

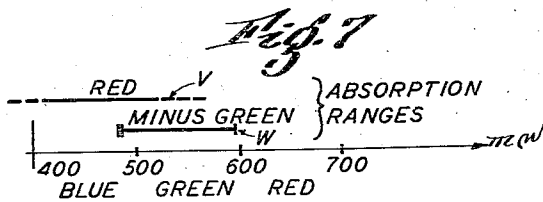
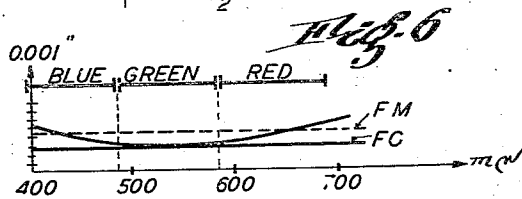
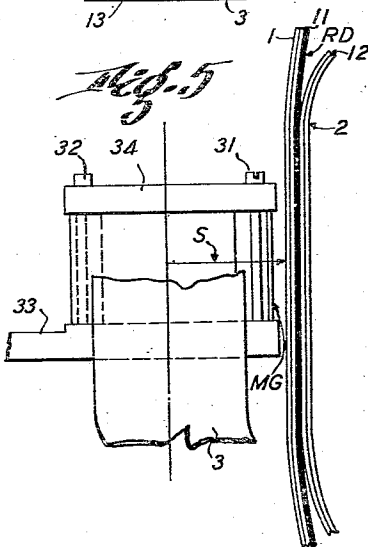
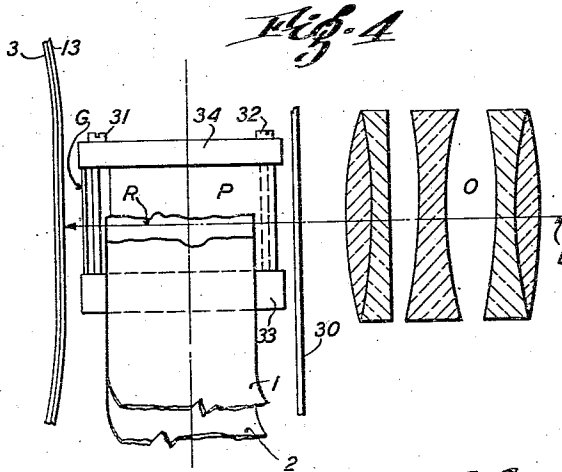
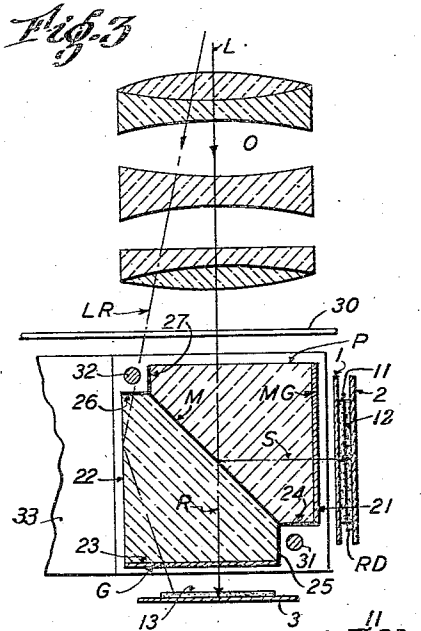
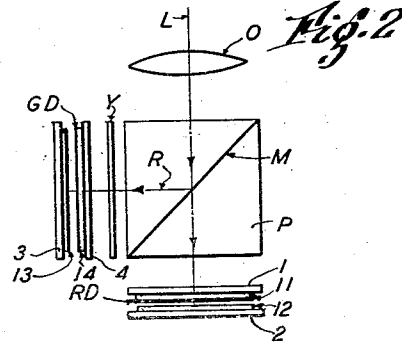
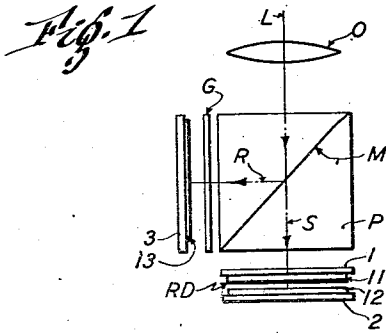
May 7, 1935.

J. A. BALL

2,000,058

THREE-COLOR PHOTOGRAPHY

Filed June 22, 1931



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UNITED STATES PATENT OFFICE

2,000,058

THREE-COLOR PHOTOGRAPHY

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mesne assignments, to Technicolor, Inc., New
York, N. Y., a corporation of Delaware

Application June 22, 1931, Serial No. 545,951

23 Claims. (Cl. 95-2)

One of the many proposed methods of color photography involves the use of superposed emulsions (monopacks, bipacks and tripacks) in the same incident light path. Another method involves dividing the light beam from the object field into as many component beams as color aspects are desired and exposing the different color records with the component beams respectively. Each of these methods has certain disadvantages if more than two color aspects are required, these disadvantages being well known to those skilled in the art and consisting mainly in difficulties of obtaining proper registration, sharp definition and sufficient light intensity.

Objects of the present invention are to avoid the aforesaid disadvantages and more particularly to obtain uniform balance between successive records of the two colors (red and green e. g.) which contribute chiefly to the body or substance of the final pictures, to expose superposed emulsions with different color components of light (red and blue e. g.) for which the optical system used has substantially equal focal lengths and, at the same time, to obtain maximum chromatic correction for a record of another color component (green e. g.), to obtain satisfactory color separation notwithstanding the use of a filter of the surface-dye type which ordinarily can not be produced with uniformity in every respect, simultaneously to expose emulsions in juxtaposed apertures without substantial fogging due to scatter light reflected from one emulsion to the other or from other surfaces, and generally to improve the art of three (or more) color photography, particularly for motion picture use.

Further objects are to provide a green color separation record of maximum sharpness, to eliminate the effects of chromatic defects of the optical system employed for exposing the negatives, to avoid the detrimental influence of light reflected or scattered from certain elements of the optical system, to provide an arrangement which does not necessitate the use of special and abnormal emulsions and permits color separation without special sensitizations and which permits the incorporation of a key record without substantial change in the three color system. Still further objects are to avoid difficulties inherent in color filters which are integral with motion picture films, and generally to provide improved optical arrangements and methods which permit efficient commercial production of motion picture films under conditions which

are as nearly as possible similar to those required for the taking of ordinary motion picture negatives. Additional objects of my invention will be apparent from the following explanation accompanied by a drawing in which:

Fig. 1 is a diagrammatic side view of one embodiment of the present invention;

Fig. 2 is a similar view of a modification;

Fig. 3 is an axial section of another embodiment;

Figs. 4 and 5 are side elevations of the embodiment shown in Fig. 3, viewed from the right-hand side and rear end of Fig. 3, respectively;

Fig. 6 is a curve showing the focal lengths of a lens system for different wave lengths, the so-called secondary spectrum; and

Fig. 7 is a schematical drawing indicating the absorption ranges of certain filters employed in the present invention.

Herein the terms "blue, green and red ranges of the visible spectrum" and corresponding terms are not strictly confined to the ranges having these hues but connote the three main regions of the spectrum namely those of low, medium and high wave lengths; the terms are not intended to define definite limits of these ranges.

The subject matter of this invention relates to that type of color photography where the image bearing beam is divided by suitable light-dividing means into two components, one of these components being used to expose superposed emulsions (of a bipack e. g.) and the other component being used to expose at least one other emulsion, as described in my Patent No. 1,889,030, of November 29, 1932, for multicolor photography with bi-packs, of which this is in part a continuation. A characteristic feature of this arrangement consists in providing one of said first two emulsions substantially like the third emulsion, both emulsions being preferably panchromatic and cut from the same stock. By forming on these like emulsions the two images (e. g. the red and the green) which contribute mainly to build up the gradation or, in other words, supply the "body" or "substance" of the final picture (the gradations of the blue record, which in a subtractive print appear as gradations of yellow dye, being rather weak) and which must therefore be carefully balanced in exposure and development, the desired balance may be obtained uniformly and with facility. This balance can not be obtained by recording the red and green aspects in the same light path for various reasons, chiefly because it has thus

far been impossible to prepare a green sensitive film satisfactory for bipack use in front of a red sensitive film. But even if this could be accomplished, the emulsion would have to be thin and relatively transparent and, since its color selection must depend upon sensitization rather than filtering, it would be radically different from the red sensitive film and the two could not be properly balanced in exposure and development throughout varying conditions such as are encountered in cinematography.

It is well known that in cases where different color aspects are exposed with a single lens in a single focal plane, the lens must produce images which are identical as to size, configuration and definition. One of the most serious difficulties in designing a photographic lens with a view to these requirements is the so-called secondary spectrum caused by the chromatic aberration of the normal lens which has not a single focal plane for all colors but different focal planes for different wave lengths, the focal planes corresponding to the lower wave lengths ordinarily being closer to the lens than those corresponding to the higher wave lengths. With the ordinary means known to the lens designer it is possible to design a high speed lens which has exactly the same focal lengths for any two selected wave lengths. In other words, rays of these two selected wave lengths will be brought to form images in the same plane but other wave lengths will form images on either side of this common focal plane. It is furthermore known that the color separation negative which records the medium or green range of the visible spectrum contributes primarily to the definition of the final positive and should therefore be as sharp as possible, especially as it may be used for making neutral key prints as proposed in my copending application Serial No. 519,721, filed March 3, 1931.

According to the present invention, the red and blue aspects are recorded on emulsions which are substantially in the same plane, with a lens system having a secondary spectrum as shown in Fig. 6 in which the deviations of the focal lengths for the various wave lengths of the solar spectrum, from an arbitrary selected focus, are plotted against the wave lengths, the three principal color ranges also being indicated in this figure. From the curve it can be seen that the green range has a substantially horizontal tangent to which each point of this range of the curve is very close so that the record of this range has a substantially perfect chromatic correction. The fact that the red and blue ranges are not so well corrected is of minor importance since these ranges do not contribute largely to the definition of the positive color reproduction. However, the average focal lengths, or the focal lengths of the centers of these marginal ranges, substantially coincide, resulting in substantially identical focal distances for the blue and red records which, according to the present invention, are recorded upon emulsions located substantially in one and the same plane. The fact that the focal distances for the green range on the one hand and the red and blue ranges on the other hand are not equal is of little consequence since this irregularity can be easily adjusted as will be described hereinafter.

As stated above, the light is separated into two component beams and the green aspect recorded in one beam and the red and blue aspects (or in other words the minus green aspect) in

the other beam. Since each of the recording elements will, if permitted, reflect from its surface to the other element light of all wave lengths including that which the other element is to record, and since light may be scattered from other surfaces into the recording apertures, I propose to obstruct this reflected and scattered light from the apertures. For this purpose certain surfaces of the optical system are made opaque as will be described in detail hereinafter, and furthermore the filters which are arranged in front of the apertures cooperate in excluding any light which is not to be recorded in the coordinated aperture. Hence, a minus green filter is inserted in front of the red and blue recording aperture, in addition to the green filter in front of the green recording aperture.

The minus green filter has still another important function, made possible by the peculiar general arrangement of the invention. As will be described later on in detail, a red filter is inserted intermediate the blue and red recording emulsions, this red filter moving with the two films and being for example applied as a surface dye upon the blue recording front emulsion, as for instance disclosed in the Reissue Patent No. 18,680 of December 6, 1932, of Leonard T. Troland for "Color photography." In applying a filter layer to a photographic emulsion it is practically impossible to maintain an exact limitation of the absorption range (or the cut of the filter as it is sometimes called) uniformly over the entire length of the film strip. For this reason, the color selection as recorded upon the film behind this filter would fluctuate and impair the quality of the final positive. This is effectively prevented by the minus green filter, as indicated in Fig. 5 which shows the absorption ranges of the red and minus green filters. As indicated by the dotted end of the line corresponding to the absorption range of the red filter at V, the cut of the red filter may vary within the absorption range of the minus green filter without causing any detrimental effect, since the end of the red admission at W is determined only by the stationary minus green filter.

In order that the invention may be more easily understood, I will now describe the specific embodiment shown in Fig. 1 where O represents an optical system of any suitable construction, and P a light splitting device comprising a partly reflecting and partly transmitting surface M which divides an incident light beam L into two divisions S and R as indicated by arrows. 1, 2 and 3 are suitable supports, for instance, cellulose films, bearing emulsions 11, 12 and 13; 11 is an ordinary silver bromide emulsion, blue sensitive only, requiring no special treatment and of a kind which can easily be obtained with the required thin and transparent characteristics necessary for the front film of a bipack; and 12 and 13 are panchromatic emulsions of usual characteristics. The heavy line RD represents a filter, in this instance a surface layer of red filter dye applied to the front film, which transmits only the range of radiation required for the red image to be recorded upon emulsion 12. G is an ordinary green filter inserted between the optical system and emulsion 13 and transmitting only the range of radiation required to record the green aspect upon emulsion 13. It is understood that film 3 and filter G can be placed in the direct rays and films 1 and 2 in the reflected rays as in Figs. 3, 4 and 5. In certain cases it becomes desirable to add to

the three records of a three-color photographic process a fourth so-called key print, usually reproduced in gray or black which has the main purpose of giving definition to the colored picture and in certain cases to supply the deep shadows. My invention lends itself well for the production of colored pictures with key prints and a four-color system of this kind will now be described, referring especially to Fig. 2. O, P and M is again an optical system and 1, 2, 3 and 4 are supports, the fourth support 4 having been added to 1, 2 and 3 of Fig. 1. Emulsion 14 upon support 4 may be a panchromatic emulsion which is thin and transparent enough to transmit as much light as possible to the back emulsion 13. A green surface dye GD is for example applied to emulsion 14, having the purpose of admitting to emulsion 13 only the radiations suited for recording thereon the green aspect, the surface dye filter GD replacing separate filter G of Fig. 1. Y is a yellow filter which absorbs light in the same manner as filters which are used with orthochromatic emulsions for making ordinary black and white pictures.

Emulsions 11, 12 and 13 are of the same nature as the corresponding emulsions of Fig. 1; 12 and 13 being substantially identical panchromatic emulsions, preferably slittings from the same stock, and 11 an ordinary blue sensitive transparent emulsion. It is of course necessary that the key print be as definite in sharpness as possible and that the definition be preserved through the process. For this purpose it is desirable to print key positives by means of contact printing which does not cause loss of definition and does not build up graininess. With the arrangement shown in Fig. 2 it is possible to use contact printing in spite of the fact that the reflected image is reversed, because the key emulsion is exposed through the back, which counters the reversal of the image by reflection.

A further advantage of this arrangement arises from the fact that it is desirable to have for the purpose described key prints of a gamma of approximate unity, the same gamma commonly used for photographic sound records. In making sound motion pictures the sound track is therefore printed together with the key print, thereby making unnecessary any differentiation in the character of picture and sound records. The negative sound record (ordinarily made on a separate negative) may be printed on the positive film along with the aforesaid key pictures and this combined print developed to approximately gamma unity after which the film may be fixed, washed, dried and the color aspects applied by imbibition.

According to my method of recording the red and green aspects in different light paths, I am enabled to use substantially identical emulsions of a normal type for these two aspects, and (not considering the key record) require a special emulsion only for the blue aspect, this emulsion being special only in its transparency and in its surface coating. I am also enabled to balance, with uniformity and facility, the color values of the two records which are most important and most difficult to balance.

Still another advantage of having the red and green records on identical emulsions and therefore well balanced, arises from the fact that the human eye is much less sensitive to variations of blue and yellow light than to variations of red and green light. This circumstance is probably due to the fact that various sources of

artificial light and also daylight vary a great deal in their blue components, that is to say, they vary from blue-white to yellow, depending upon the greater or lesser intensity of the blue component as compared to normal. Normal is usually taken to be noon sunlight, in which case north sky-light is considerably more blue; late afternoon sunlight is considerably more yellow; high intensity arc light generally more blue; and incandescent light very much more yellow than normal. For this reason it does not matter much if the blue component of a color motion picture film is not particularly well balanced with respect to the red and green records. However, the red and green records have to be well balanced as the eye is very sensitive to changes of these colors and irregularities of the relative values of red and green are therefore to be avoided. The arrangement of the present invention with like emulsions for the red and green color aspects takes care of these facts in a simple manner and assures the proper balance of colors also with respects to this phenomenon.

Referring now to Figs. 3, 4 and 5, with a lens system having a secondary spectrum according to Fig. 6, the blue and red aspects are recorded on emulsions 11 and 12 substantially in the same plane, the plane of emulsions 11 and 12 corresponding to the focal plane FM of Fig. 6 and the plane of emulsion 13 corresponding to focal plane FC of Fig. 6. By this arrangement the red and blue images are recorded sharply upon the bipack at the same focus setting and, since the minimum focal length is in the green, the maximum chromatic correction is obtained in the green which is desirable for reasons explained above. The difference between the two focal planes can be easily adjusted by varying the distance of the emulsion planes from the prism faces 21 and 22, as for instance by inserting cover glasses of different thickness between the prism faces, or the filters G and MG, and the films. As shown in Fig. 3, the filters may be affixed directly to the prism faces, MG being the minus green filter and G the green filter. As mentioned before, the film in the aperture reflects light of all colors which have been allowed to fall on it, including light of the color to be recorded at the other aperture; and this reflected light, if allowed to reach the film in the other aperture, would fog that film. This fogging tendency is most pronounced at the sides of the apertures which are close together, namely, near the edge formed by prism faces 21 and 23. Furthermore, the prism faces reflect light as indicated by dotted line LR. The green light which is reflected from the film 3 is effectively excluded from the other aperture by the minus green filter MG, whereas the minus green light reflected from film 1 is eliminated by green filter G. In order to shield the apertures against the especially pronounced reflection in the corner between faces 21 and 23, this corner is made opaque either by blackening the adjacent marginal parts of 21 and 23, or by making the margins of the mirror plane M opaque or, as shown in the drawing, by providing a notch with blackened faces 24 and 25. In order also to exclude the light reflected at surface 22 (as indicated by ray LR) another opaque edge or notch with blackened faces 26 and 27 is provided. These notches have the further advantage of providing space for screws or posts 31 and 32 which connect yoke 34 with base plate 33, clamping the prism between these construction elements.

This arrangement permits the utilization of the optically beneficial notches for a mechanical design which makes the prism mount compact so that it can be easily confined in the restricted space available for it in the camera.

Figs. 3 and 4 also show a shutter 30 of conventional design, arranged intermediate the lens system O and the prism P. Figs. 3 and 5, in connection with Fig. 7, further explain the cooperation between the red filter RD intermediate the emulsions 11 and 12, and the minus green filter MG. As discussed above, the filter RD, which should be integral with one of the bipack films and determines the color selectivity of the rear emulsion 12, can not readily be made uniform throughout lengths of film. This causes manufacturing difficulties so that specifications concerning the transmission qualities of the filter layer can not always be met. However, with the arrangement according to Fig. 3, the requirements concerning the red filter can be less exacting because the minus green filter MG determines the limit towards the green range of the wave lengths of light recorded, as the red color aspect, upon emulsion 12.

It is very important exactly to maintain this limit because it is on the one hand desirable to admit as much light as possible to the red recording back film in order to obtain the speed necessary for motion picture work whereas, on the other hand, if the admission range of the red filter is widened beyond a certain wave length, the color separation degenerates. Therefore if the cut of the red taking range is exactly determined by a fixed filter (viz. minus green filter MG) the limit of optimum efficiency for both requirements can be continuously maintained.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. Photographic apparatus comprising juxtaposed apertures, one for a green sensitive film and another for superposed films sensitive to blue and red light respectively, means for focusing light at the apertures respectively, a green filter in the light path to the first aperture, and a minus green filter in the light path to the second aperture.

2. Photographic apparatus comprising a lens system having substantially equal focal lengths for spaced color ranges and a different focal length but maximum axial chromatic correction for an intermediate range, means for dividing the beam of said system into two component beams, means for recording said intermediate range in one component beam and means for recording said spaced ranges on superposed emulsions in the other component beam.

3. Photographic apparatus comprising a lens system having substantially equal focal lengths for the red and blue ranges and a different focal length but maximum axial chromatic correction for the green range, means for dividing the light from said system into two component beams, apertures in said component beams, identical panchromatic emulsions in the respective apertures and in one aperture a transparent emulsion in front of the panchromatic emulsion, and a filter in front of the latter aperture excluding light of a color to which at least one of the films at that aperture is sensitive.

4. Photographic apparatus comprising a lens

system having substantially equal focal lengths for the red and blue ranges and a different focal length but maximum axial chromatic correction for the green range, means for dividing the light from said system into two component beams, a green filter in front of one of said apertures and a panchromatic emulsion behind said green filter, a minus green filter in front of the other aperture and superposed in the latter aperture a transparent blue sensitive emulsion and a panchromatic emulsion.

5. Photographic apparatus comprising a lens system having substantially equal focal lengths for the red and blue ranges and a different focal length but maximum axial chromatic correction for the green range, a reflector behind said lens system for splitting the light into direct and reflected light components, a green filter in the direct component, a minus green filter in the reflected component, a panchromatic emulsion behind the green filter, a panchromatic emulsion behind the minus green filter, a transparent emulsion intermediate said minus green filter and said second panchromatic emulsion and a red transmitting, blue absorbing filter intermediate said transparent emulsion and said second panchromatic emulsion.

6. Photographic apparatus comprising a lens system having substantially equal focal length for the red and blue ranges and a different focal length but maximum axial chromatic correction for the green range, a partial reflector behind said lens system for splitting the light into two component beams, said reflector comprising a glass block with a diagonal partial reflecting surface, the corners of the block adjacent said surface being notched and mounting-means arranged in said notched corners, a green filter in one component beam, a minus green filter in the other component beam, a panchromatic emulsion behind the minus green filter, a transparent emulsion intermediate said minus green filter and said last panchromatic emulsion, and a red transmitting, blue absorbing filter intermediate said transparent emulsion and said last panchromatic emulsion.

7. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises producing an image bearing beam with an optical system having substantially equal focal lengths for the red and blue spectral ranges and accurate axial chromatic correction for the green range, dividing the beam into two component beams, recording with one component beam the green aspect of the object field upon a panchromatic emulsion, recording with the other component beam the blue aspect upon a transparent emulsion, and recording with the same beam the red aspect upon an emulsion like that used for recording the green aspect and placed behind said transparent emulsion.

8. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises producing a light beam bearing images of the red and blue aspects of substantially equal axial chromatic correction and an image of the green aspect of maximum chromatic correction, dividing the beam into two component beams, one beam being reflected and the other transmitted without reflection, recording the green aspect of the object field upon a panchromatic emulsion in one beam and recording the blue and

red aspects with the other beam on superposed emulsions.

9. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises producing a light beam bearing images of the red and blue aspects of substantially equal axial chromatic correction and an image of the green aspect of maximum chromatic correction, dividing the beam into two component beams, one beam being reflected and the other transmitted without reflection, recording the green aspect of the object field upon a panchromatic emulsion in the direct beam and recording the blue and red aspects with the reflected beam on superposed emulsions.

10. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises producing an image bearing beam with an optical system having substantially equal focal lengths for the red and blue spectral ranges and substantially perfect axial chromatic correction for the green range, dividing the beam into two component beams, recording the green aspect of the object field upon a panchromatic emulsion behind a green filter with one beam, and recording the blue and red aspects on superposed emulsions behind a minus green filter with the other beam.

11. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises producing an image bearing beam with an optical system having substantially equal average focal lengths for the red and blue spectral ranges and more accurate axial chromatic correction for the green range, dividing the beam into two component beams, one beam being reflected and the other transmitted without reflection, recording the green aspect of the object field upon a panchromatic emulsion behind a green filter with the transmitted beam, recording the blue aspect upon a transparent emulsion behind a minus green filter with the reflected beam and recording with the latter beam the red aspect upon an emulsion like that used for recording the green aspect and superposed behind said transparent emulsion.

12. The art of color separation photography which comprises producing an image bearing beam with an optical system having substantially equal focal lengths for the red and blue ranges and substantially equal focal lengths for the margins of the green range, dividing the beam into two component beams, recording the green aspect with one component beam and recording the blue and red aspects in superposed juxtaposed emulsions with the other component beam.

13. In the art of color separation photography the method of obtaining a green record of maximum definition which comprises producing an image bearing beam with an optical system having substantially equal focal distances for the center portions of the red and blue ranges and maximum axial chromatic correction for the green range, dividing the beam into directly transmitted and reflected beams, recording the green aspect with the direct beam and recording the blue and red aspects with the reflected beam on superposed emulsions.

14. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises divid-

ing the light from the field into two component beams, with one beam recording the green aspect behind a green filter and with the other beam recording the blue aspect on a blue sensitive emulsion behind a minus green filter and the red aspect behind said minus green filter and a red transmitting blue absorbing filter the blue and red recording emulsions being superposed.

15. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises dividing the light from the field into two component beams, one beam being reflected and the other beam directly transmitted, with the direct beam recording the green aspect behind a green filter upon a panchromatic emulsion and with the reflected beam recording the blue aspect behind the minus green filter and the red aspect behind the minus green filter and a red transmitting, blue absorbing filter upon a panchromatic emulsion like the green recording emulsion the blue and red emulsions being superposed.

16. The method of cinematographically recording two color ranges upon two superposed emulsions which comprises exposing consecutive picture areas of the film by excluding the spectral ranges not recorded on either emulsion with a filter having an unvarying absorption range, and excluding the light not to be recorded on the back emulsion with a filter having an absorption range which varies, for different areas, within the range of the first filter.

17. The method of cinematographically recording two color ranges upon two superposed emulsions respectively which comprises exposing consecutive picture areas of the film by excluding the spectral ranges not recorded on either emulsion with a filter having a definite absorption range, in front of both emulsions, and excluding the light not recorded on the back emulsion with a filter progressing with the emulsions intermediate thereof and having an absorption margin varying, for different areas, within the range of the front filter.

18. Apparatus for recording the blue and red color ranges upon two superposed emulsions which comprises a minus green front filter for excluding the green range, and a red filter intermediate the two emulsions for excluding the minus red light.

19. Apparatus for recording the blue and red color ranges upon two superposed emulsions which comprises a minus green front filter for excluding the green range and a red filter intermediate the two emulsions for excluding the minus red light, said red filter having an absorption range whose margin towards the green side lies within the absorption range of the minus green front filter.

20. In the art of color photography the method of recording the blue, green and red color aspects of an object field which comprises dividing the light from the field into two component beams, recording the green spectral range on a panchromatic emulsion in one component beam, recording the minus green range on films including a panchromatic emulsion in the other component beam, and excluding the entire minus green range from the green recording beam and the entire green range from the minus green recording beam, thereby reducing detrimental effects of scatter light deviated from one beam into the other beam.

21. Apparatus for recording the blue and red color ranges upon two superposed emulsions

which comprises a substantially minus green front filter for substantially excluding the green range from said emulsions, and a substantially blue absorbing filter intermediate the two emulsions for substantially excluding blue light from said red recording emulsion.

22. Apparatus for recording the blue and red color ranges upon two superposed emulsions which comprises a minus green front filter for substantially excluding the green range from said emulsions and a substantially blue absorbing filter intermediate the two emulsions for substantially excluding the blue light transmitted by said blue recording emulsion, said blue absorbing filter having an absorption range whose margin towards the green side lies within

the absorption range of the minus green front filter.

23. The method of cinematographically recording two color ranges upon two superposed film strip emulsions which comprises exposing consecutive picture areas of the emulsions by excluding the spectral ranges not recorded on either emulsion with a stationary filter in front of both emulsions, and excluding the light range not to be recorded on the back emulsion with a surface filter on one of said emulsions, and having an absorption range whose margin towards said first mentioned ranges lies within the absorption range of said stationary filter.

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