a blue phosphor and elliptical mirror **36** is coated with a green phosphor. The specific phosphor coating substances will be discussed hereinafter in more detail with the description of FIG. **5**. The red, blue and green phosphors are chosen so that they will emit color and intensity-modulated light consistent with their individual related photodetector. Each printing light source **27**, **32** and **37** also has a tapered density filter or mask **28**, **33** and **38** respectively. Each density filter **28**, **33** and **38** is enclosed within its elliptical mirror so that the printing light source is between the end wall of the elliptical mirror and the density filter. The density filters are each coated with the same phosphor as their corresponding elliptical mirror. The purpose of the density filter or mask is to reduce light scattering and to reflect scattered light back on to the elliptical mirror so that the light may be focused into a line on flat surface mirror **23**. As shown in FIG. **2** the elliptical mirrors and printing light sources are arrayed so that the light emanating from each mirror has a common focal line on to flat surface mirror **23**. The impinging light on mirror **23** has an angle of incidence so that most of the light is reflected on to a cellular or honeycomb collimator **22**. The collimator **22** collects that light in parallel beams and focuses them on to the convex surface of a second cylindrical lens **21**. The cylindrical lens **21** is situated transversely of a so-called film sandwich comprising master film **13** and duplicating material **14** and focuses color and intensity-modulated light line source on to the film sandwich.

Referring now to FIG. **3**, there is shown a schematic diagram of a preferred embodiment of a continuous motion color film contact printer. In FIG. **3** the master film **13** travels by suitable transport means from supply reel **39** over idler roller **41**, through the sampling detector head **10** into the printing gate **42**, over idler roller **43** to the takeup reel **44**. The duplicating material **14** travels in synchronism with the master film from the duplicating supply reel **46** over idler roller **47** into the printing gate where it is exposed to the printing light sources and lens a line at a time while in close contact with the master film **13**. The duplicating material then moves over idler roller **48** and then to takeup duplicating reel **49**. In FIG. **3** the orientation of the detector head **10** is transverse to the direction of motion of the master film **13**. Likewise, the printing lens **21** is also positioned transversely to the direction of motion of the film sandwich consisting of the master film **13** and duplicating material **14** in the printing gate zone **42**. However, the physical location of the various components may vary according to the desired design.

Referring to FIG. **4**, there is shown a step and repeat open gate color film printer which is similar to the printer shown in FIG. **3**. However, in FIG. **4** a moveable air bearing pad **52** is provided to maintain the separation between printing light sources **56**, **57** and **58** and the film sandwich comprising the master film **13** and the duplicating material **14**. The air bearing pad **52** supports or carries the printing light sources **56**, **57** and **58** which are arrayed to project their light on to a common focal line. The air bearing pad **52** is encircled by an air plenum **53** and suitable means are employed such as air ducts to furnish air to the air bearing pad. The detecting head **10** is oriented differently in FIG. **4** from its orientation in FIG. **3**. However, the master film is still detected before arriving at the printing gate. A support platen **51** supports the film sandwich as it passes through the exposure station.

In FIG. **5** the air bearing pad **52** and light sources are shown in more detail. Three colors of phosphor red, blue and green coat the elliptical mirrors **61**, **62** and **63** of the individual light sources. The phosphor coatings can be tailored to suit any desired color response by the use of mixtures of commercially available materials. The binder materials for the phosphor may comprise any suitable resin or resin mixtures. Typical resins include polymethacrylate, polyvinylchloride, polyvinylacetate, or polystyrene. The red phosphor may be zinc phosphate $Zn_3(PO_4)_2$:Mn or $Zn_3(PO_4)_2$:Eu. The europium-activated equivalent $Zn_3(PO_4)_2$:Eu will provide higher efficiencies. An alternate red phosphor of lower efficiency may be zinc cadmium sulfide (Zn,Cd)S:Ag. For the blue phosphor calcium magnesium silicate $CaMg(SiO_3)_2$:Ti may be employed. An alternate blue phosphor of lower efficiency may be zinc sulfide ZnS:Ag. For the green phosphor zinc ortho silicate Zn_2SiO_4:Mn may be used. In all of the above phosphor chemical compounds, the element following the colon (:) is a trace activating agent usually present in quantities of less than 1 percent by weight.

The coating may be applied to the inside surfaces of the elliptical mirrors in all embodiments of the invention by blending the phosphor in the selected resin, flow coating, and drying the coating at elevated temperatures to polymerize the resin.

The light sources **56**, **57** and **58** may be a germicidal mercury lamp tube type. Each light source has a phosphor-coated glass density filter or mask **66**, **67** and **68** red, blue and green respectively which prevents ultraviolet radiation from striking the duplicate film. The coating of the individual masks is the same as the coating on their respective elliptical mirror. The light sources emit a nonlinear distribution of light along their length with fall off at the ends of the tube. The phosphor-coated glass density filter or mask will permit correction of the nonlinear characteristics as well as end effects encountered in the tube light source. The three printing light sources are individually controlled and the red, blue and green phosphors will permit control over exposure color balance. It is important that the three light sources remain located at one focus of the elliptical reflector and the printing aperture **71** at the other focus. Therefore, the distance between the printing head from the film sandwich is carefully maintained by using hydrostatic bearing techniques. That is, air bearing pad **52** containing the printing light sources is supported on a cushion of air over the film sandwich in the printing gate. A discussion of hydrostatic bearing techniques may be found in U.S. Pat. No. 3,229,268.

In FIG. **6** there is shown a block diagram of a continuous color printer. The output of the red, blue and green photodetectors are fed to amplifiers **71**, **72** and **73** respectively. The samples obtained from the three photodetectors are amplified with the appropriate gain correction factors by the three amplifiers and sent to an analog computer which processes the samples in accordance with well-known logarithmic time ex-

posure equations. A discussion of the theory of color processing and detection can be found in U.S. Pat. No. 3,120,782. The output signals from computer **74** represent the tricolor correction signals for each sampling increment of the negative or master film which can be delayed or stored in delay line **76** and recalled from the store in synchronism with the moving light source to control the individual light sources **31**, **32** and **33** through lamp modulator driver **79**.

FIG. **7** is a block diagram representation of a step and repeat contact printer and it is similar to the system of FIG. **6** except that a buffer store **77** and sync control circuitry **78** are substituted for the delay line of FIG. **6**.

In operating the continuous motion color film contact printer of FIGS. **3** and **6**, the master film **13** is installed over master supply reel **39** and takeup reel **44**. The duplicating material **14** is likewise installed upon the duplicating supply reel **46** and takeup reel **49**. The master film **14** travels past the color-detecting head **10** by suitable transport means. The same transport device may also drive the duplicating material **14** in synchronism with the movement of the master film. The color detectors **17**, **18** and **19** sense the color balance on a line at a time basis. The sampled signals are amplified (FIG. **6**) in amplifiers **71**, **72** and **73** and fed to computer block **74** wherein simultaneous computation and storage is performed. The duplicating material is brought into contact with the master film in the printing gate **42**. Then the continuous motion of both films are initiated in synchronism. The signals from the lamp modulator driver modulates the individual light sources **31**, **32** and **33** in color and intensity in accordance with the stored continuum of correction factors. The master film **13** and duplicating material **14** are then separated.

The operation of the step and repeat contact color film printer of FIGS. **4** and **7** differs from the continuous printer operation of FIGS. **3** and **6** in that one master film frame is detected at a time and then the duplicating material is brought into contact with the master film, then the printing light sources **56**, **57** and **58** are swept across the master film and duplicating material while they are at rest in the exposure station **42**.

From the foregoing, it will be understood that the exposure control system disclosed will detect the color and intensity of the master film and modulate a printing light source to expose a film sandwich of the master film and duplicating material to obtain a print which is substantially color balanced.

What is claimed is:

1. A continuous motion photographic color contact printer having an exposure control system for sampling master film comprising:

a. a continuous light source;

b. a cylindrical lens interposed between said light source and said master film for focusing said light source into a line source for projection upon said master film as said master film continuously travels past said light source;

c. a light pipe having a flat surface normal to the light modulated in color and intensity as it passes through said film and an arcuate surface for reflecting said modulated light on to a second flat surface of said light pipe joining said first flat surface at an angle of 90° and said arcuate surface connecting the free ends of said flat surfaces;

d. a plurality of photodetectors each adapted to sense a particular spectrum of said modulated light, and adapted to have individually controllable gain factors, said photodetectors being located adjacent said second flat surface of said light pipe and there being one photodetector for each of the red, green and blue spectrum of said continuous light source;

e. a plurality of amplifiers adapted to receive the output signals from said photodetectors and to adjust said signals to compensate for individual characteristics of said photodetectors;

f. computer means connectable to said amplifiers and adapted to receive said detected color and intensity-modulated light signals from said amplifiers and to process said signals and to furnish at its output signals indicative of the color and intensity of said detected light;

g. a plurality of printing light sources connectable to said computer means each of said printing light sources being adapted to be modulated by the output signals of said computer means;

h. duplicating material; and

i. means for transporting said master film and duplicating material to the printing gate of said printer said master film and duplicating material adapted to be in contact relationship in said printing gate at the time each of said printing light sources are receiving signals from said computer means whereby said contacting master film and duplicating material are exposed to said light emanating from said printing light sources.

2. A continuous color contact printer in accordance with claim **1** wherein said printing light sources comprise a red, green and blue light source each of said printing light sources being individually controllable and each related to a corresponding red, green and blue photodetector.

3. A continuous color contact printer in accordance with claim **2** wherein each of said printing light sources further comprises an elliptical phosphor coated mirror and a phosphor-coated density filter adapted to reduce the scattering of light from said mirror, said phosphor coating being excited by said signals from said computer to emit red, green and blue light for its respective elliptical mirror and density filter.

4. A continuous color contact printer in accordance with claim **3** wherein said red phosphor comprises zinc phosphate with a europium trace activating agent, said blue phosphor comprises calcium magnesium silicate with a tungsten trace activating agent and said green phosphor comprises zinc orthosilicate with a manganese trace activating agent.

5. A continuous color contact printer in accordance with claim **4** wherein the printing light sources are each arrayed to project its light on to a common line of a reflecting mirror surface.

6. A step and repeat open gate color contact film printer for sampling master film having an exposure control system comprising:

a. continuous light source;

b. a cylindrical lens interposed between said master film and said light source for focusing said light onto said master film on a line at a time basis said light being modulated in color and intensity as it passes through said film;

c. a light pipe having a flat surface normal to said modulated light and an arcuate surface for reflecting said light on to a second flat surface of said light pipe, said first and second flat surfaces joining at an angle of 90°, and said curved surface joining the free ends of said flat surfaces;

d. a plurality of photodetectors each adapted to sense a particular spectrum of said modulated light, said photodetectors being located in the second flat surface wall of said light pipe;

e. computer means comprising amplifier means adapted to receive output signals from said photodetectors, said computer means processing said signals representative of said detected modulated light,

f. a buffer store in said computer means for storing the processed signals until said master film reaches the printing gate of said printer,

g. a plurality of printing light sources mounted in an air bearing pad, said printing light sources each being individually controllable and adapted to be modulated by output signals from said computer means,

h. duplicating material, and

i. means for transporting said master film and said duplicating material to said printing gate said master film and duplicating material adapted to be in contact relationship in said printing gate for exposure to said printing light sources whereby the modulated light emanating from said printing light sources transfers the image on said master

film to said duplicating material with the same color and intensity of said master film.

7. In a step and repeat printer in accordance with claim 6 wherein said photodetectors are red, blue and green and wherein said printing light sources are each respectively enclosed within a red, blue and green phosphor coated elliptical mirror.

8. The apparatus according to claim 7 wherein said air bearing pad is adapted to float on a cushion of air over said master film and duplicating material in said printing gate.

9. The apparatus according to claim 8 wherein said printing light sources are arrayed to emit light on to a common focal line.

* * * * *