PATENT SPECIFICATION

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COMPLETE SPECIFICATION.

Improvements in or relating to Optical Systems for the Production of Complemental Color Images for Color Photography.

We, KALMUS, COMSTOCK AND WESCOTT, INCORPORATED, a Massachusetts corporation, and DANIEL FROST COMSTOCK, a citizen of the United States of America, both of 110, Brookline Avenue, Boston, Massachusetts, United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to optical systems for the production of complemental color images for color photography.

The principal object of the present invention is to secure complemental images which are geometrically identical so that they may be accurately registered or superposed according to either "additive" or "subtractive" methods. Other objects are to secure such images in juxtaposed relationship on the same side of the film, to reduce the distance between the objective and the image plane, and generally to improve the art of forming complemental images.

The invention consists in photographic apparatus for simultaneously producing on the same side of the same film, or at least in substantially the same plane, two or three separate complemental images, the apparatus comprising means for dividing a beam of light into two or three similar beams and directing the respective divisions to the focal plane, characterized in that all of the respective divisions are reflected in the same general direction along substantially equivalent optical paths to form complemental images which geometrically are substantially identical so that they may be registered to a high degree of accuracy. Preferably the divisions are first reflected in one general direction and then in a different general direction as, for example, first to the left and then to the right. The paths of the divisions are preferably made optically equivalent by making them geometrically equal in length; and corresponding portions of the paths (*e.g.* the portions between the first and second reflections and the portions between the second reflection and the focal plane) are preferably parallel. Other characteristic features of the invention will appear from the following description of illustrative embodiments of the invention.

In the accompanying drawings, Figs. 1 to 4 inclusive illustrate diagrammatically several optical systems for obtaining a plurality of images of the same scene from accurately the same point of view at the same time.

Referring to Fig. 1, O represents the object field (the scene to be photographed), L represents the lens, and F represents the film. The light beam B from the object passes through the lens and the glass prism P, perpendicular to surface x^1 of prism P, to the semi-transparent reflecting surface x, which may be made by half-silvering the surface of prism P, or by introducing between P and P^{11} a film of some transparent substance of suitable refractive index, or which may be a light-dividing "grid" of transparent material having distributed thereon distinct areas of transmission and of reflection. A part of the light (ordinarily about one-half the light in two-color work) is reflected from surface x along the path B^1 to the totally reflecting surface x^2, and thence along path B^{11} to the film, forming an image on the film F at M. The remainder of the light passes through surface x and through prisms P^{11} and P^1 to the totally reflecting surface y, parallel to x, of the

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prism P^1, and is thence reflected along the path B^2 to the totally reflecting surface y^1, parallel to x^2, of prism P^1, and thence along path B^{22} to the film, and forms a second image on the film F at N. Prism P^1 is separated from prisms P and P^{11} by a thin film of air or other substance of sufficiently low refractive index to insure total reflection from surface y^1. This system gives images similarly arranged, that is, head to foot, since each beam is reflected twice. By the inclusion of prism P^{11} the geometrical lengths of the two paths of the divided beam in the same or similar media are the same.

Fig. 2 shows the same principle applied to the formation of three simultaneous pictures similarly arranged (head to foot), and scarcely needs additional explanation. The beam B enters prism $P^{11\,1}$ through surface x^2, which is normal to the beam. Partly transparent reflecting surface x reflects essentially one-third of the light along path B^1, to the totally reflecting surface x^1 and thence along path B^{11} to the film F, forming an image at M. The remainder of the light passes through prism P^{iv} to semi-transparent reflecting surface y, where the beam is again split, substantially half being reflected along path B^2 to the totally reflecting surface y^1 and thence along path B^{22} to form the image N on the film, while the remainder of the beam passes through prism P^{11} (which furnishes a medium of glass) and prism P^{v} to totally reflecting surface z, thence along path B^3 to totally reflecting surface z^1, and thence to the film forming an image at O. The surfaces x^1, y^1 and z^1 are totally reflecting surfaces, the latter two being rendered so by films of air between said surfaces and the adjacent prisms, or by applying to the surfaces y^1 and z^1 of prisms P^{iv} and P^{v} some medium of suitable refractive index such as ordinary balsam which has a sufficiently low index of refraction to yield total reflection, as in the case of air, and also affords protection against the soiling of the glass surfaces. The prisms $P^{11\,1}$ and P^{iv} are hollowed out opposite surfaces y^1 and z^1, and are coated with black balsam as shown at k, k^1, or other suitable material, to prevent any stray light from passing between the prisms $P^{11\,1}$ and P^{iv}, or between the prisms P^{iv} and P^{v}. For z^1 in particular it is desirable to use a film of only slightly lower index than the glass, which, without interfering with the total reflection of ray B^3, will diminish the loss by reflection of part of the initial beam B when entering the prism P^{v}.

Figs. 3 and 4 show perspective and plan views, respectively, of another arrangement of prisms for producing a result similar to that of the system shown in Fig. 2, namely, the formation on the same film of three pictures simultaneously from accurately the same point of view, at equal optical distances from the lens. This arrangement involves a longer optical path than that of Fig. 2, one advantage over the latter being that it involves no angles other than 90° and 45° angles, thus requiring only standard shapes of prisms.

Both Figs. 3 and 4 are diagrammatic or schematic, and the oblique view of the system, shown in Fig. 3 as an aid to visualization, is a view from an angle of approximately 45° to the plane of Fig. 4, from the lower left-hand corner, and in both figures no account is taken of the refraction of light due to entering and leaving the prisms at angles other than right angles; in other words for the sake of clearness and to avoid complication in drawing, the diagrams show the paths of the beams as though the prisms were leaves-of-a-book mirrors. The beam B is to be divided into three parts, and for clearness is shown in three lines. From the lens L the beam falls upon the partly transparent reflecting surface c, which may be any suitable form of light-dividing means such as a partly silvered surface, or a light-dividing grid, adapted to transmit substantially two-thirds of the light and to reflect substantially one-third of the light, said surface c being arranged at an angle of 45° to the path of the beam. The reflected part of the beam passes along path b to the totally reflecting right-angle prism C, whose apex C^1 is in a plane below and parallel to the horizontal plane of the light beam, and in a vertical plane at an angle of 45° to the split beam b. The beam b strikes the upper face C^2 of the prism and is reflected downward along path b^1 to the lower face C^3, and thence along path b^2 to the film F, forming an image at M. Said lower right-angle prism C thus shifts the beam sidewise with relation to the prism, that is, lengthwise of the film, and reverses the image.

The rest of the beam B passes along the path b^3 to semitransparent reflecting surface d, which is a suitable light-dividing means adapted to transmit substantially half of the light and to reflect substantially half of the light, said surface d being arranged at an angle of 45° to the path of the beam. The reflected part of the beam, *i.e.* substantially half of the beam b^3, or one-third of the total beam B, passes along path b^4 to the totally reflecting right-angle prism D whose apex is in the same horizontal plane as the light beam b^4 and at an angle of 45° thereto. This prism D, being centrally located with respect to the horizontal plane of the beam, does not shift the beam but reverses the image and reflects the beam along path b^5 and forms an image on the film at N. A plane reflector would accomplish the same purpose as prism D, except that it would not reverse the image, which would then not be arranged similarly to the other two.

The part of the light transmitted by surface d, passes along path b^6 to the upper right-angle totally reflecting prism E, which is similar to prism C but oppositely arranged and has its apex E^1 above the plane of the light beam. The beam b^6 strikes the lower face E^2, from which it is reflected along path b^7 to the upper face E^3. This shifts the beam sidewise with relation to the prism, that is, upward and lengthwise of the film, and reverses the image. From surface E^3 the beam passes along path b^8 to the totally reflecting surface r, which is at an angle of 45° to the beam, and thence along path b^9 to the film F, forming an image at O.

The three images are similarly arranged, or head-to-foot, since each split beam is once reversed by a right-angle prism, and once reflected. The entire apparatus may be made in the form of a solid block of glass, of which the prism-surfaces indicated form part of the bounding surface. The incidence is in all cases so oblique as to insure total reflection.

A feature characteristic of the present invention is substantial equality between the two or more optical paths from lens to images, this being due to the fact that the lengths of the paths of the split beams in glass and in air are the same. This is highly advantageous as only in this way can the optical corrections for the glass be performed all at once by a single correcting device for the entire beam before the beam is split.

An important problem solved in each of the above devices is to obtain the desired arrangement of images and the necessary equality of paths, without excessive length of path from lens to images. This restriction results from rigid limitation imposed by practical considerations on the focal length of the lens used—a limitation which excludes many possible arrangements because of the too great length of path they require.

It follows that, unless metal reflectors are used (which in general is not feasible), in systems involving a single lens, a large part of the path from lens to images must lie within the glass prisms used to divide and manipulate the light.

This mass of glass acts as a lens and unless the prisms are coordinated with the objective so that the optical system as a whole is optically correct, aberrations (curvature of field, chromatic aberrations, and spherical aberration) will result. In order to coordinate the elements of the optical system, especially where the objective lens is in the path of the main beam in contradistinction to a separate objective in the path of each divided beam, it is highly desirable that the part of every path from lens to image which lies in glass be made equal; that is, that each part of the beam, after division, traverse the same distance in glass. This is an important feature of all the above arrangements.

It is of great importance that the geometrically identical images before referred to should be taken on the same film and not very distant from each other. There are several reasons for this. In the first place, any film during the mechanical and chemical processes of developing and fixing, undergoes a certain amount of change in form, principally shrinkage, and in general it cannot be assumed that two separate films will shrink to the same degree. Therefore, if the images were taken on two or more different films, they could not be relied upon to remain accurately the same in size through the process of development, printing and projecting upon the screen.

In the second place, the accurate superposition of two or more pictures on the projecting screen depends on the two or more images on the film used in projection, being other positioned to extreme accuracy or out of position by the same small amount. Actual practice proves that lack of register on the screen is more annoying than an irregular displacement of the picture as a whole, that is, of all of the two or more superimposed images to the same degree. It is therefore important that the relative position on the screen of the two or more geometrically identical images should be more accurately constant than the mere positioning of non-attached films by the mechanism of the projector can accomplish. When the two or more images are on the same film and the film is treated uniformly throughout its length, pictures on the projecting screen once in register will remain accurately in register, since the slight irregularities of the mechanism when the pictures are similarly printed involves similar displacements for all of the superimposed screen images.

A characteristic of the present invention, at least in its preferred forms herein disclosed, is that the component beams are first deflected to one side of the path of the main beam and are subsequently reflected in the reverse sense. For example in Fig. 2 the component beams are first deflected to the left at x, y and z, and subsequently are deflected to the right at x^1, y^1 and z^1. Likewise in Fig. 5 the component beams 2 and 3 are first deflected to the left and then to the right.

Another characteristic contributing to the value of the invention in certain of its aspects is that the divided beams are reflected through oblique angles instead of right angles, some of the angles being acute and others obtuse. When using prisms one advantage of this feature is that the surface through which the beam enters the prisms may be employed subsequently to reflect one of the divided beams, as shown for example in Figs. 1 and 5. Another advantage is that the paths of the divided beams are thereby shortened.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Photographic apparatus for simultaneously producing in substantially the same plane two or three separate complemental images comprising means for dividing a beam of light into two or three similar divisions and directing the respective divisions to the focal plane, characterized in that the respective divisions are reflected in the same general direction along substantially equivalent optical paths to form in substantially the same plane separate complemental images which geometrically are substantially identical, and which are similarly orientated or directed.

2. Photographic apparatus according to Claim 1 further characterized in that the reflections of the divisions are first to one side (right or left) and then to the other side (left or right).

3. Photographic apparatus according to either of the preceding claims further characterized in that the paths of said divisions are substantially equal in geometrical length and corresponding portions of the paths are substantially parallel.

4. Photographic apparatus according to Claim 2 further characterized in that the last reflection of each division is through an obtuse angle.

5. Photographic apparatus according to any of the preceding claims further characterized in that each reflection of each division is at an oblique angle.

6. Photographic apparatus according to any of the preceding claims further characterized in that the reflectors are so positioned that the complemental images are focused in a plane which is oblique to the axis of the main beam.

7. Photographic apparatus according to any of the preceding claims further characterized in that the prisms are so shaped and positioned as to effect the reflections at interior surfaces.

8. Photographic apparatus according to Claim 7 further characterized in that the prisms form substantially continuous paths for the light from the lens to the focal plane.

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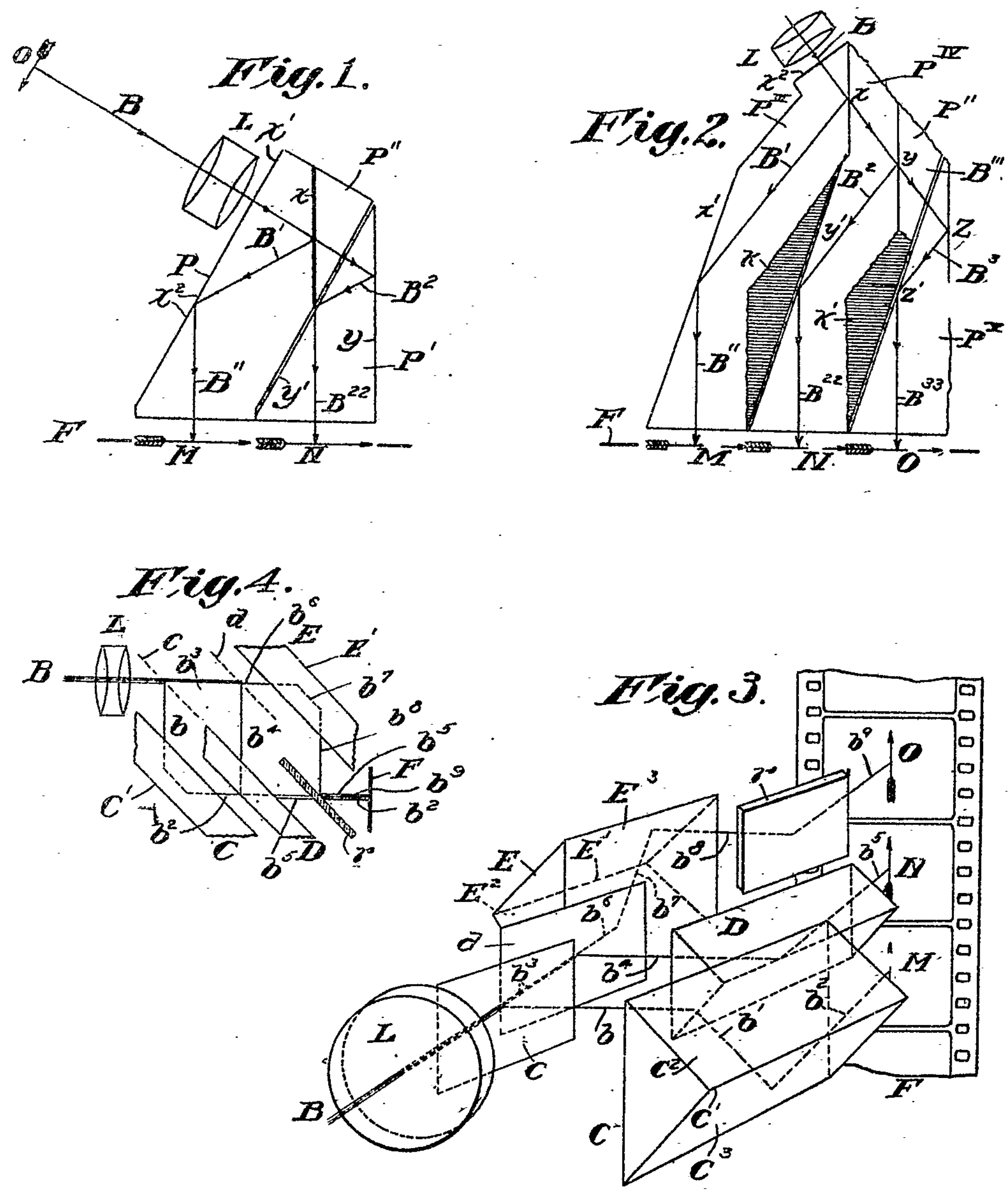
[This Drawing is a reproduction of the Original on a reduced scale]



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