March 28, 1939. R. THOMAS 2,152,224

MULTIPLE IMAGE OPTICAL SYSTEM

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Fig. 1

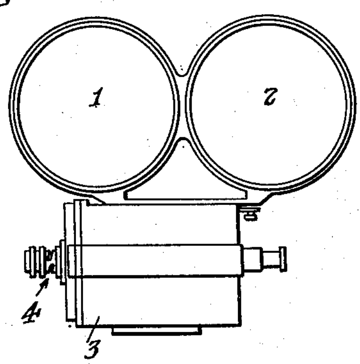

Fig. 2

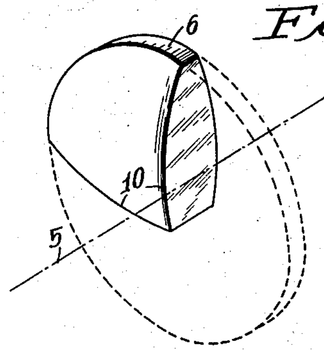

Fig. 15

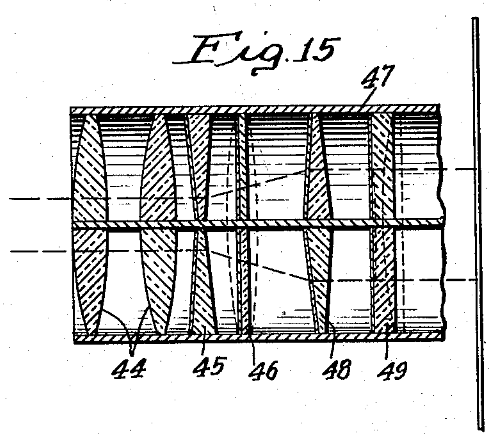

Fig. 14

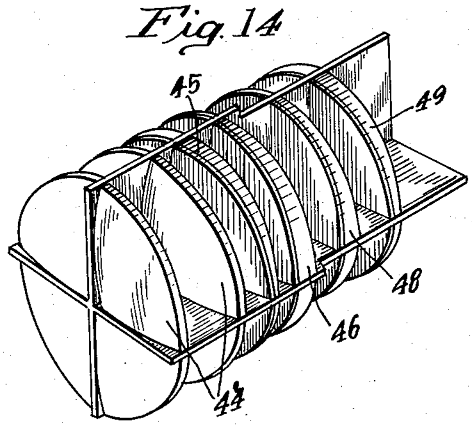

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Fig. 5

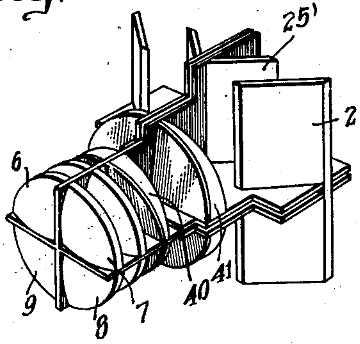

Fig. 6

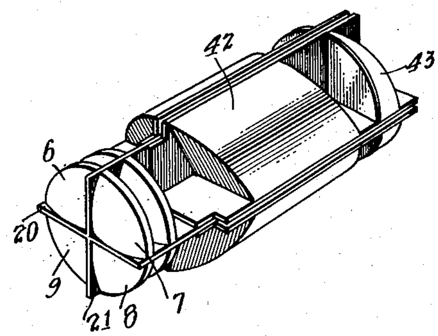

Fig. 3

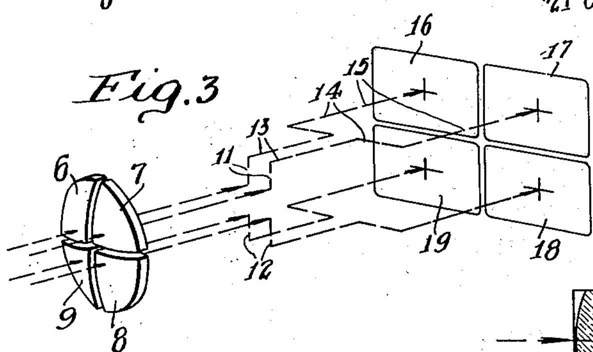

Fig. 7

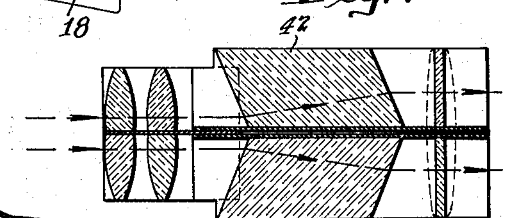

Fig. 4

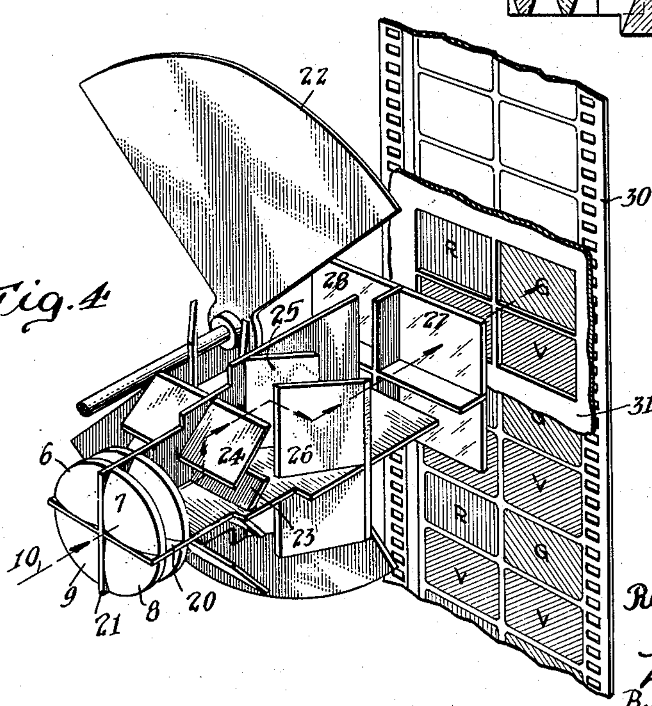

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Fig. 8

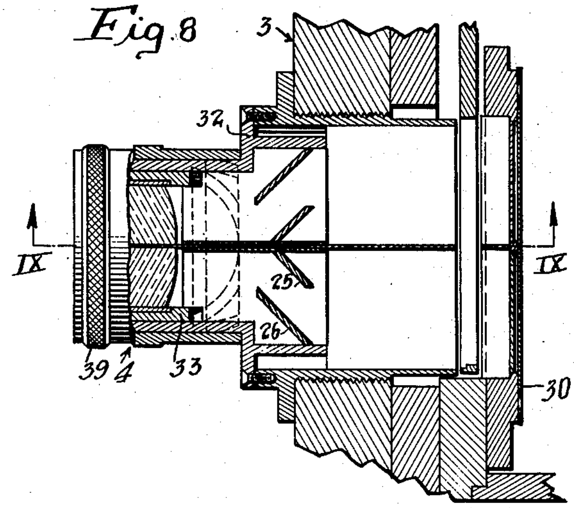


Fig. 12

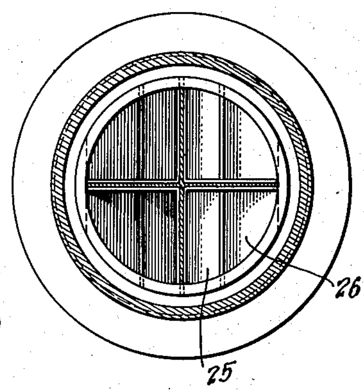


Fig. 9

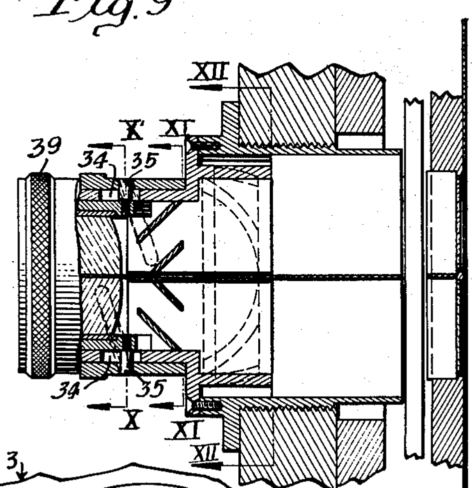


Fig. 11

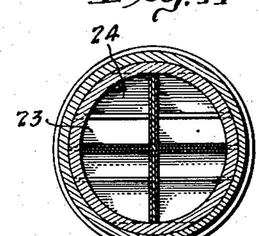
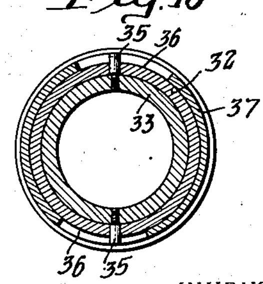


Fig. 10



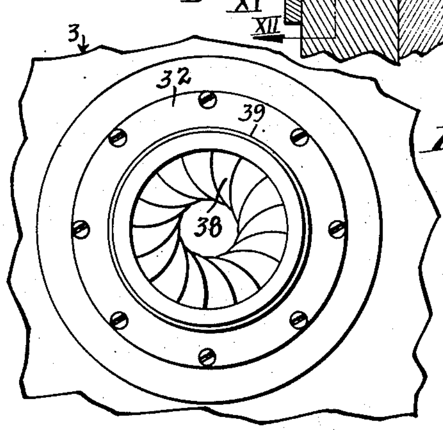


Fig. 13

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Fig. 16

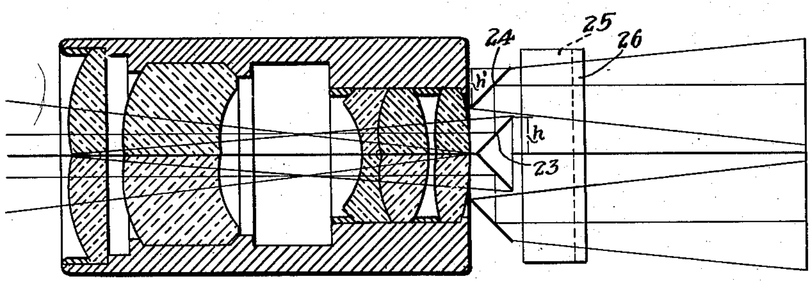


Fig. 18

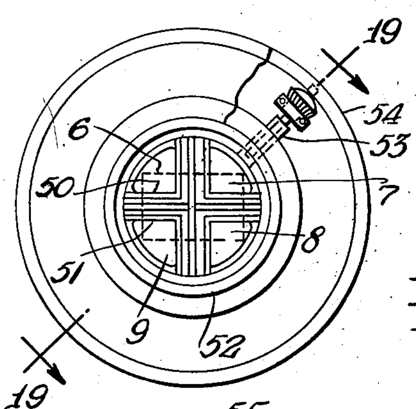
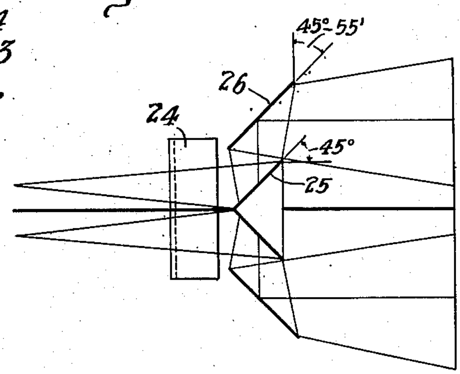


Fig. 17



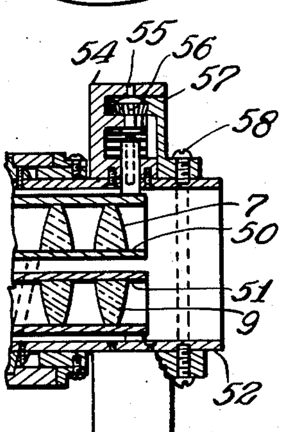


Fig. 19.

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Patented Mar. 28, 1939 2,152,224

UNITED STATES PATENT OFFICE

2,152,224

MULTIPLE IMAGE OPTICAL SYSTEM

Richard Thomas, Los Angeles, Calif.

Application June 30, 1936, Serial No. 88,151

7 Claims. (Cl. 88—16.4)

This invention relates to means and methods whereby a plurality of isomorphous photographic images may be readily obtained without the introduction of optial errors or undue loss of light. The isomorphous images may be of different color values and the resulting negatives may be used in either additive or subtractive processes of color reproduction, either in motion picture photography, photolithography, or the like.

Heretofore, methods have been devised whereby two isomorphous images could be obtained simultaneously. When a single objective lens and a bi-pack are used to obtain this result, the process is limited to two color work and either one or both of the resulting images lack definition and detail. By using light-splitting devices, such as half silvered mirrors, etc., two separate emulsions or films can be simultaneously exposed through a single objective but the amount of light reaching the emulsions is materially reduced, thereby necessitating the use of higher light intensity on the scene or object or longer exposures. Furthermore, the cameras are bulky and expensive. The use of separate lenses, each supplying light to a separate film or emulsion, introduces parallax. Parallax (due to the separation of the optical axes of the two or more lenses used) is evidenced by the fact that the resulting images are not truly insomorphous and can not be successfully and accurately registered. Unless perfect registration is obtained, the composite image will show fringing and be indistinct, particularly when such images are used for simultaneous projection through suitable light filters upon a single observation surface.

The present invention offers a solution to the problems and objections heretofore encountered.

In accordance with this invention, an optical system is employed which comprises a plurality of lens segments, each lens segment containing its optical center and axis. These lens segments are arranged with their optical axes substantially parallel, the optical axes being placed very close together. When the invention is used for the production of cinematographic films, these optical axes should be closer together, both horizontally and vertically, than the geometric centers of the separate, full image areas to which light is supplied by the lens segments. By utilizing the axial portion of lenses in this manner, errors due to spherical aberration, chromatic aberration, astigmatic error, etc., common to systems which utilize the outer portions of a lens, rather than the axial portion, are of no significance. The complete compound lens assembly of this invention is faster and has more light gathering capacity than a single, normal lens of the same overall diameter.

Ordinarily, the image areas would overlap if the optical axes were placed as close together as this invention contemplates. This problem is solved in accordance with this invention by the use of suitable deflecting means whereby the light passing through each of the lens segments is maintained separate and deflected away from the adjoining lens segments to an equal and predetermined extent. As a result, it is possible to obtain a plurality of isomorphous images of the required size without sacrificing normal exposure or definition, the resulting image areas containing images of objects in identical positions and relationships so that parallax or lack of registration is not visible even though the images are highly magnified during superimposition.

The invention also contemplates methods and means of reproducing objects in substantially natural colors by the use of light filters of a kind and number more specifically described hereinafter whereby the characteristics of normal panchromatic photographic emulsions are utilized to best advantage in the formation of color films of great fidelity.

It is an object of the present invention, therefore, to disclose and provide a method whereby a plurality of substantially isomorphous photographic images may be simultaneously obtained without visible parallax.

Another object is to disclose and provide a method whereby a plurality of separated, substantially identical images of different color value may be obtained from a substantially identical point of view, without undue loss of light.

A further object of the invention is to disclose and provide a structure and a combination of elements whereby a plurality of isomorphous separated images may be simultaneously produced for use in various processes of color reproduction.

Other objects, advantages and uses of the present invention will become apparent to those skilled in the art from the following detailed description of preferred forms of the invention, it being understood that such preferred forms are described in considerable detail for the purpose of illustration only.

In order to facilitate understanding of the invention, reference will be had to the appended drawings, in which:

Fig. 1 is a side elevation of a motion picture camera provided with elements which permit the performance of the method.

Fig. 2 is a perspective view of a segmental lens element which may be used in the optical system of this invention.

Fig. 3 is a diagrammatic isometric view illustrating the paths of paraxial rays in the production of the isomorphous images.

Fig. 4 is an isometric view illustrating one form of construction.

Figs. 5 and 6 are isometric views illustrating modified forms of construction.

Fig. 7 is a longitudinal section through the optical system shown in Fig. 6.

Fig. 8 is a horizontal section through a camera lens provided with the means of this invention.

Fig. 9 is a vertical section through the camera lens of Fig. 8, the section being taken along the plane IX—IX of Fig. 8.

Figs. 10, 11 and 12 are transverse sections taken along the planes X—X, XI—XI and XII—XII of Fig. 9.

Fig. 13 is a front view of the camera lens shown in Figs. 8 and 9.

Fig. 14 is an isometric view of an optical system embodying the inventions herein described.

Fig. 15 is a vertical section through the optical system of Fig. 14, illustrating the relationship between the elements when focused at infinity.

Figs. 16 and 17 are diagrammatic representations showing in greater detail the path of light passing through one of the quadrantal lens segments when reflecting means are used.

Fig. 18 is a front view, partly diagrammatic, of a camera provided with the multiple image optical system of this invention, and with means for adjustably positioning the lens segments. Fig. 19 is a section taken along the plane XIX—XIX through a portion of Fig. 18.

As shown in Fig. 1, a form of camera provided with magazines 1 and 2 removably mounted upon the camera housing 3 is provided with an optical system generally indicated at 4, said optical system being adapted to focus upon the film passing through the camera and simultaneously expose adjacent areas of the film to form a plurality of isomorphous spaced images capable of registration with one another upon superimposition, either mechanically or by projection.

The optical system embodied in the camera lens 4 may be designed to simultaneously focus and produce three or more isomorphous spaced images. For purpose of illustration, the optical systems hereinafter described are those adapted to produce four images simultaneously. For this purpose, lens segments of the character illustrated in Fig. 2 are employed, each of these lens segments subtending more than 90° of the arc of a complete lens, thereby including the optical center or optical axis of the original lens. In Fig. 2 the optical axis is indicated at 5 and the desired segment is indicated at 6. The angle 10 is about 90° but it is understood that when a smaller or larger number of images is to be simultaneously obtained, this angle may be either greater or smaller than 90°. Furthermore, although a single thick lens segment is shown in Fig. 2, it is to be understood that a segment of similar character is formed from the compound projection or camera lens when such compound lenses are used.

Fig. 3 diagrammatically illustrates the arrangement of the segmental lens. As there shown the lens segments 6, 7, 8 and 9 are arranged with their optical axes close together. These optical axes should be closer together than the geometric centers of the complete separate isomorphous images which it is desired to obtain. The image planes or image areas on which each of the lens segments forms its image are indicated at 16, 17, 18 and 19.

In order to minimize parallax to such an extent that the images formed on areas 16 to 19 inclusive are capable of being superimposed without fringing or lack of definition, the optical axes of the lens segments 6 to 9 inclusive are placed very close together. In all instances, such optical axes are closer together than the geometric centers of the separated image areas. For motion picture work it has been found highly desirable to place these optical axes about 0.30 inch apart. Even better results are obtained when the optical axes are closer together but in all instances each lens segment must include its true optical axis and the sides of the segment should not pass directly through the optical axis.

In order to obtain separated images from an optical system including lens segments, such as 6 to 9 inclusive, the bundle of light passing through each lens segment is kept separate from the bundle of light passing through adjoining segments. Furthermore, each bundle of light is deflected away from an adjoining bundle of light. As shown in Fig. 3, paraxial rays through the upper lens segments 6 and 7 are first bent upwardly as at 11 whereas the paraxial rays passing through the lower lens segments 8 and 9 are bent downwardly as indicated at 12. Thereafter the paraxial rays passing through the upper lens segments 6 and 7 are directed toward the image plane as indicated at 13 and then separated by being oppositely deflected as indicated at 14. These rays are then directed toward the geometric centers of the image fields 16 and 17, as indicated at 15, the paraxial rays passing through the lower lens segments 8 and 9 being similarly deflected, reaching the geometrical centers of the image frames 18 and 19.

The deflecting means may assume various forms. Refraction through members provided with parallel sides or prisms may be used either alone or in combination with suitably positioned reflecting surfaces, or such reflecting means may be combined with refracting means.

The arrangement shown in Fig. 4 diagrammatically illustrates the use of reflecting means only. As there shown the lens segments 6, 7, 8 and 9 are separated by suitable septa 20 and 21 which extend rearwardly substantially to a plane through which a shutter indicated at 22 rotates. The path of the paraxial ray 10 is illustrated and it will be seen that it is upwardly deflected by means of a reflecting member 23, then reflected toward the image plane by the reflecting member 24, subsequently reflected outwardly by the reflecting means 25 and again reflected toward the image plane by the member 26. When it is desired that the isomorphous images be of different color value, suitable light filters such as the filters 27, 28, etc., are positioned between the optical system and the image plane in which the emulsion carried by the film 30 is positioned. A suitable gate is indicated at 31. Means for intermittently moving the film are not shown, it being understood that in cinematography the film 30 will be periodically advanced longitudinally a distance equivalent to the height of a pair of isomorphous, simultaneously produced images, in timed relation with the rotation of the shutter 22.

The reflecting means 23, 24, 25 and 26 are preferably aluminized or made surface-reflective in any suitable manner, thereby preventing the secondary reflections and loss of light which takes place when mirrors are employed. Furthermore, the reflecting members 23 to 26 inclusive are preferably of progressively increasing height, the spacing between reflecting members of the second pair being progressively greater than the space between the members of the first pair. The progressively increasing height and spacing of the reflecting members accommodates the gradual spread of the bundle of light passing through each of the lens segments. The reflecting members 23, 24 and 25 lie in planes at 45° to the optical axis 10. The reflecting member 26 is preferably placed at such an angle that the angle of incidence with a paraxial ray is between 45°—30′ and 46°—30′.

The height of the member 23 should be only sufficient to gather and reflect all of that bundle of light which is supplied thereto by the segmental lens 7. Moreover, all of the reflecting means 23 to 26 inclusive should be positioned as close to the segment lens 7 as possible but preferably between the lens and its principal focal point. The total travel of the rays through the various reflecting means (or refracting means) to the film should be equal to the focal length of the lens segments used. In the embodiment shown in Fig. 4, the entire assembly, including the lens segments and reflecting means, is moved bodily during focusing although in certain embodiments of the invention a part, or even all, of the reflecting or refracting means may be stationary with respect to the film, only the lens segments moving during focusing of the device.

The simultaneous movement of the lens segments and reflecting or deflecting members is particularly adapted for use with lens segments of the wide angle type or lenses in which the adjustment for different focal depths (or objects at different distances from the lens) involves an appreciable movement of the lens toward or away from the image plane. When the focusing movement of the lens is inappreciable, the lens may move toward and away from reflecting or deflecting members, which members are then stationary with respect to the image plane on which the photographic images are to be obtained. A detailed construction embodying the above is illustrated in Figs. 8 to 13 inclusive. As there shown, the camera 3 is provided with a fixed iris cylinder 32, the lens barrel 33 being slidably mounted within the iris cylinder. The iris cylinder is provided with a pair of opposing slots 34 parallel to the axis of the cylinder whereas the lens barrel 33 is provided with a pair of pins 35 slidably extending through the slots 34 and into helical grooves or apertures 36 formed in a rotatable sleeve 37 carried by the iris cylinder. Rotation of the sleeve 37 can thus be translated into axial movement of the lens segments carried by the lens barrel 33. The forward end of the iris cylinder 32 is provided with a suitable iris diaphragm, such as the diaphragm indicated at 38, this single diaphragm modulating and stopping the light passing through the plurality of lens segments. The iris 38 may be adjusted by means of a ring 39.

The reflecting members, such as the members 23 to 26, are firmly attached to the member 32. The septa separating the various lens segments and separate bundles of light may be of an extendable, overlapping type so as to positively prevent any interference between light beams admitted into the camera through adjoining lens segments.

Instead of employing reflecting members, similar results may be attained by the use of deflecting members in the form of prisms, refracting blocks, etc. Fig. 5, for example, represents an optical system in which light passing through the lens segment 7 is upwardly deflected by means of a prism 40, the light being then corrected or rendered substantially parallel to the optical axis by means of a prism 41. Light upwardly displaced (with respect to the optical axis of the lens segment 7) by means of the prisms 40 and 41 may then be deflected in a direction substantially at right angles to the first deflection by means of the reflecting members 25′ and 26′. The correcting prism 41 may be of slightly greater power than the prism 40, the difference being of the order of 1° and sufficient to make a difference of not more than about 0.002 inch in the position of an object point on the film when the lens employed is of such character that it is subject to a travel of about $\frac{1}{8}$–$\frac{3}{16}$ inch in focusing from infinity to 6 or 8 feet.

The arrangement illustrated in Fig. 7 eliminates the use of reflecting members altogether. Light from the segmental lens 7 passes into a refracting block 42 provided with parallel sides whereby the bundle of light is upwardly refracted. The light is then outwardly deflected by means of the prism 43. The path taken by the light rays through an arrangement such as is shown in Fig. 6, is illustrated in Fig. 7.

Fig. 14 discloses an arrangement whereby light passing through the segmental lens 44 is upwardly deflected by a prism 45 and then outwardly deflected by means of the prism 46. The lens segments and the prisms 45 and 46 may move together and may be mounted within a barrel 47. Between such optical unit and the image plane compensating prisms may be positioned. Such compensating prisms may include a prism 48 which is oppositely angulated with respect to prism 45 and a prism 49 which is oppositely angulated with respect to the prism 46. Whenever reference is made to prisms herein, reference is made to normal prisms provided with plane surfaces. Each prism is preferably positioned in such manner that neither of the two plane faces lies in a plane at right angles to the optical axis of the optical unit as a whole.

Moreover, although the prisms may vary in refracting power, prisms having an angulation of from about 3° to 15° have been found entirely satisfactory, the refracting power of the prism used depending somewhat upon the focal length of the lens and the desired size, contour and spacing of the final images. The compensating prisms, such as the prisms 48 and 49, are preferably of a power equivalent to or slightly greater than the power of the prisms 45 and 46 respectively. The prisms as shown in the diagrammatic representations thereof are made from a plurality of glasses for the purpose of correcting the prisms for aberration and color separation.

It is to be understood that all of the prisms can move with the lens segments as shown, or the compensating prism 48 may be positioned between the prisms 45 and 46 and be held stationary whereas the primary prisms 45 and 46 are movable with the lens segment 44. Those skilled in the optical arts will appreciate that numerous changes and modifications may be made in the arrangement of the various prisms.

In the production of cinematographic films in colors, it has been found highly desirable to employ a novel arrangement of color filters. It has been found, for example, that the present panchromatic emulsions are very susceptible to light of shorter wave length than blue, such as for example, violet. In order to compensate for this unusual sensitivity of present panchromatic emulsions to these short wave lengths, it has been found highly desirable to use a red light filter, a green light filter, and expose two frames to dense violet filters. The arrangement of color filters and the resulting color impressions are shown in Fig. 4. It has been found necessary to use violet filters of appreciable opacity, particularly when aluminized reflecting surfaces are used in the optical system, because the short wave lengths such as violet, are apparently reflected by such aluminized surfaces without the loss which characterizes the reflection of other wave lengths. Moreover, by the use of very dense violet filters, two partially exposed violet images are obtained and a much better color rendition is obtained in this manner. Furthermore, by obtaining two underexposed violet images, the process and the blending of the colors is more readily controlled.

The present invention is not limited to the use of the hereinabove referred to specific arrangement of color filters since the optical system of the invention may be used with light filters of any desired character. For example, the four color filters may include red, green, violet and yellow. This arrangement is of particular value when the subject matter being photographed contains appreciable quantities of yellow which it is desired to emphasize. Red, green, violet and blue may be used. Again, one of the image areas may be retained for an ordinary monochromatic black and white image which may be used either for the purpose of adding density to the composite or such black and white image may be reserved for the production of ordinary black and white releases.

When Eastman panchromatic emulsion was used, it was found that a red color filter similar to Wratten No. 25-A, transmitting wave lengths from about 580 to 700, could well be employed with a Wratten No. 58 selectively transmitting wave lengths in the 480–600 range and a Wratten No. 47 transmitting wave lengths ranging from about 350–520. When it is desired to use a yellow filter, a filter similar to No. 6-K1 has been found suitable. Violet filters similar to No. 35, frequently transmitting wave lengths ranging from about 320 to 460, and some of the red, have also been successfully employed.

Figs. 16 and 17 diagrammatically illustrate the essentials which need be followed in satisfactorily arranging various mirrors, when reflecting means are employed. It is to be noted that the mirrors **23** and **24** are placed just as close to the lens as possible, the forward edge of the mirror **24** being, as a matter of fact, more forwardly positioned than the front edge of mirror **23**. As but a very narrow beam of light is emitted by the lens, the height of the mirror **23** (indicated at h) need not be more than one-half of the radius of the lens used. Actually this height will be between one-third and one-half of the radius. The mirror **24** is of slightly greater height than the mirror **23** so that h' exceeds h. Mirrors **23**, **24** and **25** may be positioned so as to lie in planes at 45° to the optical axis of the lens. The reflecting means **26**, however, may be positioned either at an angle of 45° or preferably at an angle of about 46°. The angulation of the last mirror generally varies from about 45°—30′ to about 45°—55′. Even larger angulations may be used for certain purposes. This increase in the angulation of the beam has the effect of minimizing and rendering invisible what small degree of parallax is inherently present and due to the minor spacing of the optical axes of the quadrantal lens segments.

In an actual case in which 75 millimeter lenses were employed for a focal length of 3 inches, the spacing between the optical axes was 0.2 inch. The front element of each lens had a diameter of 1.25 inches, the last or rear elements having a diameter of 0.75 inch. The height h of the first mirrors **23** was .24 inch. The distance between mirrors **23** and **24** (along the paraxial ray) was 0.295 inch. The distance between mirrors **25** and **26** along the paraxial ray was 0.427 inch. In that case, mirrors **24** and **26** were both inclined at an angle of 45°—55′.

In actual practice, a 65 or 70 millimeter negative film is exposed in a camera provided with an optical system of the character described herein and the prints are then preferably made by optical reduction onto a 35 millimeter film. Such 35 millimeter film is then projected through a suitable projection lens consisting of lens segments, such as the lens segments **6**, **7**, **8** and **9**, but without the use of the reflecting or refracting means. The lens segments are necessarily adjustable so as to produce a superimposed image upon the screen.

During projection, suitable color filters are introduced in the path of the light rays coming from each of the image areas so that the finished projected image is in substantially natural colors. In the event the negative is to be used for photolithographic or other process work, the steps and procedure normally followed in such photolithographic or other process work are also followed in treating the negatives obtained by means of the optical system hereinabove described.

In order to properly center the images upon the respective rectangular frames, it may be highly desirable to adjust the lens segments, such as the lens segments **6**, **7**, **8** and **9**, radially with respect to their common axis. Preferably, the adjustment of the lens segments should be along a plane passing through the diagonally related corners of the aperture or image area. Means for accomplishing this adjustment are shown in Figs. 18 and 19 but reference is made to a copending application Serial No. 2,807, filed January 21, 1935, now Patent No. 2,097,706, in which one form of device capable of being employed in obtaining such regulatable adjustment is described and claimed in detail.

As shown in Figs. 18 and 19, the lens segments **6**, **7**, **8** and **9** may be carried by segmental holders, such as **50** and **51**, the plane sides of such holders acting to form septa. These lens holders may be movably positioned within a barrel **52**. Attached to each lens holder and extending radially therefrom is an internally threaded socket block such as the socket blocks **53** and **54**. These socket blocks extend through perforations in the barrel **52** and lie along the diagonals x—x of the picture areas being projected. Carried by the barrel **52** is a holder **59** in which there is journaled a plurality of radially arranged stems **55** provided with externally threaded ends engaging the internally threaded socket blocks **33**. The stems **55** carry pinions **56**. The pinions in turn engage a ring gear **57** which may be rotatably mounted upon the barrel 52 and which may be locked in any desired position as by means of set screws 58. It will be evident that rotation of the ring gear 57 will rotate the pinions 56 and thereby cause the threaded stems to move the internally threaded socket blocks 53, thereby imparting motion to the lens holders 50, 51, etc. along lines which coincide with the diagonal axes of the picture areas which are being projected.

I claim:

1. A photographic optical system whereby a plurality of images of a scene may be obtained simultaneously without visible parallax, comprising: four segmental optical units arranged about a common axis parallel to the optical axes of said units, each of said units including an objective lens segment containing the optical center thereof, the objective lens segments being arranged with their optical centers closer together than the geometrical centers of image areas in an image plane; means for deflecting light from each of said objective lens segments in a direction away from an adjoining optical unit; compensating reflective plane means adapted to direct deflected light onto desired image areas, said compensating means being stationary with respect to the image plane and lying at an angle of more than 45° to the optical axis; shutter means operably positioned between said deflecting means and the image plane; septum means separating said segmental units; and color filters positioned between said optical units and the image plane whereby images of complementary color value can be simultaneously recorded.

2. An optical system including: four segmental optical units arranged about a common axis parallel to the optical axes of said units, each of said units including an objective lens segment containing the optical center thereof, and planes provided with reflecting surfaces adapted to direct light from said lens units toward separated image areas on a single film, a series of said planes acting upon light from each of said units, the planes of each series being of progressively increasing size, the front planes of each series being adapted to reflect light from said lens units in directions lying in parallel planes, two of said front planes reflecting their incident light in one direction and the other two front planes reflecting their incident light in an opposite direction.

3. An optical system of the character stated in claim 2 in which the rear planes of each series are positioned a distance farther apart, along the path of axial rays, than the front planes.

4. An optical system of the character described in claim 2 in which the last plane of each series is at an angle of slightly more than 45° to the optical axis.

5. An optical system of the character described in claim 2 in which the rear planes of each series are farther apart, along the path of axial rays, than the front planes, the last plane of each series being at an angle of slightly more than 45° to the optical axis, said optical system being spaced with respect to the image plane so that the total travel of light rays from the nodal point of lens units to the image plane is equal to the focal length of the lens unit.

6. In an optical system whereby a plurality of separate images may be simultaneously exposed upon a film, the combination of four quadrantal lens systems, each including its optical axis, said four systems being positioned with their optical axes substantially parallel and closer together than the geometric centers of the image areas on which the images are to be exposed; means for deflecting light from each of said quadrantal lens systems in a direction away from an adjoining lens system, means for directing said deflected light onto a desired image area, a color filter selectively transmitting red wave lengths positioned in the path of light from one of said lens systems, a color filter selectively transmitting green wave lengths positioned in the path of light from another lens system, and color filters transmitting violet positioned in the path of light passing through the remaining two lens systems.

7. A photographic optical system whereby a plurality of images of a scene may be obtained simultaneously without visible parallax, comprising: a plurality of segmental optical units arranged about a common axis parallel to the optical axes of said units, each of said units including an objective lens segment containing the optical center thereof, the objective lens segments being arranged with their optical centers closer together than the geometrical centers of image areas in an image plane; means for deflecting light from each of said objective lens segments in a direction away from an adjoining optical unit; septum means separating said segmental units; and means for adjusting said segmental units radially.

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