

✓

July 9, 1940.

H. S. NEWCOMER

2,207,409

ANAMORPHOSING COLOR OPTICAL SYSTEM

Original Filed June 22, 1936

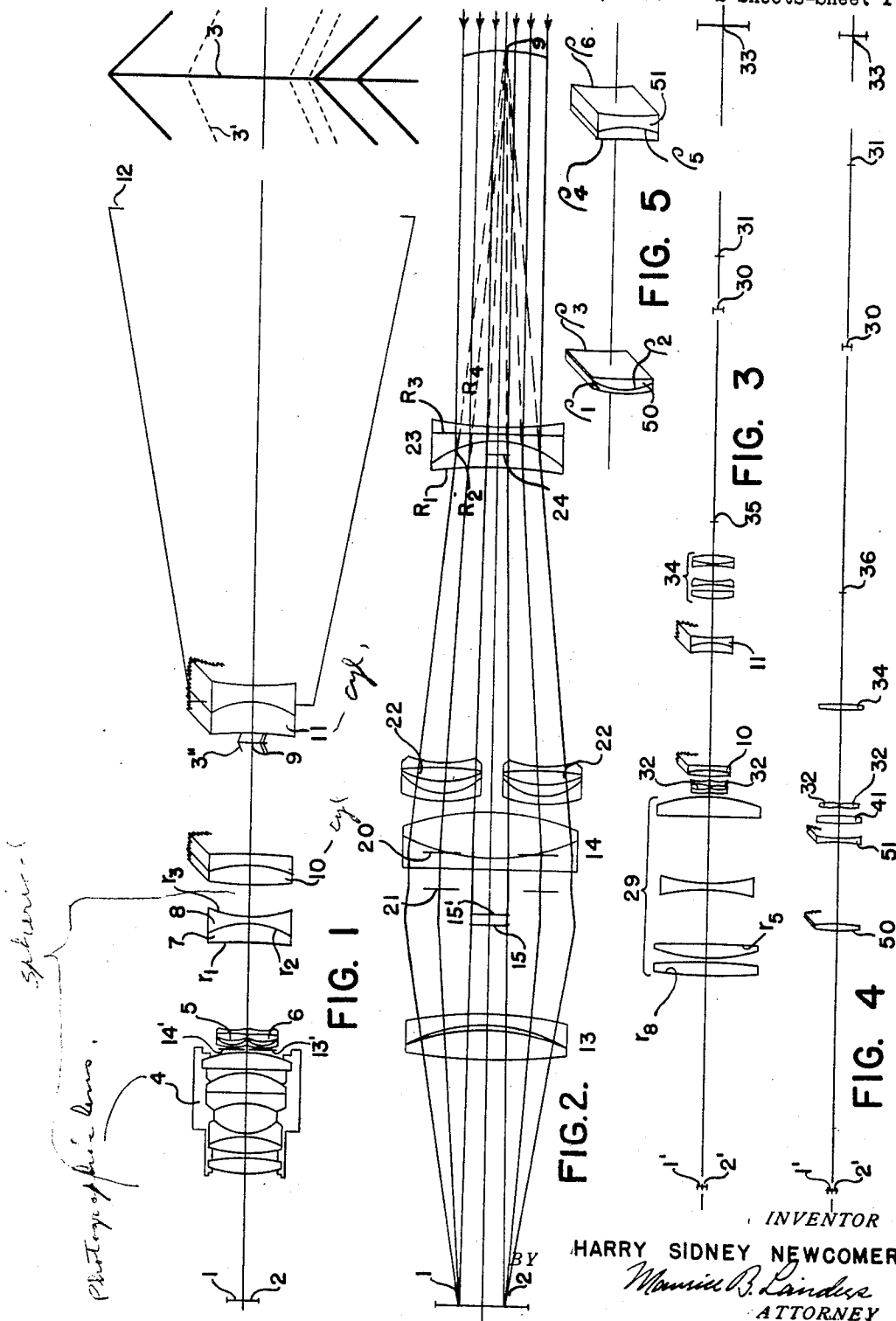
2 Sheets-Sheet 1

T2017

X2002

X2003

X2274



INVENTOR
HARRY SIDNEY NEWCOMER
Maurice B. Lindess
ATTORNEY

July 9, 1940.

H. S. NEWCOMER

2,207,409

ANAMORPHOSING COLOR OPTICAL SYSTEM

Original Filed June 22, 1936

2 Sheets-Sheet 2

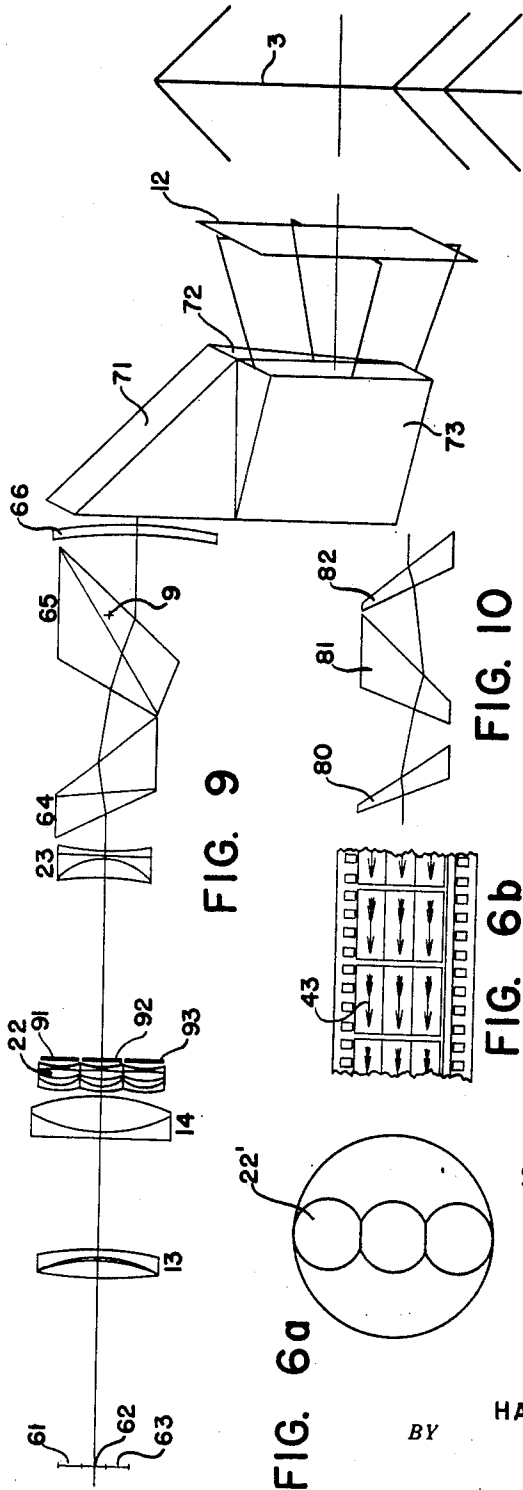
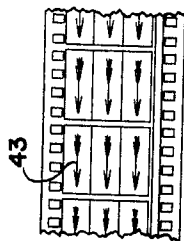
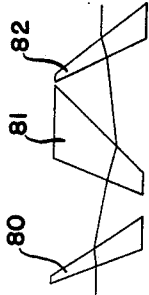
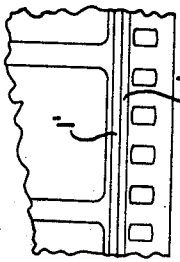
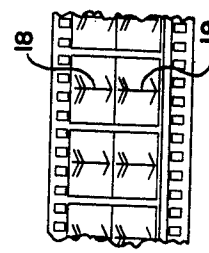
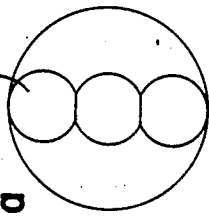
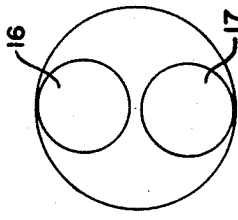
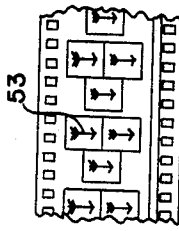
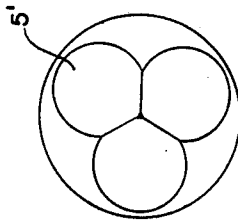


FIG. 10



INVENTOR
HARRY SIDNEY NEWCOMER
Maurice B. Landau
ATTORNEY

Patented July 9, 1940

2,207,409

UNITED STATES PATENT OFFICE

2,207,409

ANAMORPHOSING COLOR OPTICAL
SYSTEM

Harry Sidney Newcomer, New York, N. Y.

Application June 22, 1936, Serial No. 86,648
Renewed December 31, 1938

14 Claims. (Cl. 88—1)

This invention relates to color optical systems and has for an object to provide an improved optical system of the type in which a multiple image forming system is associated with an anamorphosing unit to form side by side on a motion picture film a plurality of deformed images. The invention permits the obtention of images with a higher degree of resolution than hitherto obtainable in the art.

10 In the present invention a suitable afocal anamorphoser with conjugate object and image planes lying, either in the object plane, or in the object plane displaced to infinity by virtue of the interposition of a correcting or collimating lens, is associated with an optical system arranged somewhat in the manner disclosed in the U. S. Patent 2,017,190 to Waide issued Oct. 15, 1935, but with certain important modifications adapted to the association with an anamorphosing system and greatly improving the quality of the resultant images.

15 In the device described by Waide, a negative lens acting as a sort of object glass or object lens, forms a virtual image of the object in a plane which can be fixed with reference to the rest of the apparatus by virtue of displacements possible in the object lens. In the present invention, in addition to the above mentioned modifications presently to be described, changes in the object lens to improve the quality of the images as well as others to adapt it to use in a printing machine for the formation of multiple deformed images, have been made. The latter changes permit by way of example, the printing, from a standard sound track negative, of two identical deformed sound tracks side by side in the space ordinarily occupied by a single sound track, such as might be used in so-called push-pull sound reproduction.

20 In the system described by Waide a plurality of ordinary photographic objectives or coplanar lenses (in his preferred embodiment they are Tessar lenses) with anterior conjugate focal points in the anterior focal plane of a single negative lens, are placed behind the negative lens and in front of an ordinary motion picture lens (in his preferred embodiment, a Hugo Meyer F/1.5 Kino-Plasmat). By the term coplanar lenses I refer to two or more color separation lenses positioned laterally of each other and all

lying with their frontal planes, or one of their principal planes, either amounts to the same thing, in one and the same plane perpendicular to the axis of the system and all having substantially the same focal length. This is the meaning given to this term by Waide. Actually they may not all lie exactly in one plane due to slight shifting necessary to bring their focal points in a single plane, this because of slight unavoidable inequalities in their focal lengths, the latter coincidence or approximation to coincidence being possibly preferable to the former. The effective focal length of the Waide lens bears to the focal length of the Kino-Plasmat a ratio which is a linear function of the ratio of the focal length of the front negative lens to the front conjugate focal length of the Tessars. This is an important point to bear in mind, as many of the inherent practical difficulties with the Waide system can be mitigated by increasing the focal length of the motion picture lens. Such increased focal length can only be compensated for, in the last analysis, by decreasing the focal length of the negative lens or by decreasing the distance between the common second principal plane of the coplanar lenses and the adjacent principal plane of the motion picture lens so as to permit increase in the focal lengths of the lenses in the coplanar assembly. The present invention concerns in part means of accomplishing this latter result and thus avoiding the deleterious effect of the curved field of the short focus negative lens, or of the negative lens positioned near the coplanar assembly, upon the oblique tangential imagery of the anamorphoser. I increase the focal length of the negative lens while decreasing its relative aperture.

25 Since the spacing, or distance from the common axis of the system, of the centers of the plurality of coplanar images must necessarily be less than the absolute semi-opening of the motion picture lens and is, in motion picture practice, necessarily large compared with the available openings of short focus motion picture lenses, it is desirable to increase the focus of the motion picture lens if this can be satisfactorily compensated for in some other way.

30 In the Waide device the centers of the multiple images lie on rays which, coming from the axial point of the virtual image of the object formed

by the negative lens, pass through the optical centers of each of the plurality of photographic objectives or coplanar lenses and then are brought to a focus by the posteriorly placed motion picture lens in a point, conjugate with respect to said lens, to the first mentioned axial virtual image point. Therefore in any particular embodiment of the Waide invention the spacing of the multiple images and the maximum available diameter of the motion picture lens determine the position of the virtual image plane.

Not only must the ray from the axial point of the virtual image plane through the center of one of the multiple photographic lenses fall within the opening of the motion picture lens, but the entire aperture of the photographic lens must project within this opening. Thus, in practice, the virtual image plane must be as near as possible to the motion picture lens in order that the conjugate plane on the other side of the motion picture lens can be sufficiently far away from the said lens so that the centers of the multiple images and the corresponding exit pupils project from its axial point within the aperture of the said lens.

This, therefore, only leaves two means for getting the apertures to fall within the opening of the motion picture lens. One of these means, that of enlarging the opening of the motion picture lens, was adopted by Waide when he chose an f/1.5 lens. But it is desirable, particularly in anamorphosing practice, as well as generally in order to obtain images of suitable quality, to confine the opening of the motion picture lens to at most F/2.3.

The other means, which constitutes one of the features of the present invention, consists in employing optical means for placing the second common principal plane of the plurality of photographic lenses much nearer than heretofore to the first principal plane of the photographic lens so that the apertures of these coplanar lenses will not project so far out away from the axis upon this latter plane, and so that the other relationships described, the position of the conjugate focal points of the motion picture lens, will be altered so as to operate at the same time to still further decrease the opening required in the motion picture lens.

This not only has great advantages from the point of view of motion picture quality because of the smaller diameter of the aperture utilized in the motion picture lens, but it permits also employing a negative lens of longer focus, spaced further from the coplanar assembly and having a much flatter virtual image field than would otherwise be the case for a Waide lens of a given equivalent focus. This is a great improvement where combination is had of the color objective with an anamorphoser of the type described and claimed in my Patents 1,898,787, issued Feb. 21, 1933, 1,931,992, issued Oct. 24, 1933; 1,945,950 and 1,945,951 issued Feb. 6, 1934, Re. 19,056 issued Jan. 23, 1934 and in my Patent 2,088,660.

In order to arrive at a value for the curvature of the tangential image field of the negative member or object lens of the Waide lens, we can make use of the Newcomer-Czapski equation as given in my Patent 1,945,951; namely

$$\frac{1}{R_t} = -\frac{3n+1}{nF} + 6x \left[\frac{(n+1)}{nrF} - \frac{n}{(n-1)F^2} \right] - 3x^2 \left[\frac{n+2}{r^2nF} - \frac{2n+1}{r(n-1)F^2} + \frac{n^2}{(n-1)^2F^3} \right]$$

where R_t is the radius of curvature of the tangential image surface, F , the focal length of the lens, r , the radius of curvature of the surface upon which the parallel light is incident, n , the index of refraction of the glass and x the distance from the surface of radius r , to the point at which the incident pencil, or the prolongation of the pencil cuts the axis. All distances are considered as positive in the direction of propagation of the incident parallel light.

The apertures of the coplanar lenses act as stops for the object lens. In certain arrangements of the coplanar assembly one of these is on the axis. When none are on the axis the distance of the axial point of the common first principal plane of the coplanar system may be used to obtain a value for the curvature of the virtual image field which approximates the true value. For the above equation this distance, x' , is related to x and F of the equation by the convergence formula,

$$\frac{1}{x'} - \frac{1}{x} = \frac{1}{F}$$

The field curvature of the negative lens is thus not only a function of its focal length but also a function of the curvature of the first surface of this lens and of the separation or distance between it and the plane of the coplanar assembly of positive lenses, which plane constitutes the location of the stop of the negative lens. Practically speaking, the curvature can only readily be made very small with positive values for r , values which are inadmissible because of the resulting astigmatism introduced into the system.

Under ordinary conditions the field is concave toward the negative lens, not varying greatly in curvature with different negative values of r within practical limits, becoming large however with small negative values of r . In general it increases with decrease in the distance between the negative lens and the coplanar assembly and also with decrease in the focal length of the negative lens. I have discovered that both of these features tending to increase the curvature of the virtual image field of the negative lens can be mitigated by virtue of changes made according to the present invention. In fact the resulting curvature of the image field of the negative lens is then small enough to a large extent to be neutralized by that of the positive system. This is particularly desirable because an opposite or at least zero total curvature is needed in order that the curvature of same sign due to the anamorphoser shall not be objectionable.

The effect of excessive curvature of the virtual image field concave toward the negative lens is to give a negative tangential convergence effect to the oblique imagery of the Waide system and an image field in the plane of the film which is convex toward the motion picture lens. As set forth in my U. S. Patent 2,017,634, the cylindrical anamorphoser described in my Patents 1,945,950 and 1,945,951 and certain other anamorphosers of preferred design preferably have a negative oblique tangential convergence effect and hence operate to increase this error of the Waide system. The improvements described in the present invention serve to minimize this effect.

By way of example Waide describes, in his patent, in the particular complete lens previously referred to, an f/1.5 50 mm. Kino-Plasmat lens

2,207,409

3

associated with a trefoil of coplanar Tessars of 65 mm. focal length and a negative lens of 75 mm. focal length. The necessary spacing of these lenses, because of the thickness of the Tessars and the fact that their first principal plane is about 3 mm. behind the front lens surface and the second principal plane about 6 mm. inside the back lens surface, as well as the relatively great distance back from the front lens surface of the first principal plane of the Kino-Plasmat, about 20 mm., a principal plane position common to most large aperture motion picture lenses, makes the total strength of this assembly approximately twenty-five diopters. By the use of my invention I can get a similar strength lens using an f/2.3 75 mm. segmenting lens, a plurality of 100 mm. single Protar type lenses at such a distance from the segmenting lens as to have the corresponding adjacent principal planes about the same absolute distance apart (27 mm.) as is actually the case in the above example of Waide (29 mm.), and a 100 mm. negative lens spaced so that the distance between the adjacent principal plane of the coplanar assembly and its adjacent principal plane is 60 mm. instead of 12 mm. as in the above. The relative distance between the principal planes of the coplanar assembly is, in this example, appreciably less than in the Waide lens and could be made even less, about one-third as much, by using a Petzval type lens for the motion picture lens, as shown in one of my preferred examples given below. The gain in smaller relative openings, longer focal lengths and better spacing, without sacrifice of effective focal length and opening, is obtained in part by virtue of the Protar type lenses having their principal planes about 6.5 mm. and 11.2 mm. outside of and closer to the 75 mm. lens than the nearest surface of the Protar lens itself.

The difference in spacing and in focal length, of the negative lens, assuming in each case a negative r about 20 per cent smaller than F , make the curvature of field of the negative lens in the above example according to the invention about 50 per cent less than that of the Waide negative lens in the given example.

This difference is of great importance, particularly for the oblique imagery of the anamorphosed object. In certain preferred illustrative examples given below the curvature of field of the negative lens is made only half as great as in the Waide lens. Still other advantages are had as a result of this change in spacing and the necessary choice of new lens types with which to accomplish it.

The Protars are spaced almost one-half again as far apart as the Tessars of Waide and yet project within an opening of the segmenting lens which is about the same, really less in absolute diameter than, and much less in relative diameter than, that which it is necessary to employ in the case of the Tessar-Plasmat assembly. Like spacing of the images on the film is of course had, by way of comparison, in both instances. Other illustrative examples give even more favorable relationships.

In addition, the cemented type of lens with relatively short axial length used according to the invention for the coplanar assembly, as compared with the usual photographic lens, shows no vignetting of oblique pencils such as is especially had with closely placed and perhaps approximated lenses with contiguous faces flattened as

in a mosaic, and it is in addition very much easier to mount.

Also the single Protar type of lens, used in this manner, has stigmatic errors which are almost exactly neutralized by opposite errors in the balance of the system, particularly in the segmenting type lens. The resulting image is therefore much improved in quality for this reason, as compared with results obtainable employing a corrected central diaphragm photographic lens of the usual type in the coplanar assembly.

Waide employs an achromatized cemented doublet for the negative member with the front surface somewhat more curved than the back surface and having the flint in front. I have discovered that there is an advantage in giving the front surface relatively more curvature as this decreases the astigmatism introduced by the back surface. On the other hand, increasing the front curvature increases the curvature of the virtual image field and the barrel distortion of the object. It is therefore more advisable to flatten this surface somewhat and increase the curvature of the back surface. I have discovered that in this situation the astigmatism so introduced, due to the extra axial position of the members of the coplanar assembly, can be neutralized by having the flint glass in back, facing the coplanar assembly, and not in front as in the Waide example. The weak positive cemented surface, concave toward the coplanar assembly, then introduces sufficient astigmatism of opposite sign to neutralize the astigmatism of the exterior faces.

In the foregoing I have spoken of the use of a segmenting type lens for the photographic lens or positive member common to the entire system. Certain types of segmenting lenses have been described by me in my U. S. Patent 2,045,093 issued June 23, 1936. By the term "segmenting" I designate certain lenses which I have discovered give nearly as good or better photographic images through an asymmetrically placed anterior stop as through the unobstructed lens. Such segmenting lenses have one or more abaxial zones adapted to transmit or form a corresponding number of discrete images of an object respectively with substantially equal definition and comparable with that of an image transmitted by an axial zone. Most photographic lenses give much worse images, some practically no useful images through such eccentric stops or zones. The Kino-Plasmat used by Waide for his preferred example is of this unsuitable type.

I have discovered that certain lenses of what I call the segmenting type, some of which are made use of in my preferred examples, give greatly improved images as compared with most photographic or motion picture lenses, when used as part of the color objective herein described. There is thus, I have discovered, this important feature to be considered, in the selection of a lens for the device herein described.

The segmenting lenses described by me in my copending application are there intended for use with, and found to give particularly good images with, oblong eccentric stops. Such stops might be used herein certain arrangements of the anamorphosed images. In other arrangements of the coplanar assembly, eccentrically placed round or predominately round stops are employed, and give, with the segmenting lenses, greatly improved images as compared with those obtained with most motion picture lenses when similarly used.

In either case, for either form of stop, the segmenting lens of Fig. 3 of my Patent 2,045,093 and this application and having the following characteristics, is a suitable one.

5 *Data for the objective of Figure 3*

10	$r_1 = +49.5$ $d_1 = 7.08$ $r_2 = \text{infinity}$ $c_1 = 22.1$ $r_3 = -57.36$ $d_2 = 2.44$	heavy crown $\nu = 56.3$	$n_C = 1.61045$	$n_F = 1.62136$
	$r_4 = +63.21$ $c_2 = 16.76$ $r_5 = +467.8$ $d_3 = 6.3$			
	$r_6 = -57.6$ $c_3 = 1.2$ $r_7 = +185.4$ $d_4 = 4.32$			
	$r_8 = -185.4$			
15	$r_1 = +49.5$ $d_1 = 7.08$ $r_2 = \text{infinity}$ $c_1 = 22.1$ $r_3 = -57.36$ $d_2 = 2.44$	heavy crown $\nu = 56.9$	$n_C = 1.61949$	$n_F = 1.63044$
	$r_4 = +63.21$ $c_2 = 16.76$ $r_5 = +467.8$ $d_3 = 6.3$			
	$r_6 = -57.6$ $c_3 = 1.2$ $r_7 = +185.4$ $d_4 = 4.32$			
	$r_8 = -185.4$			
F=100		opening F/2.3		

Also the conventional Petzval portrait lens segments very well for the purposes of this invention, and is shown in certain illustrative examples, as it has other desirable features for the purposes of the invention, including an anterior principal plane relatively near to its front surface. Another preferred example is the super cinephor lens. Both of these, I have discovered, have certain definite advantages and give in combination with coplanar lenses as herein described and used and placed eccentrically up to the margins of their openings appreciably better images than through the segmenting lens alone with a full opening, whereas most motion picture lenses give very poor images when so segmented.

In one embodiment of the present invention the anamorphoser is not adjacent to the plurality of coplanar lenses, but is separated from the plurality of coplanar spherical lenses by a single negative spherical lens as described by Andibert in U. S. Patent 1,124,253 issued Jan. 12, 1915, and by Waide. I have discovered, however, that there are important advantages to be gained by making certain modifications in the balance of the system described by Waide so as to improve the quality of the images, flatten their fields, as required for the proper definition of anamorphosed images, and in part described and claimed in my U. S. Patent 2,017,634 issued Oct. 15, 1935, and also to provide for greater spacing of the plurality of coplanar lenses so that they may be arranged in a suitable configuration to correspond with the best arrangement of the deformed images corresponding with the maximum utilization of the motion picture film. A further feature of the invention is the use of a segmenting lens, as described, for the improvement of the images and to retain the advantages which follow from the changes herein set forth in the coplanar assembly and which derive in part from the consequent flattening of the virtual image field. The feature of the invention which consists in optically shortening the distance between the adjacent principal planes of the coplanar lenses and the motion picture lens by making use of a type coplanar lens having a second principal plane far outside of it in the direction of the motion picture lens, has a further advantage in that one of the simplest examples of such a lens has extraordinarily good image characteristics, including astigmatism and curvature of field, for neutralizing the aberrations of the negative lens and of the usual types of segmenting lenses, and is of compact design without air spaces, thus greatly facilitating precise assembly of the coplanar lenses and maintenance

of the proper alignments within the individual lenses.

I have also discovered that to best accomplish certain of the above objects, and to neutralize the astigmatism due to the oblique incidence on the back surface of the negative member, that is the free surface facing the coplanar assembly, and which follows from the off-center position of the members of the coplanar assembly, it is desirable to make the negative member as an achromatized doublet with the flint glass facing the coplanar assembly and having a positive refracting surface concave towards the coplanar assembly, the back surface being made relatively as curved as possible so as to further flatten the curvature of the virtual image field and decrease the distortion. Preferably it should be almost as curved as the front free surface, or even more so, both being concave.

It should be pointed out that the advantages of this invention are not limited to the production of color motion pictures. I have discovered that it can also very well be employed in printing to form two like deformed images side by side, as in the printing or recording of sound track, where it is desired to lay down two identical anamorphosed tracks side by side.

For such purposes, where printing is made from one standard film to another, the object and image, in the non-anamorphosed meridian, need to be of the same size. The negative or record-bearing film or strip, and the positive, or record-receiving film or strip, are in a one to one relationship. The functioning of the system described by Waide and the possibility of its laying down two images side by side, either anamorphosed or non-anamorphosed, depends however upon the image being appreciably smaller than the object.

I have discovered that this condition can be met by making the object lens of the Waide system a positive lens of such focal length and so positioned as to form an enlarged virtual image of the object in the usual virtual image plane of the Waide system. The constants should be so chosen in this instance that the enlargement due to the object lens is equal and opposite to the reduction introduced by the rest of the Waide system. In this and in the earlier discussed modified Waide systems employing negative object lenses, the object lens, in each case, is employed in an imagery system such that the object lens has two conjugate focal points in front of or anterior to it. They are at the object and at a virtual image thereof.

In order that the double sound track shall not occupy more width of film than the original single sound track, I have discovered that it can be anamorphosed or reduced in width, while leaving the length unchanged, by the use of an afocal cylindrical anamorphoser comprising a positive and a negative cylindrical member with axes parallel, as described herein for color photography, except that the position of the anamorphoser should be changed so as to place it in a more suitable portion of the system. If placed in front of the positive object lens, then, unlike the conditions obtaining with the negative object lens, it comes between the object and the object lens in a region where the pencils of light are very strongly convergent. If the anamorphoser is of the conventional type it cannot be made to function properly under such conditions. I have, however, found it possible to place it between the coplanar assembly and

the positive object lens; that is, just in front of the former. It is also, I have discovered, advisable to make it similar to said cylindrical anamorphosers comprising a positive and a negative cylindrical member with axes parallel, and as described and claimed in my Patents 1,945,950 and 1,945,951, placing the positive cylindrical member nearest the coplanar assembly and adjusting the distance between it and the negative cylindrical member so that they have, each, one conjugate image plane in the virtual image plane of the positive object lens, and one in common, that is in the same plane, and nearer than, and to the same side as, the virtual image. The ratio of the respective distances of the negative and positive cylindrical members from the proximal conjugate plane gives the amount of reduction in image size in the active plane of the anamorphoser. I have found it possible, by a suitable choice of focal lengths for the different elements to find room to place all the elements of the system in correct position with respect to the respective designated conjugate points and yet choose suitable construction forms for the different elements. Thus, the lens which has herein been called the motion picture lens can be a segmenting lens of desirable type; the coplanar lenses can be either of the Protar or astronomical type and the positive object lens, since it may be of relatively short focus, can likewise be a high quality photographic lens.

In this other embodiment of the invention, while the anamorphoser may be positioned adjacent to the coplanar assembly, in both this and the previously described embodiment an object lens, negative or positive, is used to produce a virtual image of the object, and in addition there is included another element not used by Chretien or described by Waide, namely the segmenting photographic lens. In fact Chretien does not use any lens at all on the other side of the coplanar assembly from the anamorphoser.

I have discovered that another desirable arrangement of the anamorphoser printing assembly, according to the invention, is to place between the image-receiving record strip (the sound track positive or reduced image track) and the motion picture lens a so-called opposed plane cylindrical anamorphoser of the type described and claimed in my U. S. patent application for Projection optical systems, Serial No. 86,647, filed June 22, 1936. This anamorphoser comprises a positive and a negative cylindrical member with axes parallel, placed between an image plane and a positive spherical system with a conjugate focal point or principal focal point in said image plane, the individual cylindrical members of the anamorphoser each having said image plane conjugate to another common conjugate plane situated to the other side of them from said image plane; and the negative cylindrical member being situated nearest the positive spherical system. This permits approximating the motion picture lens and the positive object lens and therefore shortening the focal length of the members of the coplanar assembly. The advantages of this type anamorphoser for printing assemblies are fully set forth in said application. As there described, it is best inserted on the side of the system and adjacent to the surface bearing or receiving the image to be reduced in one dimension.

It is, of course, not necessary that the reduction of sound track, with multiplying of their number, be proportionate to such number. The

invention also permits of reduction printing wherein multiple tracks, two or more in number are formed, the individual tracks being either the same size as the original or narrower or wider. Enlargement is had by reversing the anamorphoser (end for end in the case of the cylindrical anamorphoser first described) and transposing to be adjacent to the other image bearing surface (still the one bearing the image to be reduced) in the case of the latter anamorphoser.

These two embodiments of the invention comprise, as do the previously described embodiments, a positive segmenting lens, a coplanar assembly, and an object lens together with an anamorphoser. Also, since the object itself can be delimited by a gate, in these embodiments of the invention for printing, no delineator is required.

The nature and objects of the invention will be better understood from a description of particular illustrative embodiments for the purposes of which description reference should be had to the accompanying drawings in which

Fig. 1 shows a cross section of an anamorphoser and multiple image forming system according to the invention, and

Fig. 2 shows diagrammatically the relations between the optical parts of a system and their principal planes and image planes according to the invention, and

Fig. 3 shows a cross section of a multiple image printing optical train according to the invention including an anamorphoser with coincident conjugate image planes in the virtual image plane of the object lens of the multiple image forming system, and including a segmenting photographic lens as described in my Patent 2,045,093, and

Fig. 4 shows a cross section of a multiple image printing optical train according to the invention including an "opposed image" plane cylindrical anamorphoser having coincident conjugate image planes in one of the image record planes of the system, and

Fig. 5 is a perspective view of a corrected opposed image plane cylindrical anamorphoser as shown schematically in Fig. 4, and

Figs. 6a, 7a, and 8a show views of different arrangements of the coplanar spherical lenses of the multiple image forming system, and

Figs. 6b, 7b and 8b show views of portions of motion picture film with multiple images arranged in each frame thereon according to different modifications of the coplanar lenses in the corresponding Figs. 6a, 7a and 8a, the arrows in the images of Fig. 6b corresponding to the object and optical train of Fig. 9, and those in the images of Figs. 7b and 8b corresponding to the object and optical train of Fig. 1, and

Fig. 7c shows a view of a portion of a motion picture film bearing two like anamorphosed sound tracks, side by side, corresponding to the printing optical trains of Figs. 3 and 4 and the coplanar arrangement of Fig. 7a, and

Fig. 9 shows a cross section of a multiple image forming system according to the invention including a prism anamorphoser, correcting lens and set of erecting prisms for erecting the images when projecting them or laying them on the side when taking pictures, and

Fig. 10 shows a modification of the prism anamorphoser such as might be used in the optical train of Fig. 9 or Fig. 1.

In Fig. 1 I show, as an illustrative example of

an embodiment of the invention, at 1 and 2 a transverse section through the picture portion or frame of a 35 mm. film, 1 and 2 each representing a portion of said frame on which are formed side by side like deformed images of an object at more or less distance from the optical system which comprises a segmenting photographic lens 4, in this instance, of the Biotar or Super Cinephor type with $f/2.3$ opening, in the example a Super Cinephor lens, a pair of coplanar lenses 5 and 6 of the Protar type having first and second principal planes out behind them and well within the lens 4, and positioned near its first principal plane, an object lens 7, 8 comprising a positive spherical element 7 of flint glass concave toward the coplanar assembly and a negative spherical element 8 cemented thereto, the negative lens being positioned so that its conjugate focal point 9 with respect to the object 3 lies in the anterior focal plane of the coplanar lenses 5, 6, a cylindrical anamorphoser 10, 11 of the type described and claimed in my U. S. Patents 1,945,950 and 1,945,951, having conjugate focal planes both lying in the object plane 3, the anamorphoser comprising a positive cylindrical member 10 and a negative cylindrical member 11 with parallel axes lying transverse to the meridian in which compression of the image of the object is obtained, and a delineator 12 performing the function described by Waide of delimiting the individual images on the film. The delineator 12 is to be placed far enough out in front of the coplanar assembly 5, 6 so that that edge on the same side of the axis as one of the coplanar lenses is sufficiently sharply defined by said lens in conjunction with the motion picture lens 4 to limit the picture on the opposite or axial side, etc. I place, by preference, the delineator 12 at several times as great a distance from the object lens 7, 8 as does Waide, thereby to secure particularly sharp delimitation of the picture. 14' and 13' represent two color filters.

The multiple image forming lens of Fig. 1 has an equivalent focal length of about 67 mm., the lens 4 being of 114.3 mm. focal length and opening $f/2.3$. The coplanar Protar lenses 5, 6 are of 220 mm. focal length, are spaced 3 mm. from the lens 4 and have their second principal plane positioned 24.55 mm. nearer the interiorly located first principal plane of the lens 4 than the nearest surface of the Protar, namely 21.55 mm. back of the front surface of the lens 4. The first principal plane of the Protar is 14.3 mm. from its surface. The principal ray through the Protars intersects the principal planes of the lens 4 12.22 mm. from the axis when the centers of the images 1 and 2 are 5.36 mm. from the axial point of the motion picture frame image assembly as they might properly be for a tricolor image assembly as at 53, Fig. 8b. The centers of the coplanar lenses are then 10.32 mm. from the axis of the system.

The lens 7, 8 of 125 mm. focal length has the following construction data

$r_1 = -421.0$ mm. d_1 13 mm. n_d 1.6200 Abbe number 36.4
 $r_2 = -56.6$ mm. d_2 4 mm. n_d 1.5725 Abbe number 57.5
 $r_3 = +79.0$ mm.

For this focal length multiple image forming lens and consequently relatively restricted image field, this is a suitable object lens, and the system as a whole is quite free from astigmatism and curvature of field and distortion. For shorter focal length objectives less curvature of the an-

terior surface of the object lens would be desirable and is shown in the next example.

The coplanar assembly, spaced axis of lens to axis of system, as shown at 5, 6 might comprise 3 Protar type lenses arranged in a triangle as at 5' Fig. 8a so as to produce in each motion picture frame for purposes of color photography three like images, as at 53 Fig. 8b, where they are shown undeformed by reason of omission of the anamorphoser. Or they could be deformed with an anamorphoser to give on projection wide screen proportions.

The afocal cylindrical anamorphoser, as drawn, is particularly well corrected for color work and compresses the object 3 in the ratio of three to two so as to form in the plane of 3 an anamorphosed virtual image 3', which image 3' is then reimaged at 9 as 3'' by the spherical lens 7, 8. Such a compression, three to two, which gives on reprojection an image of proportions one and one half times the width of the standard motion picture frame, might be used for wide screen projection of motion picture images by the three color process with multiple image arrangement on the film as in Fig. 8b.

Because of lack of space, the object 3 and its conjugate image 3' by the anamorphoser 10, 11 are drawn relatively too small by comparison with the rest of the system and hence appear to subtend much smaller angles than are consistent with the size of the field of the image forming system. The same is true in Fig. 9. Also they are shown for convenience flat in the plane of the drawings whereas they should be shown in a plane perpendicular to the drawings.

The afocal cylindrical anamorphoser as drawn has the following construction characteristics:

Positive member

Radius of back surface, +242.7 mm.
 d_1 13.5 mm. n_d 1.5606 Abbe number 61.2
 Radius of cemented surface, -85.02 mm.
 d_2 7.8 mm. n_d 1.5737 Abbe number 41.6
 Radius of front surface, -458.4 mm.
 Interval 79.36, or infinity setting
 Negative member
 Radius of back surface, -242.7 mm.
 d_3 21. mm. n_d 1.5737 Abbe number 41.6
 Radius of cemented surface, -54.0 mm.
 d_4 10.5 mm. n_d 1.5606 Abbe number 61.2
 Radius of front surface +198.64 mm.

The coplanar assembly 5, 6 might be arranged as shown in front view at 16 and 17 in Fig. 7a so as to produce side by side in each motion picture frame in conjunction with the balance of the system and the anamorphoser two like deformed images 18 and 19 (Fig. 7b) of the object 3. Thus one can readily produce a two color negative with maximum utilization of the film space. In the drawing, Fig. 1, the actual relative dimensions of the object 3, the images 3' and 3'', and the spacing center to center of the images 1, 2 are as if compression were two to one for an image as in Fig. 7b, and for which a coplanar layout is shown in detail in Fig. 7a.

In Fig. 2 I show the optical design details of an illustrative example of an embodiment of the invention in the form of a 44 mm. equivalent focus multiple image forming objective, with the relationships between the principal planes of the coplanar assembly and the anterior principal plane of a segmenting motion picture lens, together with details of an object lens design having, as I have discovered, certain desirable characteristics. At 1 and 2 I indicate the centers of two like motion picture images lying side by side in one motion picture frame. At 13 I show the back member and at 14 the front member of an

88.9 mm. Petzval $f/2.3$ segmenting lens (for example a Solex lens) with anterior or first principal plane at 15, 25.4 mm. back of the front surface. The second principal plane is at 15'. 20 and 21 are the first and second principal planes respectively of the 180 mm. coplanar Protar type lenses 22. These planes are 11.7 mm. and 19.8 mm. respectively from the adjacent face of the Protars. The distance between the adjacent principal planes 15 and 21 is thus only 7.6 mm. (allowing 2 mm. between lens surfaces).

This very short inter plane distance brings the anterior focal plane 9 of the Protars much nearer the lens 13, 14 than would otherwise be the case and hence brings the point conjugate to 9 with respect to the lens 13, 14 relatively much further back of the film 1, 2 than would otherwise be the case. Actually it is 167.944 mm. back of the lens so that, for instance in the case of a trefoil of protars, the height of the principal ray through the Protar on the principal planes of the lens 13, 14 is only

$$\frac{167.944}{79.044}$$

times the distance 5.36 mm. of the center of the picture from the axis, Fig. 8b. This is 11.388 mm. Consequently the aperture of the Protar falls well within the 40 mm. aperture of the lens 13, 14. The Protar centers are

$$\frac{180 \times 11.388}{187.6} = 10.927 \text{ mm.}$$

from the axis.

If there were only two of them they can be arranged as at 16 and 17 in Fig. 7a and would give images as at 18 and 19 Fig. 7b. The spacing of the coplanar lenses would be potentially greater and could be compensated for without increasing the opening of the lens 13, 14 by using 150 mm. Protar type lenses and a 75 mm. object lens as in Fig. 9, that is two larger opening coplanar lenses occupying the same space, as in Fig. 9, and set 19.46 mm. center to center.

Thus there might be three (or even four) of them arranged symmetrically about the axis, the distances being great enough so that the usual sized Protar lenses of 180 mm. focal length would not quite touch each other when there were three of them.

The Protars in this example have their anterior focal points in the plane of 9 so that the distance between this plane and the plane of 20 is 180 mm. 9 is also the conjugate plane to the object with respect to the 90 mm. negative object lens 23 whose second principal point is at 24. The distance of 24 from 9 is 90 mm. when the object is at infinity and if the object, real or virtual, is nearer, then the virtual image of it at 9 is kept in fixed position by moving the lens 23 nearer the plane of 9.

The chosen position of 9 with respect to the plane 20, namely as the equal to the focal length of the lens 22 is desirable but not necessary distance relationship. My first example describes a greater distance being chosen. The principal features of the invention and of the multiple image forming system apply in either case. The image plane of the system moves nearer to the principal plane of the motion picture lens, thus compensating, with respect to principal ray and coplanar lens distances from the axis, for the greater chosen distance of the latter's anterior focal point and lesser distance of the conjugate posterior focal point of the motion picture lens.

It is obvious that the positive system 13, 14, 22 of Fig. 2 has, as a whole, conjugate anterior and posterior image planes at 9 and 1, 2 respectively and operates to image an object positioned at the anterior of these two conjugate planes with multiple imagery in the posterior of these two conjugate focal planes. Or, vice-versa, it images multiple and suitably spaced like objects, positioned at the posterior conjugate plane, as a single image in the anterior conjugate plane. It is also obvious that such an imagery possesses the advantages of the invention as provided by the principal plane constructions and axially compact and anastigmatic character above described for such lenses 22, including the cooperative relationships which I have made, described and illustrated for and between the lens 13, 14 and the lenses 22.

It might be pointed out that the two principal planes of the coplanar assembly are intersected by a principal ray through one of the lenses thereof at the intersections of said planes with the axis of the lens so that in calculating the distance of the point 9 from the anterior principal plane 15 of the motion picture lens the distance between the two principal planes 21 and 20 is neglected. The anterior principal plane 20, however, serves to locate the point 9. The posterior principal plane 21, however, as seen, locates the apparent position of 9, i. e. its optical distance, as distinguished from its physical distance, from the lens 13, 14. The further this plane 21 is behind the front surface of the lens 13, 14 the shorter is the optical distance of 9.

The negative object lens 23 is designed to have a somewhat flatter front surface than the lens 7, 8 of Fig. 1. This relatively increases the curvature of the back surface, the astigmatism along principal rays from the axial point 9 through the centers of the coplanar lenses (axial points of their principal planes) due to the surface being compensated by that introduced by a positive cemented surface of radius R_2 concave toward the coplanar assembly. The adjacent crown glass used being quite hydroscopic, it is protected by a glass of like index but different dispersion with a separating plane cemented surface R_3 . The distance of the object lens 23 from the principal plane 20 of the coplanar assembly 22 is relatively great, 90 mm. and the radius of curvature of the virtual image field at 9 of the lens 23 is, according to the Newcomer-Czapski formula 40 mm. Its semi diameter in the meridian parallel to the greater axis of the individual picture image of Fig. 8b is for the picture axis distance 5.36 mm., 9.4 mm. This is a much more favorable situation than in designs heretofore described.

The construction characteristics of the 90 mm. object lens 23 are as follows.

$R_1 = -103.134 \text{ mm.}$	$d_1 \text{ 6.059 mm. } n_d \text{ 1.57845 Abbe number 41.7}$
	Light flint
$R_2 = -22.889 \text{ mm.}$	$d_2 \text{ 1.750 mm. } n_d \text{ 1.55823 Abbe number 67.8}$
	Heavy phosphate crown
$R_3 = \text{infinity}$	$d_3 \text{ 1.616 mm. } n_d \text{ 1.55671 Abbe number 58.5}$
	Barium crown
$R_4 = +89.53 \text{ mm.}$	

In Fig. 3 I show as an illustrative example a modification of the multiple image forming objective for use in printing, as for instance in the printing from a single sound track of two sound tracks side by side, each of half the width of the original.

At 1' and 2' are shown the two tracks side by side as at 1' and 2' of Fig. 7c, the two together

occupying the space, in width, of one track 30 from which they are printed. Of course this one to one relationship is not necessary, as any other ratio of widths, larger or smaller, might equally well be chosen. At 29 I show the 100 mm. segmenting lens whose construction characteristics are given above in the specification. This lens might also substitute for the lenses 4 of Fig. 1 and 13, 14 of Figs. 2 and 9. In front of it are placed two Protar type or astronomical type or other suitable coplanar lenses, spaced for convenience of desired opening 6 mm. apart center to center. The track 1', 2' is in the principal focal plane of the lens 29 and since the tracks are 1 mm. apart center line to center line, the back conjugate focus 29 of the lens (intersection of principal ray with axis), is 120 mm. and the front conjugate focus at 33 therefore 600 mm. The coplanar lenses 32 are therefore (if the respective principal planes coincide) of 600 mm. focus. If the track 1', 2' were not in the principal focal plane of the lens 29, the focal length and conjugate focal distance of the lenses 32 from the plane 33 would be correspondingly changed to make the principal ray pass through the center of the image on the new image plane. Since, except for anamorphosis, the image and object are here to be the same size, the actual track 30 has to be pushed to the position 33 and enlarged by

$$\frac{600}{100}$$

that is six times, by the interposition of an object lens 34, in this instance a 105 mm. f/6.3 Tessar. The conjugate focal distances of the Tessar from 30 and 33 are 87.5 and 525 mm. respectively, these numbers having a ratio of one to six so that the virtual image 33 of the track 30 is six times the size of the track 30. The principal focal point of the Tessar is shown at 31. The Tessar is chosen from among other possible ones for reasons of availability and suitability.

As so far described one would thus secure two tracks like the original laid down side by side and occupying twice the space of the original. The object lens was however chosen of short enough focal length to give room for a cylindrical anamorphoser 10, 11 similar, except for magnification, to that of Fig. 1, and as described in my Patents 1,945,950 and 1,945,951. It has conjugate image planes in the plane of the virtual image 33. For each member the plane 33 is conjugate to a plane 35. The principal point spacing of the two members is in the example 42.2 mm. and the negative member is 42.2 mm. from the conjugate point 35. The distances of the other conjugate point 33 from each member are then such that the focal lengths of the positive and negative members are 98.37 mm. and 45.69 mm. respectively. Such an anamorphoser acts to reduce the virtual image 33 to half width in the active plane of the anamorphoser, that is transverse to the length of the film.

In Fig. 4 I show a modification of the optical train of Fig. 3 in which a so-called opposed plane cylindrical anamorphoser 50, 51 with conjugate image planes in the reduced image 1', 2' is employed, the individual members 50 and 51 each having a point 36 on the other side of the anamorphoser conjugate to the track 1', 2'. The conjugate distances for the two members are respectively 80 mm. and 100 mm., and 109.5 mm. and 70.5 mm., giving a magnification due to the anamorphoser of about 2, that is a reduction to

1/2 when imaging on the film 1', 2'. The anamorphoser produces at 1', 2' a virtual image of 1', 2' of twice the size in the meridian of its active plane. This is imaged by the lens 41 of focal length 112.5 mm. at infinity. With the coplanar lenses 32 spaced as before in Fig. 3 the principal ray through them and the center line of the track virtual images intersects the axis 56.25 mm. behind the track 1', 2'. Conjugate to this point with respect to the lens 41 is a point 33 339 mm. out in front of the lens 41. I choose this point 33 as the position of the anterior focal plane of the coplanar lenses 32. As before the lens 34 forms a virtual image at the point 33 of the track 30 which is to be printed. The magnification here necessary being only one to three, the conjugate focal distances for the lens 34 are 107 mm. (the distance of the track 30), and 321 mm. (the distance of the virtual image 33). The focal length of the lens 34 is therefore about 161 mm., anterior principal focal point at 31. The virtual image 33 of the track 30 is three times the size of the track 30, and not 6 times as in Fig. 3.

This anamorphoser printer arrangement giving, if desired, two like images 1', 2' of the track 30, but each only of half the width of the original, has many advantages as an anamorphosing continuous printer. They are set forth in part in my copending application of even date. There is also the advantage of greater focal length of the object lens 34 and lesser focal length of the coplanar lenses, they being in this example easier to construct than the very small very long focal length lenses 32 of Fig. 3.

The two tracks laid down side by side by means of the printing device shown in either Fig. 3 or 4 are identical. If it were desired to have one the mirror image of the other, as in Adsit or so-called toe in, or toe out, recording, then this could be accomplished by making room between the coplanar assembly and the segmenting lens for a truncated or so-called "roof" prism or reversing prism placed in the path of one coplanar lens, and a plane compensating block in the path of the other lens.

Also the object at 30, Fig. 3 or 4 could be a recording slit instead of a negative sound track image. That is one could place at 30 a slit receiving a variable area or variable density illumination through the action of suitable sound recording means, and thus by means of the device herein described record directly from a single track recorder, a double or Adsit track.

In Fig. 5 I show an example of a corrected opposed plane cylindrical anamorphoser 50, 51 as might be used in Fig. 4. This opposed plane cylindrical anamorphoser of Figs. 4 and 5 is distinguished by having its conjugate image planes in the same plane, as with other afocal anamorphosers, but with each individual cylindrical member having conjugate image planes on opposite sides of the anamorphoser and not on the same side. Also the associated spherical system is outside the anamorphoser and on the negative member side thereof.

The positive cylindrical lens 50 is a cemented doublet substantially free from spherical aberration in both directions. It is also substantially achromatic, d to g, in both directions and has all its surfaces concave toward the negative cylindrical lens so as to minimize the curvature of its tangential field and its other aberrations. Actually, since the form is fixed to be concave toward the negative lens, there is a slight amount of residual spherical aberration, being somewhat 75

over corrected for the principal focal point on the convex side and somewhat under corrected for the principal focal point on the concave side, that is toward the side facing the negative member of the anamorphoser. These two corrections therefore balance out to an approximately perfect correction for the intermediate position of the conjugate focal points. The crown glass faces the negative member and has both surfaces concave toward it. The lens has a focal length of 44.44 mm. and radii and constants as follows:

$\rho_1 = +13.289$ mm. thickness 0.443 mm. n_d 1.60801 Abbe number 46.2
Barium flint
 $\rho_2 = +6.792$ mm. thickness 1.181 mm. n_d 1.50454 Abbe number 67.0
Phosphate crown
 $\rho_3 = +59.065$

The negative cylindrical lens 51 is likewise substantially corrected for spherical aberration and color in both directions and its field flattened and coma substantially reduced. To accomplish this it is given the following constants, the focal length being 42.89 mm.

$\rho_4 = -135.337$ mm. thickness 1.400 mm. n_d 1.60801 Abbe number 46.2
Barium flint
 $\rho_5 = -10.267$ mm. thickness 1.307 mm. n_d 1.56870 Abbe number 63.0
Phosphate crown
 $\rho_6 = +25.200$ mm.

The negative cylindrical member is composed of such glasses and so formed as to be substantially free of spherical aberration in both directions, actually being somewhat under corrected for the principal focal point on the least concave side, the side facing the positive member of the anamorphoser, and that of the longest conjugate focal distance, and somewhat less over corrected to the other side, the side of the shorter conjugate focal distance. The result is an approximately perfect correction for the intermediate position of these two conjugate focal points proportionate, as to distance, to the under and over corrections for the principal focal points. The negative member has its flint glass facing the positive member and both surfaces concave toward it. In both members the spherical correction includes color d to g .

In Fig. 9 I show in plan view a modification of the optical trains of Figs. 1 and 2 in which there is included an achromatic straight vision prism objective 64, 65 as described and claimed in my U. S. Patents 1,898,787 (Fig. 1) and 1,931,992 together with a correcting lens 66 as described and claimed in my Patents 1,931,992 and Re. 19,056, to collimate the pencils coming from the object 3. A prism anamorphoser might, of course, also be used in Fig. 1 instead of the cylindrical anamorphoser 10, 11 and vice versa.

By way of illustrative example the 88.9 mm. segmenting lens 13, 14 is the same as in Fig. 2. In front of it are placed 3 Protar type lenses 22' arranged in coplanar fashion as at 22', Fig. 6a. They have focal lengths of 150 mm. which permits, for a spacing of 7.333 mm. between the centers of each of the three multiple images, a spacing of 12.975 mm. between the centers of the coplanar lenses and of 13.832 mm. between the principal ray intersection points with the principal planes of the segmenting lens. The negative object lens 23 is of 75 mm. focal length but otherwise the same as the lens 23 of Fig. 2. It is positioned with its second principal focal point at 9 in the anterior principal focal plane of the lenses 22'.

I have discovered that with this arrangement, and using only 3 to 2 image reduction or de-

formation with the anamorphoser, by rotating the images of the object 3 in the image plane 90° about their axes, I can lay three of them down side by side as at 43 in Fig. 6b so as to get maximum use of the space in the motion picture frame.

To accomplish this rotation I show in perspective an image rotating prism train 71, 72, 73 placed in front of the multiple image forming objective. This rotates the image of the horizontal object 3 90° so that it will appear vertical on the film as at 43 in Fig. 6b. Turning the camera (and projector) on its side would accomplish the same result. In front of the prism 73 is shown schematically a delineator 12 as described.

At 91, 92, and 93 I show color filters which might, instead, be placed between the lenses 22 and the lens 14.

In Fig. 10 I show at 80, 81 and 82 an anachromatic straight vision three prism anamorphoser according to my Patent 2,088,660 and as described in my copending application of even date. This might be used in place of the anamorphoser 64, 65 of Fig. 9 and elsewhere as suggested in order to accomplish approximately 2 to 1 anamorphosis.

In using the term Protar type lens it is not intended that I confine myself to the use of Protar lenses but rather do I intend to designate thereby lenses having good image forming quality and particularly having their principal planes outside of them and further from their principal focal points, as described. The Protar lens is however specifically preferred and offers certain definite advantages. The coplanar lenses are preferably turned with the principal focal plane for which they are designed to be used toward the object and not toward the motion picture lens as shown by Waide. If turned the other way they usually give, in this system, poorer images. If, however so turned, then they should be chosen to have principal planes placed away from the principal point used, as described.

The foregoing particular description is illustrative merely and is not intended as defining the limits of the invention. Whereas certain specific afocal anamorphosers are described, it is not intended that the invention be limited to the use of any particular afocal anamorphoser to accomplish the deformation of the images. The particular anamorphosers and arrangements shown and described herein offer however certain definite and specific advantages and are preferred. Moreover by the means and arrangements shown and described herein the quality of the imagery of the multiple image forming system itself has been much improved.

This application is a continuation in part of my Patents 2,088,660, 2,121,568 and 2,045,093, and of my copending application Serial No. 86,647, filed June 22, 1936. It describes in part certain improvements over arrangements shown in said patents and application.

I claim:

1. A multiple image forming system comprising, in their order along an axis, a segmenting photographic lens adapted to transmit, with substantially equal definition comparable to that through a central zone, a plurality of discreet images of an object through zones corresponding to the image transmitting zones of an assembly of coplanar lenses positioned laterally of each other in front thereof, the coplanar lenses being of substantially equal focal lengths and having their principal planes belonging to the side facing

the segmenting lens situated in a common plane which plane lies outside of their exterior surfaces and substantially nearer to the adjacent principal plane of the segmenting lens than are the adjacent surfaces of the coplanar lenses to this plane, an object lens positioned in front thereof whose conjugate points, one of which is virtual and one of which is in the plane of the object, are both anterior to the object lens and which latter is of such focal length and so positioned that the said virtual conjugate image point lies in a plane containing a fixed anterior focal point of each of the lenses of the coplanar assembly.

2. A multiple image forming system comprising, in their order along an axis, a photographic lens, an assembly of coplanar lenses of substantially equal focal length positioned laterally of each other in front thereof and having their principal planes belonging to the side facing the photographic lens lying in a common plane outside of their exterior surfaces and substantially nearer to the adjacent principal plane of the photographic lens than are their adjacent surfaces to this plane, an object lens whose conjugate points, one of which is virtual and one of which is in the plane of the object, are both anterior to the object lens and which latter is of such focal length and so positioned that the said virtual conjugate image point lies in a plane containing a fixed anterior focal point of each of the lenses of the coplanar assembly.

3. A multiple image forming system comprising, in their order along an axis, a segmenting photographic lens, an assembly of coplanar lenses positioned laterally of each other in front thereof, the coplanar lenses being of substantially equal focal lengths and having their principal planes belonging to the side facing the segmenting lens situated in a common plane which plane lies outside of their exterior surfaces and substantially nearer to the adjacent principal plane of the segmenting lens than are the adjacent surfaces of the coplanar lenses to this plane, an object lens positioned in front thereof whose conjugate points, one of which is virtual and one of which is in the plane of the object, are both anterior to the object lens and which latter is of such focal length and so positioned that the said virtual conjugate image point lies in a plane containing a fixed anterior focal point of each of the lenses of the coplanar assembly, together with an anamorphoser.

4. A multiple image forming system, as in claim 3 in which the object lens is positive and positioned in front of the afocal anamorphoser, thereby to adapt the system to printing, substantially as described.

5. A multiple image forming system, as in claim 3, in which the object lens is positive and the anamorphoser is positioned between the photographic lens and its principal focal plane, the anamorphoser having conjugate image planes in said focal plane.

6. A multiple image forming system, as in claim 3, in which the object lens is positive and the anamorphoser is positioned between the photographic lens and its principal focal plane, the anamorphoser having conjugate image planes in said focal plane, the members of the anamorphoser being corrected for spherical aberration and achromatism in both directions.

7. A multiple image forming system as in claim 3, in which the anamorphoser is a straight vision achromatic prism anamorphoser.

8. A multiple image forming system compris-

ing, in their order along an axis, a photographic lens, an assembly of coplanar lenses of substantially equal focal length positioned laterally of each other in front thereof and having their principal planes belonging to the side facing the photographic lens lying in a common plane outside of their exterior surfaces and substantially nearer to the adjacent principal plane of the photographic lens than are their adjacent surfaces to this plane, a negative object lens whose conjugate points, one of which is virtual and one of which is in the plane of the object, are both anterior to the negative object lens and which latter is of such focal length and so positioned that the said virtual conjugate image point lies in a plane containing a fixed anterior focal point of each of the lenses of the coplanar assembly.

9. A multiple image forming system as in claim 8, in which the object lens is an achromatized doublet with the flint glass facing the coplanar assembly and having both surfaces concave toward the assembly.

10. A multiple image forming system having conjugate image planes situated to opposite sides thereof, comprising a segmenting photographic lens, and an assembly of coplanar lenses positioned laterally of each other in front thereof and so placed near thereto and of such unit focal length as to effect the aforesaid conjugate imagery, the segmenting lens having interiorly situated principal planes and being adapted to transmit with substantially equal definition comparable to that through a central zone, a plurality of discreet images of an object through zones corresponding to the image transmitting zones of the assembly of coplanar lenses, the coplanar lenses being of substantially equal focal lengths and having principal planes belonging to the side facing the segmenting lens located so as to lie substantially outside of their exterior surfaces and substantially in a common plane which plane is substantially nearer to the adjacent principal plane of the segmenting lens than are the adjacent surfaces of the coplanar lenses to this adjacent principal plane.

11. A multiple image forming system as defined in claim 10 including also an object lens positioned in front of the segmenting lens and focusing an object lying in front of the system in the anterior conjugate focal plane of the system.

12. A multiple image forming system having conjugate image planes situated to opposite sides thereof, comprising a segmenting photographic lens, and an assembly of coplanar lenses positioned laterally of each other in front thereof, the segmenting lens having interiorly situated principal planes and being adapted to transmit with substantially equal definition comparable to that through a central zone, a plurality of discreet images of an object through zones corresponding to the image transmitting zones of the assembly of coplanar lenses, the coplanar lenses being of substantially equal focal lengths and having principal planes belonging to the side facing the segmenting lens located so as to lie outside of their exterior surfaces and substantially in a common plane which plane is at an appreciable distance behind the front surface of the segmenting lens and near its first principal plane.

13. A multiple image forming system as defined in claim 12 including also an object lens positioned in front of the segmenting lens and focusing an object lying in front of the system

2,207,409

11

in the anterior conjugate focal plane of the system.

14. A multiple image forming system having conjugate image planes situated to opposite sides thereof, comprising a segmenting photographic lens, and an assembly of coplanar lenses positioned laterally of each other in front thereof, the segmenting lens having interiorly situated principal planes and being adapted to transmit with substantially equal definition comparable to that through a central zone, a plurality of dis-

crete images of an object through zones corresponding to the image transmitting zones of the assembly of coplanar lenses, the coplanar lenses being of substantially equal focal lengths and having principal planes belonging to the side facing the segmenting lens located so as to lie substantially outside of their exterior surfaces and substantially in a common plane which plane is near to the adjacent principal plane of the segmenting lens.

HARRY SIDNEY NEWCOMER.