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COLOR PHOTOGRAPHIC PRINTER

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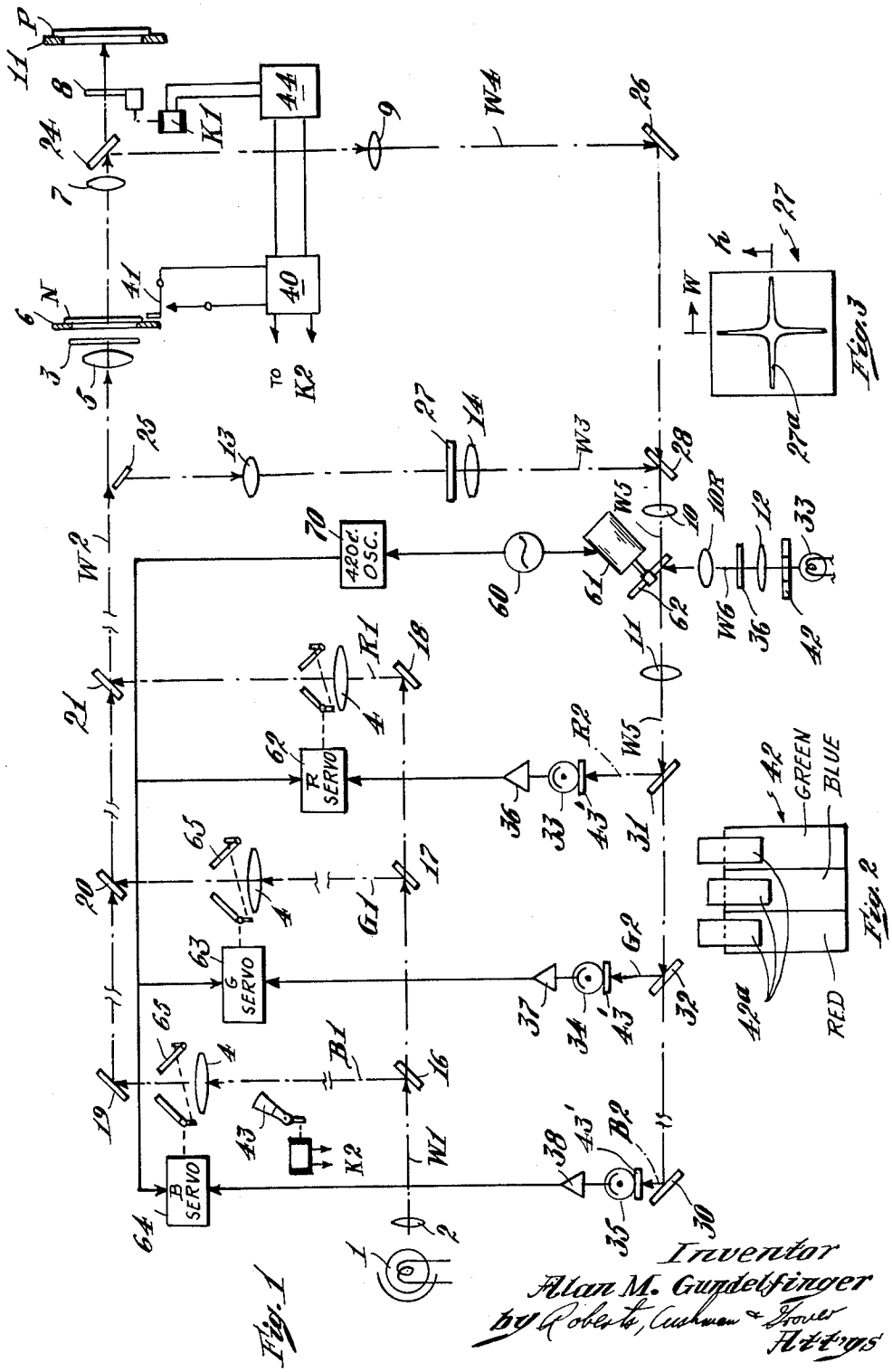


Fig. 1

Fig. 2

Fig. 3

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COLOR PHOTOGRAPHIC PRINTER

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This invention relates to the art of making color prints from a color record such as a color transparency, and particularly to automatic correction of the printing exposure in accordance with the density of the record.

Many corrections must be applied to color printer operation to compensate for well-known factors such as negative density, color balance, reciprocity failure, subject failure, and other characteristics of both negative and positive stock. A discussion of these factors is given in an article by Pieronek, Syverud and Voglesong in Photographic Society of America Quarterly, November 1956, pp. 145–156. In a printer with automatic density correction, the problem of subject failure can be lessened substantially by a lowered-correction or undercorrection for density.

Accordingly, it is an object of the present invention to provide a system for automatic undercorrection for a color printer.

A further object is to provide an undercorrection system which is operated photometrically in such a manner as to be independent of variations in electronic circuitry.

Another object is to provide means for adjusting the level of undercorrection for the blue path in the printer to compensate for the difference between daylight and tungsten exposed negative.

According to the invention, apparatus for printing from a color record comprises means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means utilizing light transmitted through said mask combined with a portion of the light transmitted from said record to produce electrical signals, and means to control respective obscuring means with said signals.

For the purpose of illustration a typical embodiment of the invention is shown in the accompanying drawing in which:

FIG. 1 is a schematic diagram of automatic color printing apparatus;

FIG. 2 is a plan view of a three-color filter; and

FIG. 3 is a plan view of an undercorrection mask.

As shown in FIG. 1, the apparatus is adapted to print from a negative N located in an aperture 6 so as to produce a print P located in an aperture 11. The printer is provided with a suitable transport for printing from colored transparencies spliced together in 500 foot rolls which are automatically advanced to the negative aperture 6. Each frame of the negative is coded with marks such as edge notches which actuate an edge notch switch 41 connected to a decoder 40. The decoder actuates a timer 44 which, in turn, energizes a solenoid K1 for opening the dowser shutter 8 for a preselected time which remains constant for all individual printing operations, that is, the exposure time is fixed for all negatives to eliminate improper printing due to reciprocity law failure. The timer also controls automatic feed of successive negatives to the negative aperture at predetermined intervals.

The light source for the printer is a lamp 1 which is operated at fixed intensity to eliminate color temperature variation. Exposure light from lamp 1 is directed to a suitable condenser lens 2 in a white beam W1 which

successively strikes dichroic mirrors 16 and 17 and a full mirror 18. The first dichroic mirror 16 splits off the blue component B1 of the white beam, the second mirror 17 reflects the green component along a beam G1 and transmits a red beam R1 to the third reflector 18. The respective blue, green and red images of the lamp 1 are formed at the relay lenses 4 in each path. Modulator shutters 65 are located substantially at nodal planes of the relay lenses 4 and are actuated by servomechanisms 62, 63 and 64, respectively, so as to variably obscure the red, green and blue beams thus varying a cross-sectional area of each beam. Beyond the shutters 65 the three color beams R1, G1 and B1 are recombined in beam W2 by dichroic reflectors 20 and 21 and a full mirror 19. The relay lenses 4 have conjugate foci at the condenser lens 2 and a negative aperture lens 5, so that an image of the condenser lens 2 is formed at the aperture lens 5. Between the aperture lens 5 and the plane of the negative N in the aperture 6 is a diffusion plate 3 which minimizes the effect of surface scratches on the negative. A copy lens 7 forms an image of the negative N at the printing plane of the positive P in the positive aperture 11. Whereas, normally, shutter images would be formed at copy lens 7, producing variable area modulation, the diffuser plate 3 between the aperture lens 5 and the negative destroys any shutter image at the copy lens and thereby produces a variable intensity modulation of the printing beam W2 rather than a variable area modulation.

In advance of the negative aperture 6 is a full mirror 25 which extends only partly into the printing beam W2. The full reflector 25 is disposed so that it does not obscure the negative aperture 6 beyond the aperture lens 5. Lenses 13 and 14 in the diverted beam W3 form an image of the condenser lens 2 at lens 10. In addition, lens 13 forms well-defined images of the three shutter gaps at lens 14. The effect of varying the width of the shutter gaps is to produce a variable area effect at lens 14, but a variable intensity effect at lens 10. The diverted beam W3 is reflected by a semireflector 28 to a lens 10. Lens 10 is imaged by a lens 11 upon three photomultiplier tubes 33, 34 and 35. In front of the respective photomultiplier tubes are absorption-type trimming filters 43'.

Adjacent the lens 14 is placed an opaque mask 27 having an opening 27*a*, as shown in FIG. 3, whose shape is such that the energy transmitted by the mask is a non-linear function of the respective shutter gaps imaged thereon, as will be explained more fully hereinafter.

Immediately adjacent the copy lens 7, in the optical path of the printing beam W2, is a beam splitter 24 consisting of a thin glass optical flat set at 45° to the optical axis. The beam splitter 24 serves to divert by reflection a fixed fraction, for example 8%, of the light intended for the paper plane. This beam splitter 24 reflects a further beam W4 along the optical axis of a relay lens 9 which has conjugate foci at the copy lens 7 and lens 10. A full mirror 26 illustrates one way in which the further diverted beam W4 may be directed upon a lens 10. In advance of the lens 10 is a semireflector 28 which combines the two diverted beams W3 and W4 into a single mixed beam W5. The mixed beam W5, comprising the light transmitted along paths W3 and W4, is split into three color beams R2, G2 and B2 by dichroic reflectors 31 and 32 and a full mirror 30, respectively.

A beam W6 from a reference lamp 33 is directed at right angles to the mixed beam W5. The reference lamp is a filament lamp operated approximately at ⅓ of its rated voltage in order to achieve long life and high stability. Beyond this lamp and in order of appearance are a filter block 42, a lens 12 and a diffusing plate 36. The filter block 42 is composed of adjacent strips of blue, green and red absorption filter material whose spectral

bands match closely the sensitivities of the blue, green and red sensitive layers, respectively, of the paper emulsion in the printing aperture 11. The amount of each color can be varied by micrometric adjustment of opaque slides 42*a* located between the filter block 42 and the lens 12, as shown in FIG. 2. A lens 10R is uniformly illuminated by a mixture of the blue, green and red reference light W6.

In the mixed beam path W5 and the reference beam path W6 is a seven-bladed reflective chopper disc 62 driven by a 60 cycle synchronous motor 61 fed from a 60 cycle power source 60. The chopper rotates at 60 revolutions per second and alternately produces images of lenses 10 and 10R at the photocathode surfaces of the photomultipliers at the rate of 840 alternations or 420 cycles per second. Thus the energy reaching each photomultiplier tube from lens 10 is constantly being compared with that from lens 10R.

The quantity of blue, green and red energy in beam W4 reaching the respective photocathodes is always a fixed fraction of the integrated blue, green and red energy, respectively, reaching the paper plane.

If the energies in the two beams W5 and W6 are unbalanced there is a succession of direct current pulses of alternating unequal amplitudes. Each photomultiplier tube will produce a pulsed D.C. signal which is amplified by one of amplifiers 36, 37 and 38 to a useful level. The amplifiers, respectively, feed the control windings of red, blue and green servomotors 62, 63 and 64.

External of the printer is a motor generator set serving as a 420 cycle, 120 volt alternating source connected to the reference winding of the servomotor. The motor of the alternator 70 receives power from the same 60 cycle source 60 as the synchronous chopper motor 61. The chopper motor 61 and the alternator 70 are therefore locked in synchronism.

The control voltages applied from the photomultiplier amplifier to the control winding of the servomotors are so phased as to be in quadrature with the reference voltage from the 420 cycle alternator 70. Thus, if the energies arriving at a photocathode from lenses 10 and 10R are unbalanced, the corresponding servomotor will rotate in a direction so as to either close or open its shutter 65 and vary the light diverted on paths W3 and W4 until the energy of these two paths mixed in path W5 balances the energy in the reference path W6.

Thus, as the modulator shutters are forced open by the control system to compensate for a more dense negative, more energy is also admitted to the photocathodes of the photomultiplier through the undercorrection path W3, with the result that the modulator shutters are not permitted to open as wide as would be the case if the undercorrection path were non-existent.

The dowser shutter 8 which controls the exposure time of the printer is just beyond the beam splitter 24 which diverts light along the further path W4. Therefore at no time is either the reference light or the printing light cut off from the control system. This affords the shutters the opportunity of arriving at their correct printing position as each negative frame is transported into printing position. After the dowser shutter 8 is open it is held in that position by the timer 44 for a fixed period, for example ½ second. The timer closes the shutter for the period that is necessary to transport a new negative frame into the aperture 6 and to allow the respective shutters to reach proper position such that the content of the respective colors in the printing beam W2 has been balanced to compensate for negative density.

As previously mentioned it has been found that instead of modulating the printing beam W2 solely with respect to the integrated transmission of the negative N it is highly preferable to undercorrect the printing beam W2. Further it has been shown that optimum results are achieved by linear undercorrection according to the following relationship.

$$\text{Log } P = gD_n + b = g \log 1/Tn + b$$

where

P=total energy over entire area of positive frame

and

Tn=total transmittance of negative frame

b=a constant

g=a constant <0

The mask shown in FIG. 3 achieves this objective. The unusual shape of the opening 27*a* in the mask is expressed by the following equation:

$$W = K\left(\frac{g}{g+1}\right)h^{\left(-\frac{1}{g+1}\right)}$$

Where

W equals the width of the mask opening transversely of the modulator shutter gap image;

h equals the height of the mask opening normal to the width W;

g is gamma, a selected constant of the log exposure versus negative density function (for example, —0.10); and

k is a constant partly dependent on the ratio of energy transmitted to that reflected by beam splitter 28.

The exposure control system of the printer is adjusted so that the undercorrection has the proper value for daylight exposed negatives. Tungsten or clear flash exposed negatives normally have about 0.30 less blue light density relative to the red and green densities than daylight exposed negatives. The automatic density correction for a tungsten exposed negative will decrease the blue exposure, but the undercorrection then interferes with the proper balance of exposures.

The difference between daylight and tungsten can be discriminated by photocells measuring the ratio of integrated blue to red transmission of the negative. When the ratio exceeds a certain value, a notch is cut in the negative on an encoder (not shown) either automatically, or manually by an encoder operator who observes a meter or a warning light on the output of the two photocells. Many negatives can be discriminated by simply observing the subject matter of the scene.

The edge notch sensing switch 41 and the decoding means 40 also control a solenoid K2 which, in turn, inserts a neutral filter 43 in the blue path B1. The filter 43 has a density of 0.30 and has the effect of adding 0.30 density of blue component to the negative so that the blue modulator shutter is forced to open wider, as if it were seeing a daylight exposed negative. Thereafter undercorrection occurs approximately as it would for a daylight picture of the same object.

Although discriminator filter 43 is shown in the blue path B1 in FIG. 1, essentially the same result can be achieved by using a yellow filter of the proper density between mirror 25 and lens 5. The yellow filter will subtract 0.3 density from the blue path without materially affecting the energy of the red or green components, thus causing the shutter in the blue path to open wider. The use of a yellow filter after mirror 25 will actually bring the undercorrection signal closer to that for daylight exposed negatives than the use of a neutral density filter located in blue path B1. The difference is not significant in the finish print however, and the location in path B1 was selected for engineering convenience.

As is readily apparent, the photcells for discriminating between daylight and tungsten exposed negative could be incorporated into the printer circuit instead of into an encoding system. The encoder is sometimes a convenient location for the discriminator since coding is usually necessary to trigger special density corrections, repeat printings, negative framing in the printing aperture, and the like.

It should be noted that both the undercorrection and the discriminating system are dependent upon the availability of a variable-area modulated light beam for sampling to provide an automatic photometric undercorrection and associated negative discrimination correction.

From the foregoing description it can be seen that the present printer has the advantage of providing optimum undercorrection with the further advantages of employing a null control system independent of drift in the photomultiplier or associated amplifiers, constant intensity of the printer lamp 1 and constant time. Such a printer can operate at high speed, without operator control and can utilize several types of negative coding for correction of density and subject failures.

I claim:

1. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and projecting the beam on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases.

2. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an under-correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases.

3. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an under-correction mask, means in advance of said record for projecting a portion of said single beam through said mask including means to image said obscuring means at said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as

the energy in respective components increases, a source of reference energy having components with steady energy intensity, and means whereby said photoelectric means and responsive means compares the energy from said source and said mixed beam to produce said signals.

4. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the single beam through said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask including means to image said obscuring means substantially at said mask, means beyond the record for diverting a portion of the transmitted beam and forming a mixed beam of said portions, means forming a reference beam containing said separate colors at components in predetermined proportion, means for converting said mixed and reference beams into electrical signals, one for each color component, including means for comparison of like color components in respective beams, and means to control respective obscuring means with said signals.

5. Photographic apparatus for printing from a color record comprising a single light source emitting a primary beam, means to form from said primary beam a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam through said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases.

6. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beam into a single beam and project the beam through said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases, and means beyond said diverting means for controlling the time of transmission of the beam from said record upon a print.

7. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the

beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intenstiy variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases, said mask having an aperture shaped to pass light from respective shutters such that said light, when combined in said mixed beam, causes the logarithm of the integrated energy of said transmitted beam to be a linear function of the density of said record.

8. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases, said mask having an aperture shaped to pass light from respective obscuring means such that said light, when combined in said mixed beam, causes the logarithm of the integrated energy of said mixed beam to be a linear function of the density of said record.

9. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask including means to image said obscuring means at said mask, means beyond the record for diverting a portion of the beam transmitted from said record and for forming a mixed beam of said portions, means for converting said mixed beam into electrical signals, and means to control respective obscuring means with said signals, said mask having an aperture shaped to pass light from respective obscuring means as an exponential function of the density of the record, the shape function of said mask being expressed by the relation

$$W = K\left(\frac{g}{g+1}\right)h^{-\left(\frac{1}{g+1}\right)}$$

where W is the width of the aperture on the axis along which the image of said obscuring means varies, h is the dimension along said axis, g is gamma, a selected slope constant of the log exposure versus negative density function, and K is a constant dependent on the ratio of reflectance to transmitaance of said mixed beam-forming means.

10. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, shutters for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means beyond the record for diverting a portion of the beam transmitted from said record and forming a mixed beam of said portions, means forming a reference beam containing said separate colors in predetermined proportion, means for alternately transmitting said mixed and reference beams along a common path at a predetermined frequency, means on said path for splitting said mixed and reference beams into color separation beams, photoelectric means responsive to said color separation beams respectively, for producing electrical signals proportional ot the intensity of respective color separation beams, a source of electrical energy alternating at said predetermined frequency, and servo means responsive to signals from said photographic means and said source to control respective shutters.

11. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, shutters for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, and undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask, means beyond the record for diverting a portion of the beam transmitted from said record and forming a mixed beam of said portions, means forming a reference beam containing said separate colors in predetermined proportion, means for alternately transmitting said mixed and reference beams along a common path at a predetermined frequency, means on said path for splitting said mixed and reference beams into color separation beams, photoelectric means responsive to said color separation beams respectively, for producing electrical signals proportional to the intensity of respective color separation beams, a source of electrical energy alternating at said predetermined frequency, means synchronizing said transmitting means and said source, and servo means responsive to signals from said photoelectric means and said source to control respective shutters.

12. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, shutters for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the single beam on said record, an undercorrection mask, means in advance of said record for projecting a portion of said single beam through said mask including means to image said obscuring means substantially at said mask, means beyond the record for diverting a portion of the beam transmitted from said record and forming a mixed beam of said portions, means forming a reference beam containing said separate colors as components in predetermined proportion, means for alternately transmitting said mixed and reference beams along a common path at a predetermined frequency, means on said path for splitting said mixed and reference beams into color separation beams, photoelectric means responsive to said color separation beams respectively, for producing electrical signals proportional to the intensity of respective color separation beams, a source of electrical energy alternating at said predetermined frequency, and servo means responsive to signals from said photoelectric means and said source to control respective shutters.

13. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, shutters for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the single beam on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask including means to image said obscuring means substantially at said mask, means beyond the record for diverting a portion of the beam transmitted

from said record and forming a mixed beam of said portions, means forming a reference beam containing said separate colors as components in predetermined proportion, means for alternately transmitting said mixed and reference beams along a common path at a predetermined frequency, means on said path for splitting said mixed and reference beams into color separation beams, photoelectric means responsive to said color separation beams respectively, for producing electrical signals proportional to the intensity of respective color separation beams, a source of electrical energy alternating at said predetermined frequency, means synchronizing said transmitting means and said source, and servo means responsive to signals from said photoelectric and source to control respective shutters.

14. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, shutters for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the single beam on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means beyond the record for diverting a portion of the beam transmitted from said record and forming a mixed beam of said portions, means forming a reference beam containing said separate colors as components in predetermined proportion, means for converting said mixed and reference beams into electrical signals, one for each color component, including means for comparison of like color components in respective beams, and means to control respective shutters with said signals, said comparison means producing a null signal when color components of the mixed and reference beams are equal, and producing an unbalance signal when they are unequal thereby to adjust said shutters, until a null signal is again produced.

15. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, filter means for subtracting a portion of the energy from one of said paths prior to projection on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases.

16. Photographic apparatus for printing from a color record comprising means to form a plurality of separate color beams including a blue beam, means for variably obscuring cross-sectional areas of respective color beams, means to form the color beams into a single beam and project the beam on said record, filter means for subtracting a portion of the energy from the blue path prior to projection on said record, a correction mask, means in advance of said record for projecting a portion of said single beam through said mask, means for diverting a portion of the beam from said record and forming a mixed beam of the portions from said mask and record, said means projecting a portion through said mask including means whereby variation of said obscuring means produces intensity variations in said mixed beam, photoelectric means for sensing the energy variations of the respective color components of said mixed beam and for producing electrical signals dependent on said energy variations, and means responsive to respective electrical signals for controlling respective obscuring means in said separate color beams so as to obscure respective beams increasingly as the energy in respective components increases.

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