April 6, 1943. O. C. GILMORE 2,315,783

COLOR PHOTOGRAPHY

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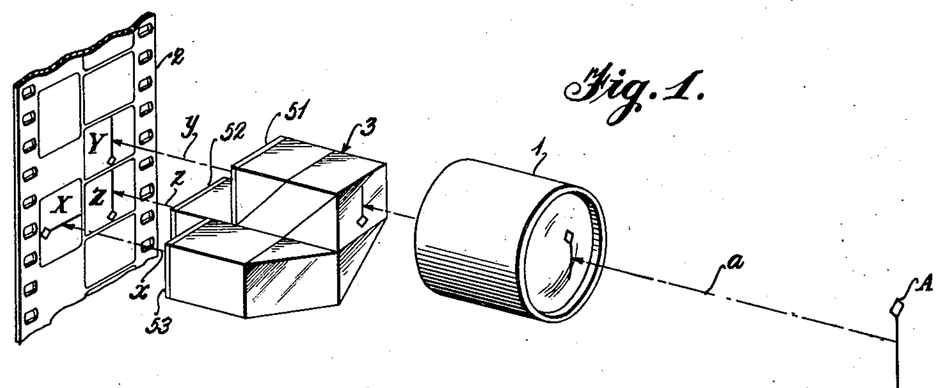

Fig. 1.

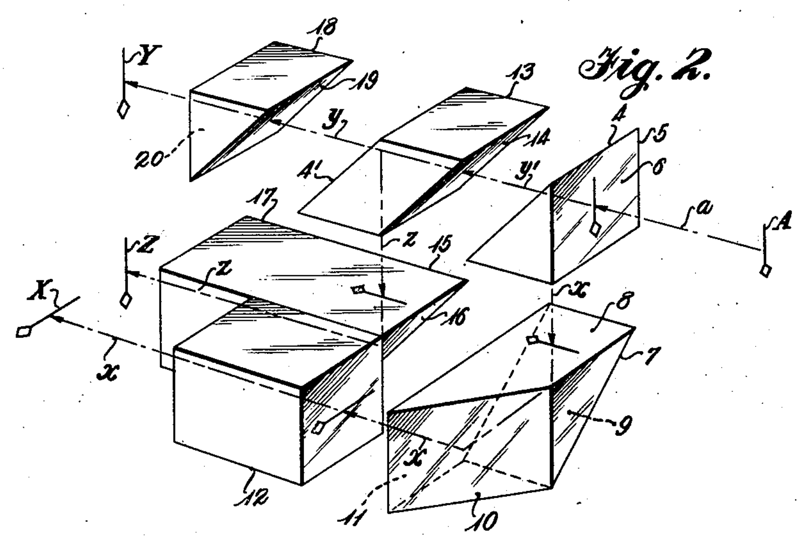

Fig. 2.

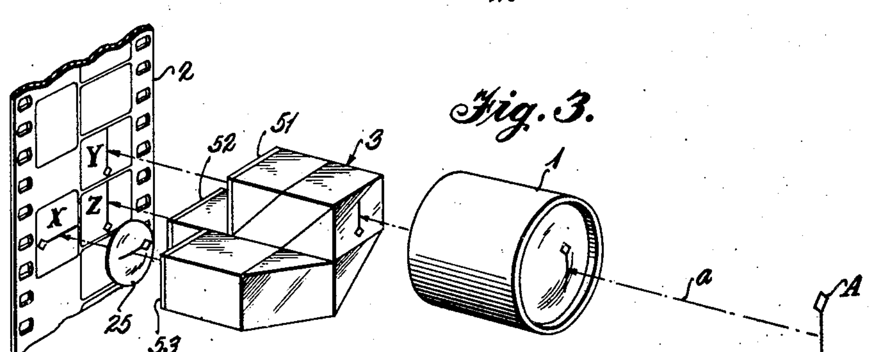

Fig. 3.

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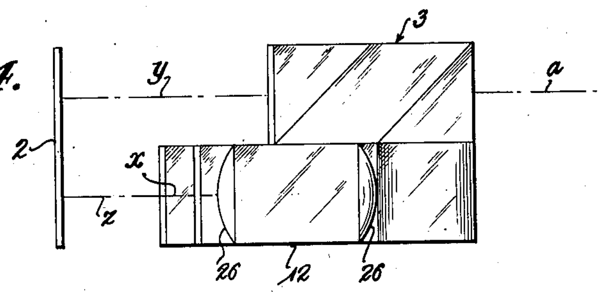
Fig. 4.



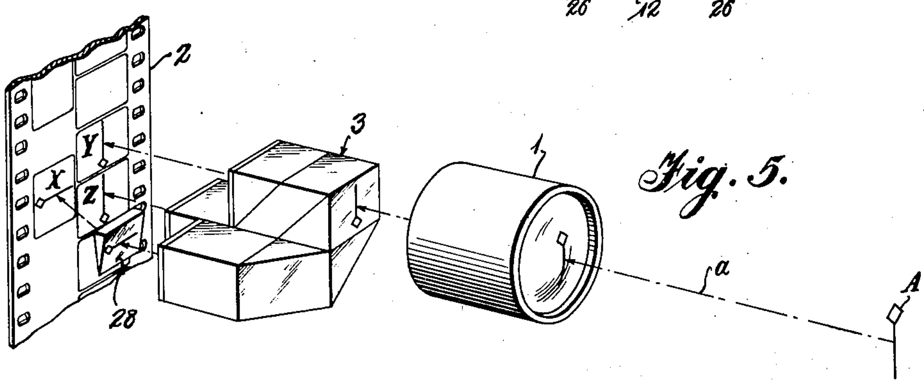


Fig. 5.

Fig. 6.

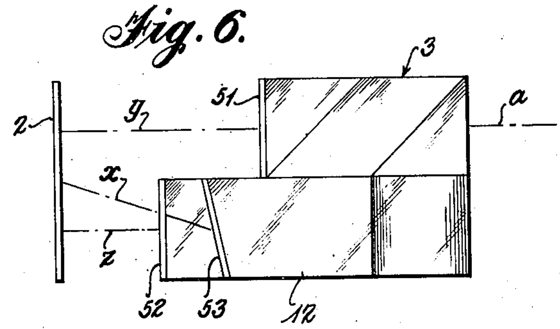
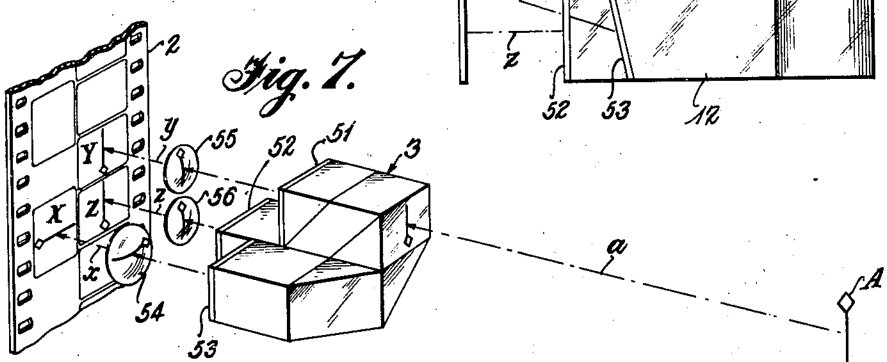


Fig. 7.



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2,315,783

COLOR PHOTOGRAPHY

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Application December 12, 1940, Serial No. 369,891

5 Claims. (Cl. 88—16.4)

This invention relates to color photography and more particularly to a process for recording a plurality of component images in a single film.

There are many different ways for obtaining color separation negatives for use in the production of multicolor prints which may be arranged to form a subtractive multicolor image. For instance, it is common to record images in superposition upon a multipack film or even upon different layers of a multilayer light-sensitive element. In these cases, the emulsion layers are usually sensitized for a particular range of the spectrum so as to record only images representing a predetermined spectral range. Another method that has been used rather extensively, at least from an experimental standpoint, comprises the successive recording of different component images on the same strip of film, in which event the alternate or every third image would represent the same color component. Still another method that has met with considerable success comprises the dividing of the optical image by means of a beam splitter and recording the two images simultaneously in side by side relation.

Each of these various methods have certain undesirable characteristics. The multipack method is very expensive both because at least twice as much film is employed and also because the individual emulsions are expensive due to the fact that they must contain specific sensitizers, filter dyes and the like. The multilayer element is undesirable as the various layers may require individual treatment that is mechanically difficult. The method wherein component images are recorded in succession has proven impractical due to the fact that two or three times as much film is used and also because the exposures must necessarily be made so fast that the process is limited in its use to only the best photographic conditions and in addition, requires high speed equipment that is both very complicated and expensive. While the method wherein the beam splitter is employed for dividing images has proven quite successful for two-color processes, this method must be combined with the multipack method in order to obtain three component images. Accordingly, all of the objections to the multipack method are inherent with the beam splitter method when three or more component images are desired.

Accordingly, it is an object of the present invention to overcome the above mentioned defects and to provide a method and apparatus whereby three color photographic images may be obtained which have a high quality of color reproduction and at the same time obtain sharp definition of the images. In addition, the present invention contemplates the combination of the more desirable features of both the image-dividing and single film methods, and in the elimination of the defects inherent in these methods. Likewise, satisfactory results are more assured by the present invention so that the number of pictures which have to be rephotographed is decidedly reduced. Furthermore, the subject matter of the present invention is comparatively inexpensive to produce and may be operated with ordinary equipment and by regularly trained technicians without the aid of specialists in the art.

Briefly, for example, three separate images may be simultaneously recorded on a single film so that the film costs do not rise above normal, the normal exposure conditions are available, and standard equipment may be used merely by replacing the optical device in the equipment which, of course, is always replaceably mounted anyway. This highly desirable object may be effected by dividing an image into three component parts while reducing the images in size and registering all three of the images within an area on a single film that is normally occupied by a single image. In order to obtain the maximum size of the divided images, two of the images may be recorded in upright position, one above the other, while the third may be turned through an angle of 90° and recorded on its side and adjacent the sides of the two companion images.

The beam splitter methods have heretofore been considered undesirable due to the loss of light but it has now been found that by selecting the resultant divided beams for recording certain spectral ranges, that very little effective light is absorbed or otherwise lost. Accordingly, by the use of a single optical device comprising an objective and a new type of beam splitter, very excellent component images can readily be obtained and recorded within a single panchromatic emulsion layer. The new type of beam splitter is devised so as to produce three like images having substantially equal intensities. These images may subsequently be used in the normal way for the production of lavenders or master images which are employed for producing the regular commercial exhibition films.

The invention both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of the specific embodiments when read in connection with the accompanying drawings, wherein like reference characters indicate like parts throughout.

Fig. 1 is a view in perspective of the preferred optical system for simultaneously producing three component images and the film on which the images may be recorded with the arrangement of the images indicated thereon;

Fig. 2 is an exploded view of a preferred type of three-way beam splitter;

Figs. 3 and 5 are views in perspective similar to Fig. 1, and showing modifications of the basic invention;

Figs. 4 and 6 are views in elevation of the sides of modified beam splitters, and

Figure 7 is a view in perspective of another modification of the invention.

Referring particularly to Figure 1 of the drawings, it will be seen that an image beam a of the object A may be received by an objective **1** and focused upon a photographic film **2**. The objective **1** is preferably the type having a long back focus in order to mechanically accommodate a beam splitter **3** between the emergent side of the objective **1** and the film **2**. As objectives having a long back focus are inclined to also have a relatively narrow object field it may be desirable to combine a dispersive member, or so-called "wide angle" lens with the objective to obtain both the wide field and the long back focus. Satisfactory lenses of this type are shown in U. S. Patent No. 1,910,492, granted to L. L. Mellor on May 23, 1933; and U. S. Patent No. 1,955,590, granted to H. W. Lee on April 17, 1934. The beam splitter **3** is provided with two partially transparent, partially reflecting faces **4** and **4'** so that an image is initially divided into two like images and one of the divided images is again divided into two like images whereby three like images are obtained. Blocks of glass are interposed in the paths of at least two of the divided images to compensate for their longer light paths. The film **2** preferably comprises a standard type of panchromatic emulsion but, of course, two or more spectrally selectively sensitive emulsion layers may be used.

Color filters are interposed in the paths of these three images so as to filter the images to thereby obtain three-color component part images. A blue filter **51** is positioned in the path of one of the divided images to obtain a blue component image, a yellow filter **52** is located in the path of another of the divided images to obtain a yellow-green component image, and a red filter **53** is interposed in the path of the third divided image to obtain a red component image. While this combination of colors is preferred, it will be understood that other colors may be used, such as blue, green, and red, or blue-violet, yellow-green, and orange-red. As a matter of convenience, the color filters may be mounted on the emergent faces of the beam splitter although of course they may likewise be separately mounted as a removable unit so that they may be replaced or other filters of slightly different absorption values may be substituted.

As best shown in Figure 2, the beam splitter comprises a right angle prism **5**, one face **6** of which comprises the incident face of the beam splitter and is positioned normal to the image beam a. The face **4** of this member **5** lies at 45° to the image beam a and may be treated as by sputtering silver, gold, aluminum or the like, thereon so as to form a partially reflecting, partially transmitting surface. This face **4** is prepared so that approximately one-third of the light which strikes said face is reflected while two-thirds of the light incident to said face is transmitted. The reflected light beam x is directed to a six-sided prism **7** which has an incident face **8**, two full reflecting surfaces **9** and **10** and an emergent surface **11**. By means of this prism the reflected image is not only set off to one side of the original image beam a, but is also turned through an angle of 90° so that the image X, which is recorded on the film, lies upon its side.

After the image beam x emerges from the face **11** it then passes through a compensating block **12** to equalize the paths of the reflected beam x and the transmitted beam y'. Upon passing through the compensating block **12**, the beam x then passes through the red filter **53** so that the resulting image X comprises the red component. The light beam y' that is transmitted by the face **4**, which comprises two-thirds of the light incident thereto, then passes into a prism **13** having an incident face **14** lying adjacent the face **4** and a partially reflecting, partially transmiting face **4'** on its emergent side. This surface **4'** is adapted to reflect as beam z one-half of the light comprising beam y' and to transmit as beam y one-half of the said light so that two like images are formed, each of which comprises approximately one-third of the total light of the original image and is substantially equal to the power of the first reflected image.

The image beam z reflected by the surface **4'** is directed into a prism **15** having a totally reflecting surface **16** which lies at an angle of 45° to the direction of the image beam z and parallel to the surfaces **4** and **4'**. The image beam z is thereby reflected through the extended portion **17** of the prism **15** which comprises a compensating element to equalize the length of image beam z with respect to the paths of the other divided images. The image beam z emerging from the prism **15** is passed through the yellow filter **52** so as to record the yellow-green component image Z upon the film. The image beam y which is transmitted by the surface **4'** passes into a right angle prism **18** having a surface **19** which is adapted to lie adjacent the surface **4'** and an upright emergent surface **20** that lies normal to the beam y and from which the image is passed through the blue filter **51** to the film **2** and recorded thereon as a blue component image Y.

The principal objection to the use of beam splitters has heretofore resided in the fact that there has been a considerable loss of the light as it passes through the various optical elements. It has now been found that this loss may be offset to a minimum by treating the optical surfaces of the various elements to provide them with thin films or the like so as to eliminate reflections from the surfaces. For instance, the surfaces of the elements in the objective **1** may be so treated as well as the various transmitting surfaces of the elements of the beam splitter. Loss of light is also decreased by providing the full reflecting surfaces of the beam splitter, namely surfaces **9**, **10** and **16**, with coatings which render the highest possible value of reflection.

According to present-day methods, it has been found that the best reflection is obtained by evaporating aluminum upon the reflecting surfaces. It has also been found that the light dividing surfaces of the beam splitter, that is, those surfaces which partially transmit and partially reflect the light, are the most efficient when they are formed by sputtering silver on the surfaces. In the present instance the surfaces **4** and **4'** would have the silver sputtered thereon in accordance with the amount of light that each of these surfaces is supposed to reflect.

Another unique feature which has been incorporated in this system resides in the discovery that the light reflected by the light dividing surfaces is relatively high in the red values of the spectrum, whereas the transmitted or direct beam of light is relatively high in the blue values of the spectrum. Accordingly, the first reflected image which is relatively high in the red values, is filtered with a red filter, whereas the directly transmitted beam of light is filtered with a blue filter. This principle is further borne out by the fact that the second reflected image is filtered with a yellow filter to record the yellows and greens. By this arrangement the maximum amount of the respective light values is obtained for recording each of the component images on the film.

As shown in Figure 1, the three images are recorded on the film as having exactly the same size. Each image is .495 inch long by .360 inch high. It has been found, however, that it is preferable to have the best possible definition in the green part image to be projected, and therefore to have the best possible definition in the red component image X, that is originally recorded. This provides an additional advantage in recording the red component image with the first reflected beam which contains a predominant proportion of red light. The red component image X may be considerably enlarged in the recording step by a very slight reduction in the size of the blue and yellow-green component images Y and Z or, preferably, by occupying the film area which is normally allotted to the sound record as well as the normal picture area.

According to such an arrangement, the blue and yellow-green component images may remain at the same size of .495 inch by .360 inch and the red component image may be enlarged to .660 inch by .480 inch. This arrangement obtains a highly desirable result without working any hardship due to the fact that in taking the original records the picture images and the sound records are usually recorded separately. The difference in size of the images does not matter in their reproduction as the picture records obtained by the present system are all enlarged to the normal size for a motion picture image, which is .825 inch by .600 inch, during the intermediate steps of producing the commercial exposition films.

The enlargement of the red component image may be readily effected by interposing a lens **25** in the path of the reflected beam *x* that emerges from the block **12**. This effect may likewise be obtained by the use of a modified structure as shown in Figure 4, wherein the block **12** is provided with one or more lens segments **26** on the entrance or emergent faces of said block **12** or on both of said faces. It will also be seen by Figures 3 and 4 that the red filter **53** may be positioned between the emergent face of the block **12** and the lens **25** or between the emergent face of the lens and the film.

The center of the red component image X normally lies in substantially the same horizontal plane as the center of the yellow-green component image Z, and that due to the turning of the red component image X, the ends thereof extend beyond one of the horizontal boundaries of its companion images Y and Z. While this offsetting of the images works no particular hardship in the average case, it is sometimes desirable for all three of the images to be positioned completely within the area normally occupied by a single standard sized image. As shown in Figure 5, the normal size area **27** is indicated by broken lines on the film **2**. The position of the red component image X may be readily adjusted by various means. For instance, as shown in Figure 5, a very thin wedge prism **28** may be interposed in the red image beam *x*, either in lieu of or along with the lens **25**. By this means the red image beam *x* will be refracted so that its image X will lie completely within the normal image area **27**.

In Figure 5 the red component image X has been shifted to a position where its center lies in the horizontal plane that runs between the adjacent horizontal edges of the companion images Y and Z, although it will be understood that it need not be shifted as much. Instead of employing a separate wedge prism **28**, the emergent face of the compensating block **12** may be arranged at an angle as shown in Figure 6, so as to cause the red component image X to be refracted to the desired position. Of course, the shifting of the image can also be obtained by tilting the magnifying lens **25** shown in Figure 3 although some slight distortion might result by so doing. Likewise, the magnifying lens **25** might be formed in more or less of a wedge which would cause the necessary refraction of the image.

The three component images X, Y and Z may be arranged in various manners with respect to each other. That is, the two horizontal images may be inverted and the vertical image to the left, the top thereof extending to the right or left, or it may lie on the right hand side with the top thereof extending to the right or left. Likewise, the vertical image may be in either of these two positions relative to its companion images with the top thereof extending right or left and the horizontal images may be upright. Practically any desired arrangement of images may be effected by rearranging the various prism elements of the beam splitter and/or by inserting lens elements between the beam splitter and the film so as to reverse the individual images. In the vast majority of instances, however, the exact arrangement of the images relative to each other is not of importance as these images are all enlarged to normal size and arranged in the necessary positions during the intermediate steps of producing the final commercial three-color exhibition films.

Still another modification of the invention is shown in Fig. 7, wherein the optical image beam *a* is received and divided by the beam splitter **3** into three like image beams and filtered by the color filters **51**, **52** and **53** as hereinbefore described. The principal difference in this modification resides in the fact that a separate lens may be used for each of the image beams after they have been divided in lieu of the objective **1** for receiving the original image beam. It will be understood that the separate lenses may be employed in combination with the principal objective **1** if it is desired to control the separate image beams in any manner. It will be seen in Fig. 7 that a lens **54** may be placed in the image beam *x*, a lens **55** may be placed in the image beam *y* and a lens **56** may be placed in the image beam *z*. By such an arrangement, the original image may be received by the beam splitter and divided into three like beams, colored by complementary color filters to form complementary color images, the color filtered complementary images may then be focused upon the plane of the film and thereby recorded in a single light sensitive silver halide emulsion.

Where in the following claims an expression is used to define the long dimension of the larger image as approximately the sum of the short dimensions of the two small images, it is to be construed as meaning that the area of the large image is of such an amplitude that, when added to the combined areas of the two small images, is substantially equal to the area of a normal frame on a motion picture film. It will be understood, of course, that the normal frame area occupied by the three component images may apply to films either with or without sound track, it being evident that in the former case the normal area is somewhat less than in the latter.

Although certain specific embodiments of the present invention have been shown and described, many modifications thereof are possible, and the present disclosure should be construed only in an illustrative sense. The present invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and the spirit of the appended claims.

I claim:

1. A motion picture film having recorded thereon a plurality of consecutive groups of images each group comprising three separate oblong color component images; two of said images being of substantially equal size and being arranged one above the other and the third image being arranged beside the other two, turned on its side with respect to them and larger than either of the other two to an extent such that its long dimension approximates the sum of the short dimensions of the small images and the three images cumulatively occupy an area substantially commensurate to the area of a normal motion picture frame; the ratio of short side to long side being equal in all of said images.

2. A motion picture film having recorded thereon in an area no greater than about that normally occuiped by a single picture, a red component image and two other primary color component images, said two other images being placed one above the other and the red component image being placed on its side with respect to the first two images and alongside them and being larger than either of the other two images.

3. Apparatus for simultaneously producing three separate, latent, black-and-white oblong photographic images of the same scene from exactly the same viewpoint, each image corresponding to a different color aspect of the scene and all three images being recorded in closely adjacent relationship upon a single sheet of emulsion in the same plane, that comprises focusing means for light from the scene, means between the focusing means and the emulsion for dividing the light from the focusing means into three parts, redirecting two of the three parts and passing one of the three parts onto the emulsion, means to further redirect one of the redirected parts of the light onto a place on the emulsion adjacent and substantially in vertical alignment with the place where the first portion of light falls, means to further redirect the second portion of redirected light to turn the image carried thereby on its side and project it onto a place on the emulsion adjacent the place where the other two portions of light fall, means to change the focus of this third portion of light to cause it to form a larger image than those formed by the other two portions of light, and means in each light path intermediate the means for dividing the light into three parts and the emulsion for removing predetermined color components therefrom, the paths of all three portions of light being such that the images carried by the three portions all come to focus in the plane of the emulsion with the two smaller images one above the other and the third image beside the other two, turned on its side with respect to them and larger than the other two to an extent such that its long dimension approximates the sum of the short dimensions of the smaller images and the three images cumulatively occupy an area substantially commensurate to the area of a normal motion picture frame.

4. Apparatus for simultaneously producing three separate, latent, black-and-white, oblong, photographic images of the same scene from exactly the same viewpoint, each image corresponding to a definite color aspect of the scene and all three images being recorded in closely adjacent relationship upon a single motion picture film in the same plane thereof; that comprises focusing means for light from the scene; means between the focusing means and the film for dividing the light from the focusing means into three parts, redirecting two of the three parts and passing the other of them onto the film with the short side of the resulting image extending lengthwise of the film; means for filtering the part passed onto the film to remove the complement of blue therefrom; means to further redirect one of the redirected parts of the light onto a place on the film adjacent and substantially in vertical alignment with the place where the first portion of light falls also with the short side of the resulting image extending lengthwise of the film; means to filter this portion of redirected light to remove the yellow-green complement from it; means to further redirect the second portion of the redirected light, turn the image carried thereby on its side and project it onto a place on the film beside and adjacent the place where the other two portions of light fall; and means to filter this third portion of light to remove the red complement therefrom, the light paths of the three portions of light being such that the images carried by all three portions come to focus in the plane of the film.

5. Apparatus for simultaneously producing three separate, latent, black-and-white, oblong, photographic images of the same scene from exactly the same viewpoint, each image corresponding to a definite color aspect of the scene and all three images being recorded in closely adjacent relationship upon a single motion picture film in the same plane thereof; that comprises focusing means for light from the scene; means between the focusing means and the film for dividing the light from the focusing means into three parts, redirecting two of the three parts and passing the other of them onto the film with the short side of the resulting image extending lengthwise of the film; means for filtering the part passed onto the film to remove the complement of one of the primary color components therefrom; means to further redirect one of the redirected parts of the light onto a place on the film adjacent and substantially in vertical alignment with the place where the first portion of light falls also with the short side of the resulting image extending length-

wise of the film; means to filter this portion of redirected light to remove the complement of another primary color component from it; means to further redirect the second portion of the redirected light, turn the image carried thereby on its side and project it into a place on the film beside and adjacent the place where the other two portions of light fall; means to filter the red complement from this third portion of light; and means to change the focus of this third portion of light to cause it to form a larger image than those formed by the other two portions of light, the light paths of all three portions of light being such that the images carried by them all come to focus in the plane of the film.

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