Fig. 1

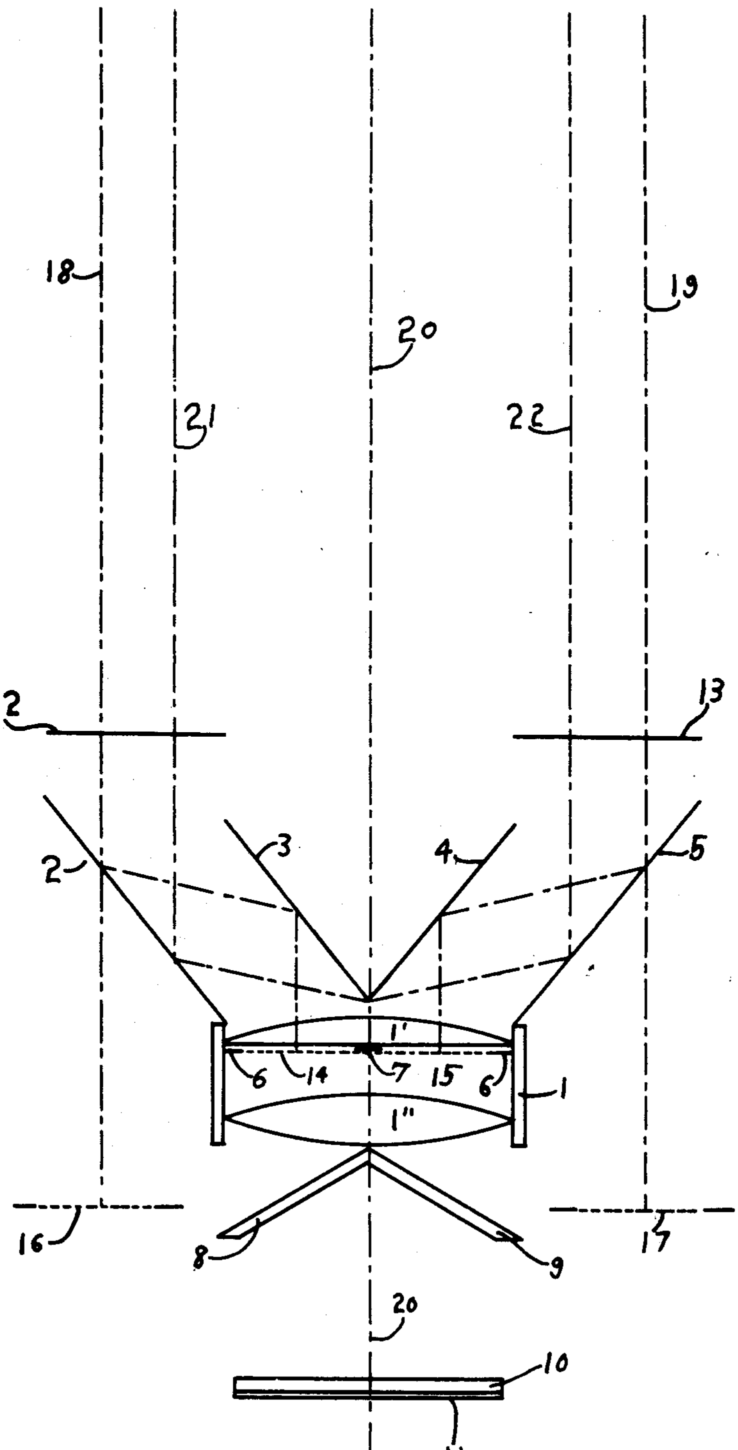

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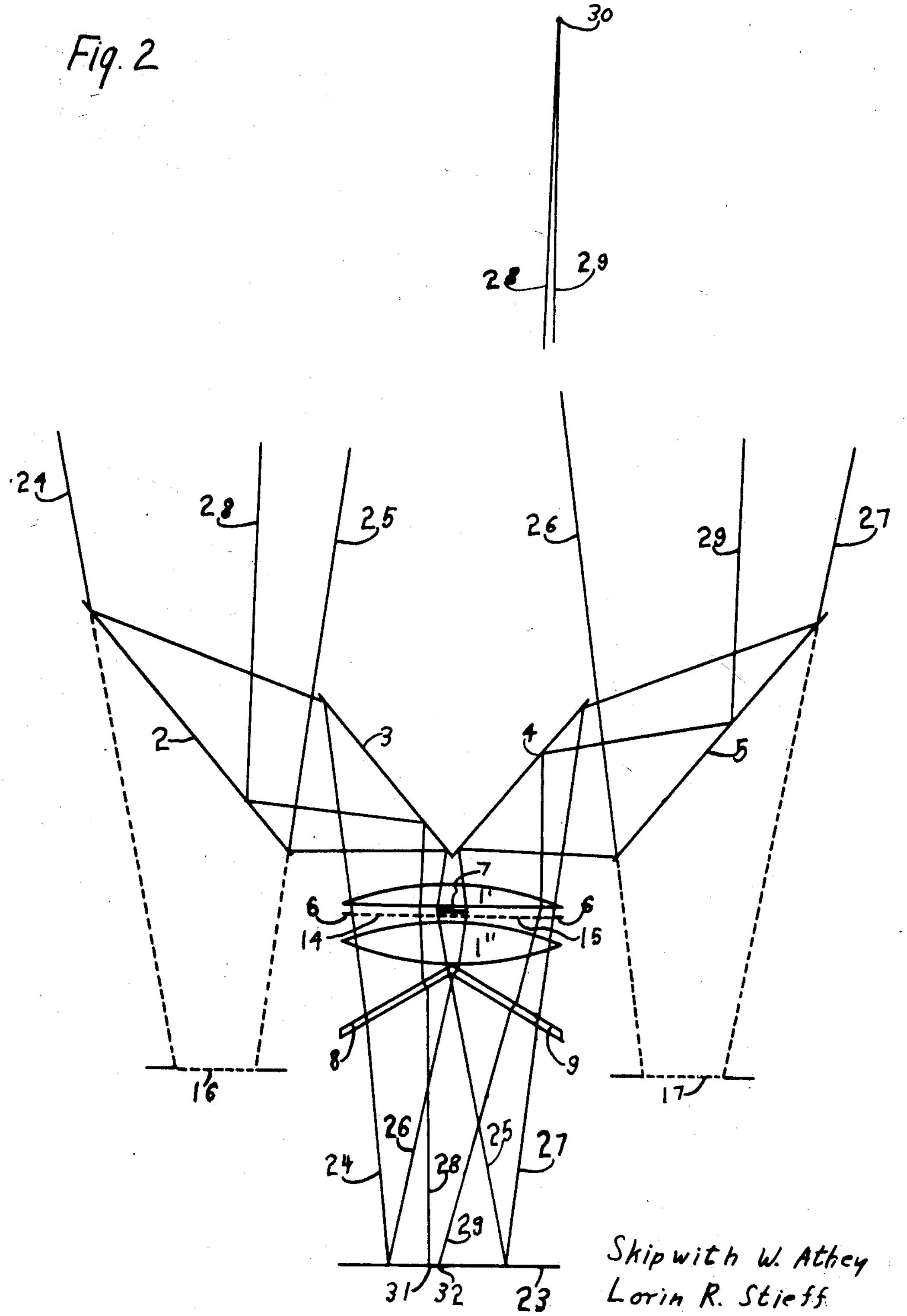
Fig. 2



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BY William W. Varney atty.

Fig. 3

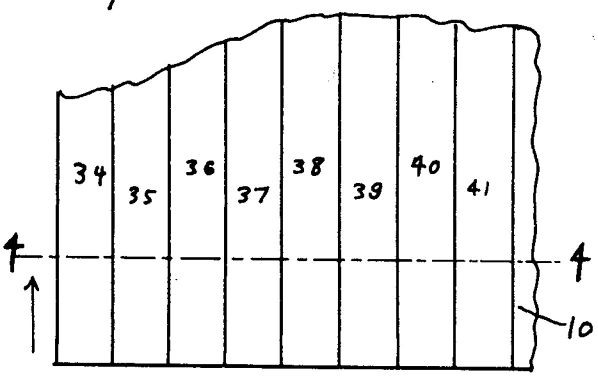

Fig. 4

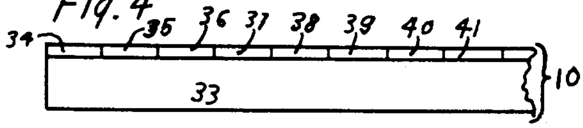

Fig. 5

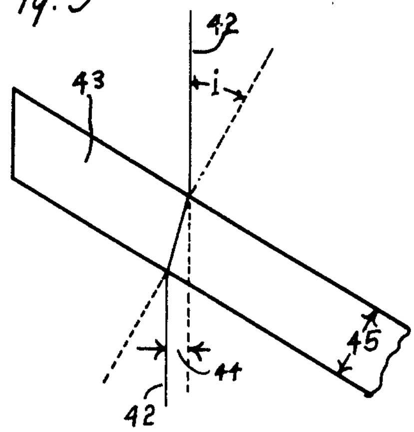

Fig. 6

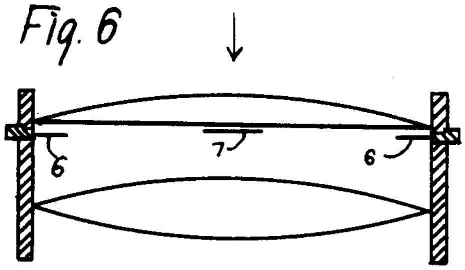

Fig. 8

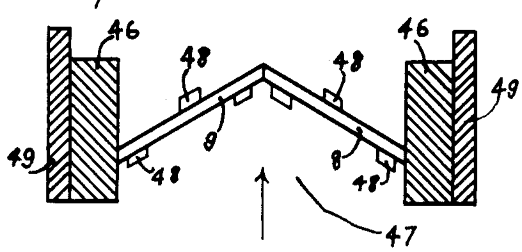

Fig. 7

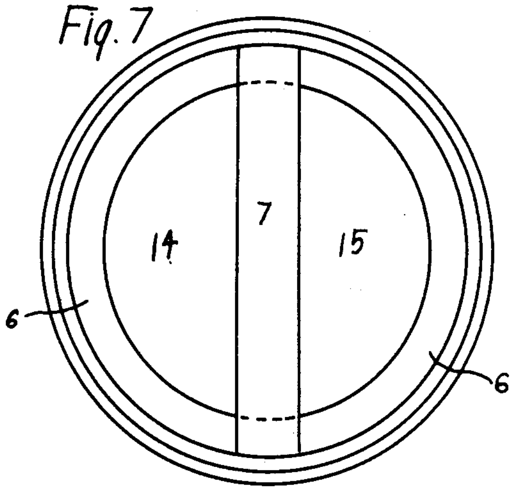

Fig. 9

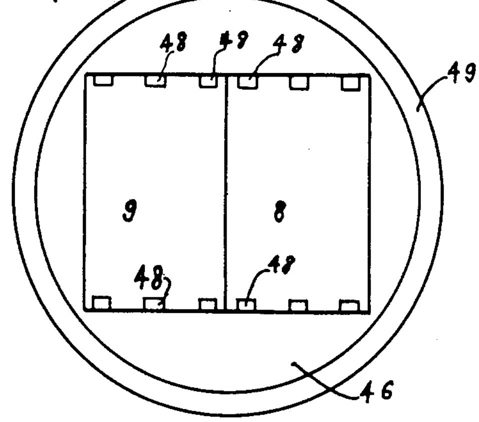

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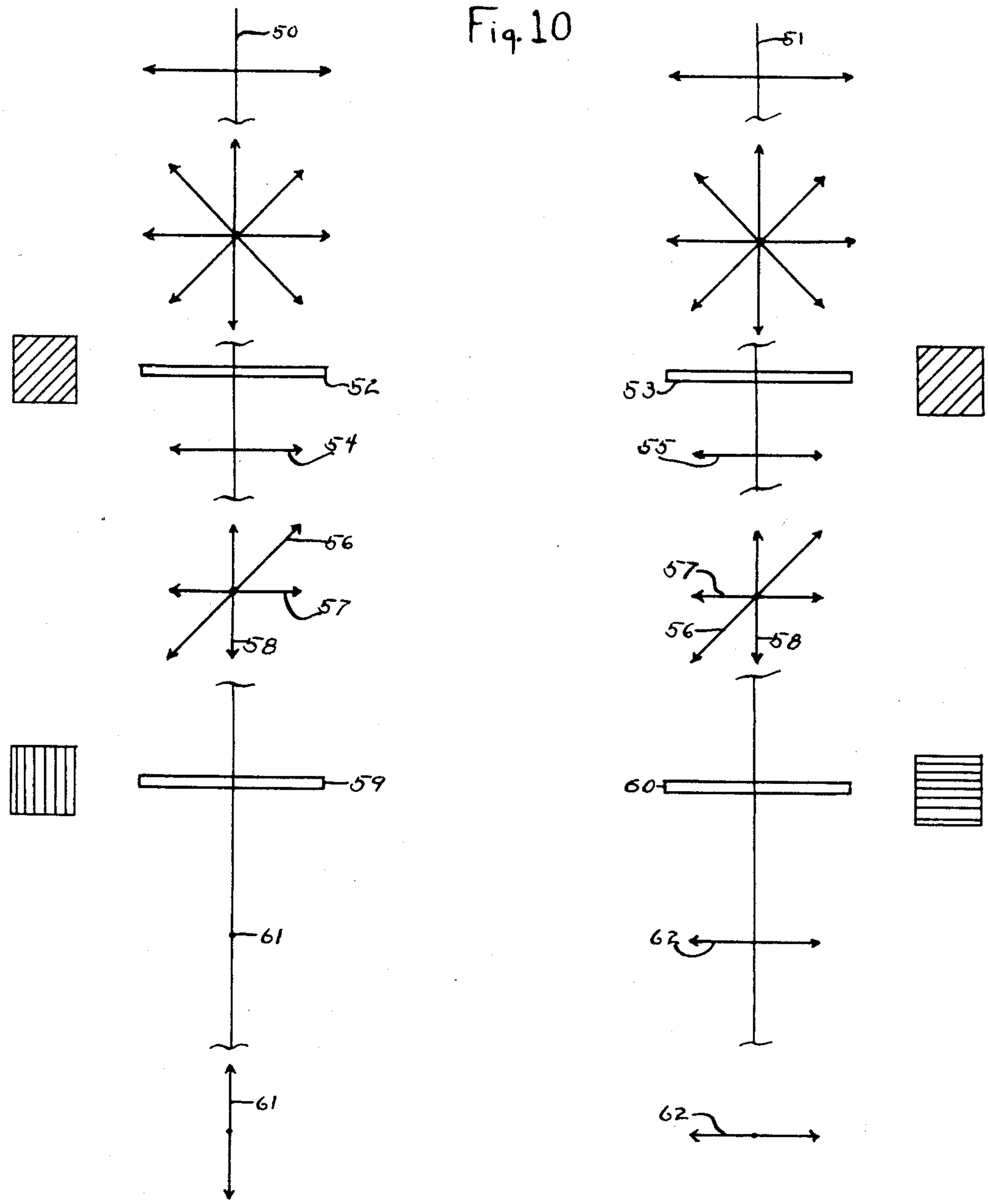
Fig. 10



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BY William W Varney Atty

Fig. 11

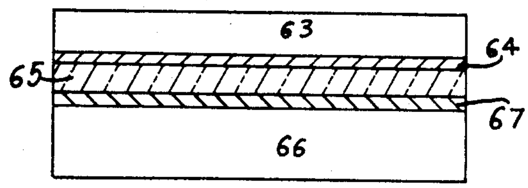

Fig. 12

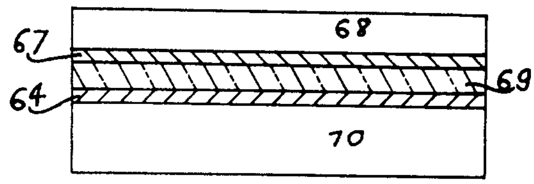

Fig. 13

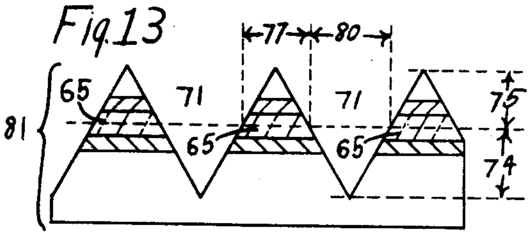

Fig. 14

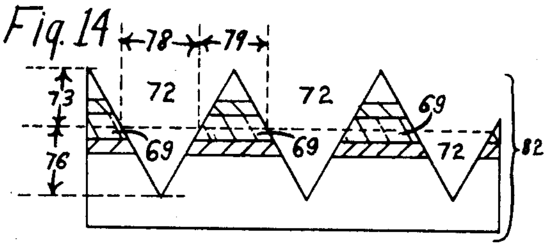

Fig. 15

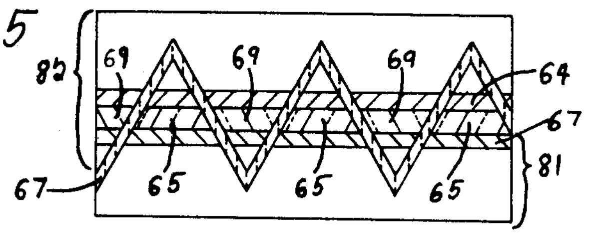

Fig 16

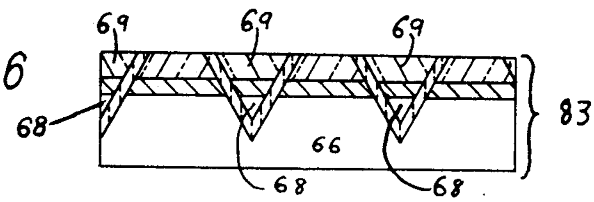

Fig. 17

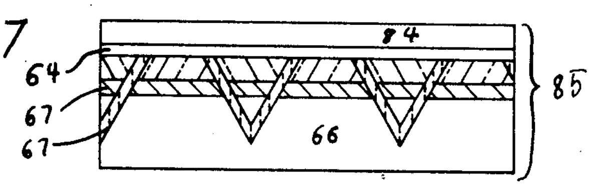

Fig. 18

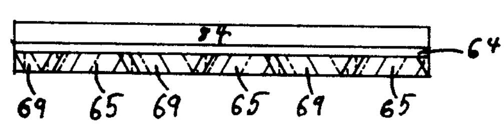

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Fig. 21

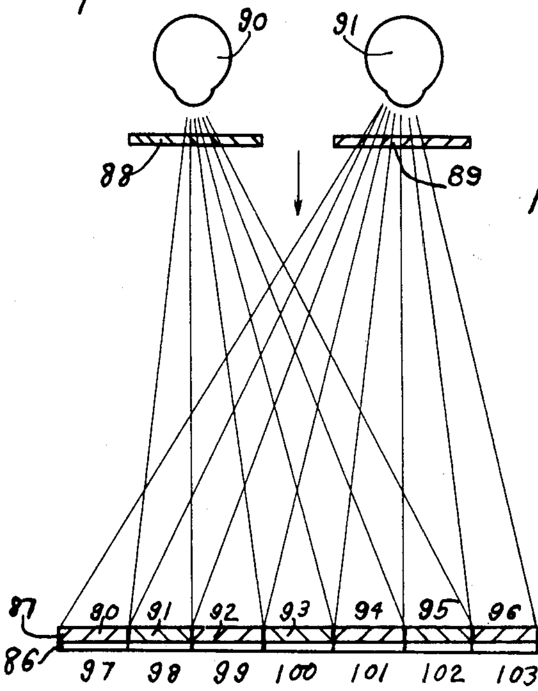


Fig. 20

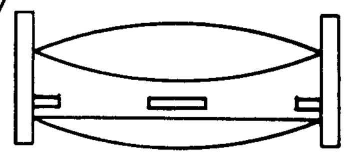


Fig. 19

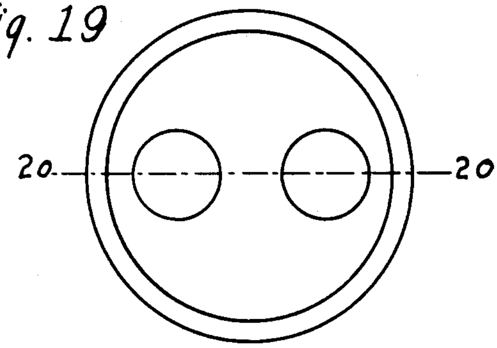


Fig. 22

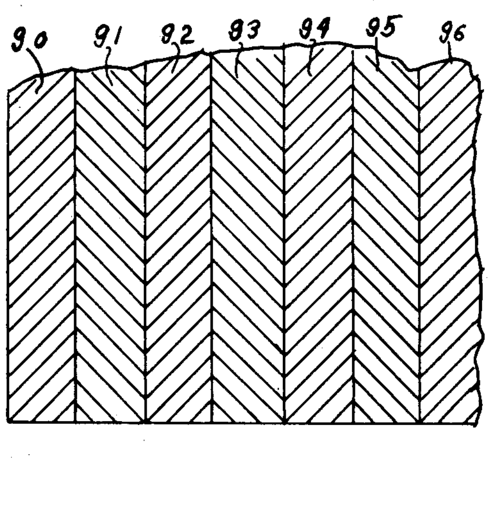
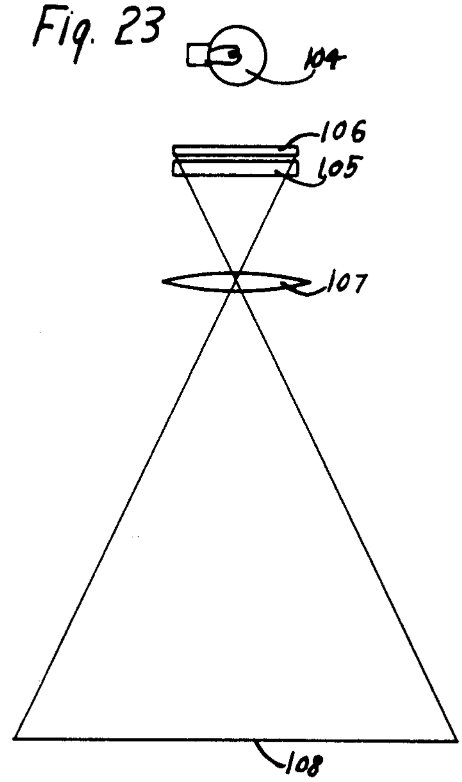


Fig. 23



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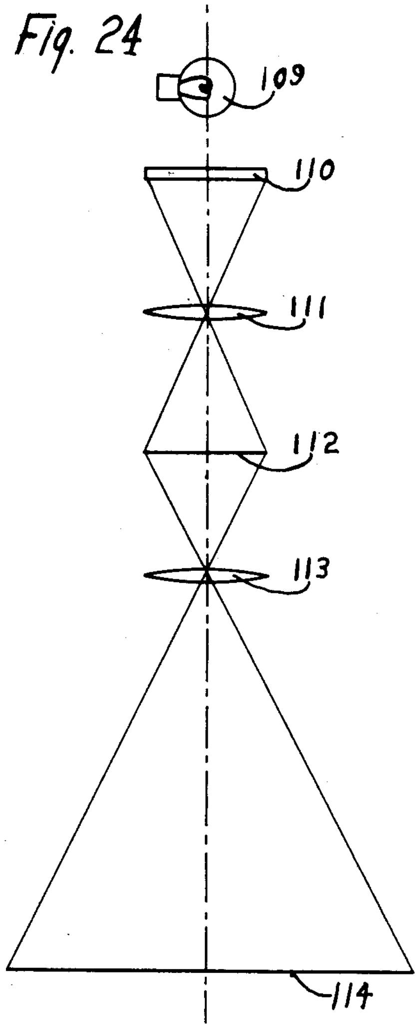

Fig. 24

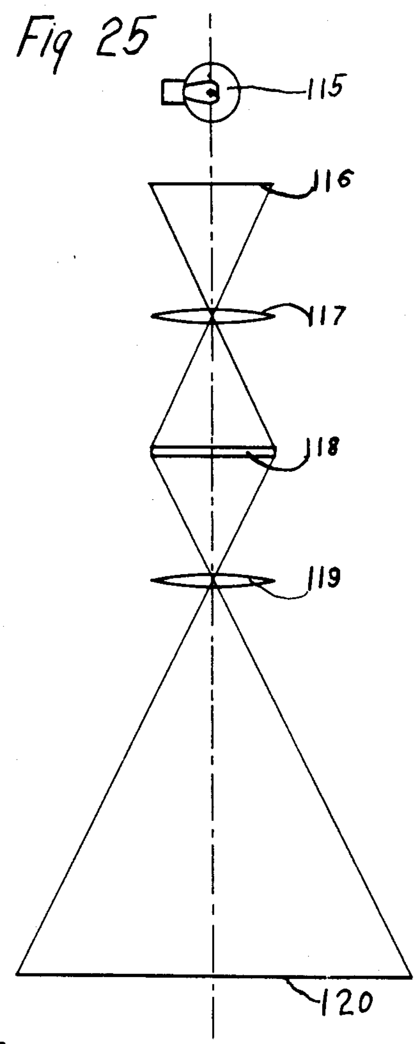

Fig 25

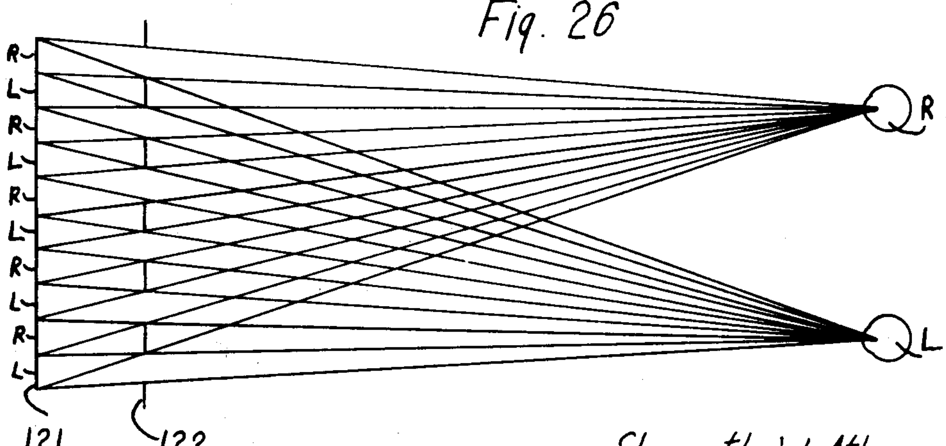

Fig. 26

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Fig. 28

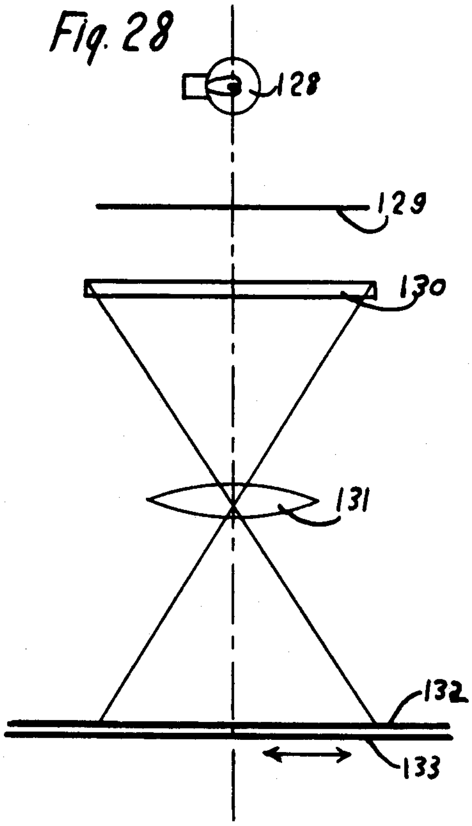


Fig. 29

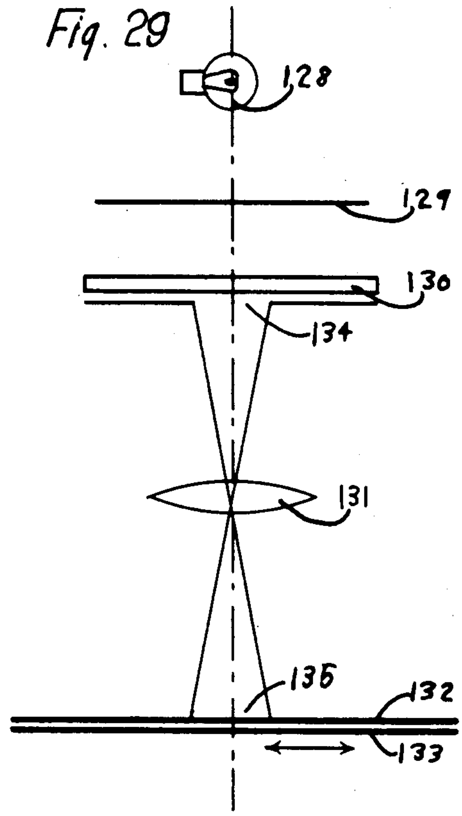


Fig. 27

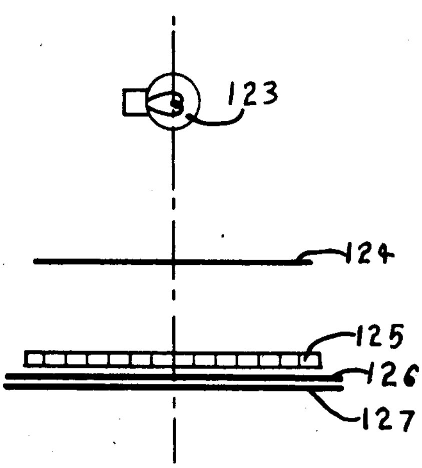
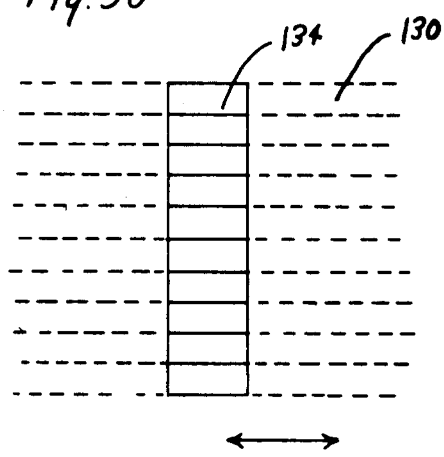


Fig. 30



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William W. Varney atty.

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Fig. 31

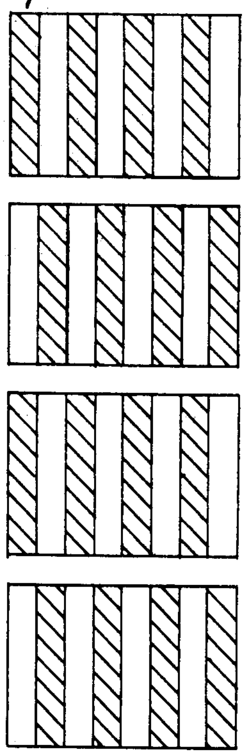


Fig. 33

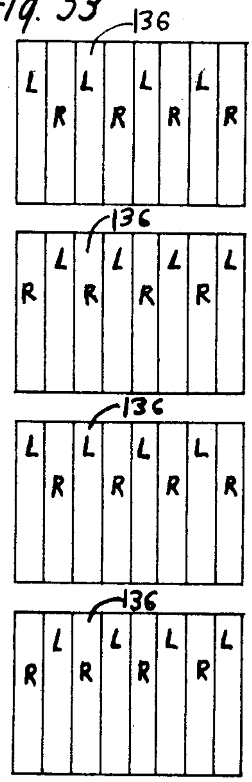


Fig. 32

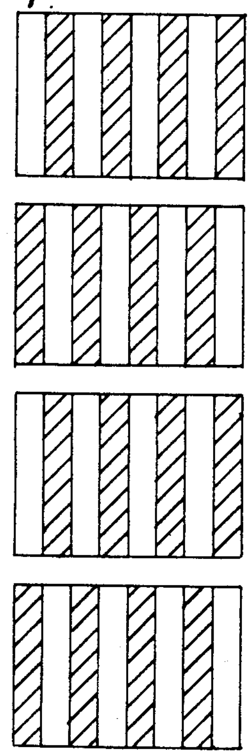


Fig. 34

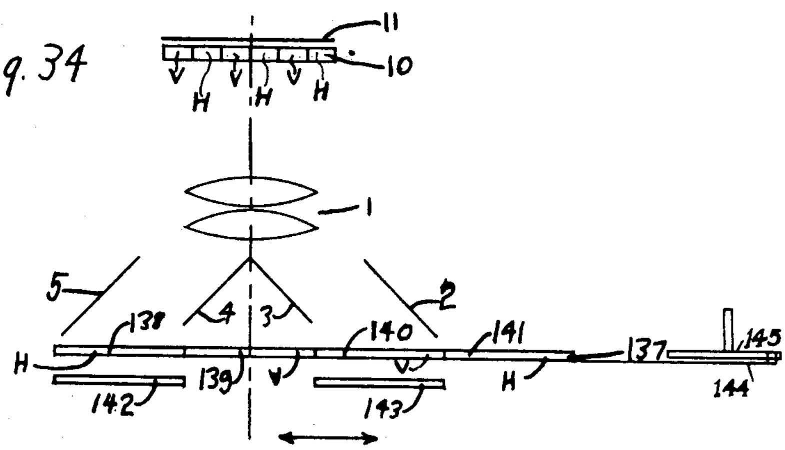
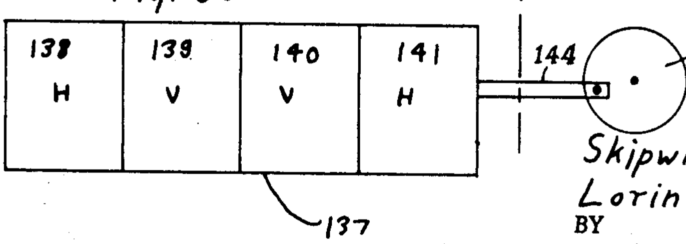


Fig. 35



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Patented Apr. 27, 1943

2,317,875

UNITED STATES PATENT OFFICE

2,317,875

STEREOSCOPIC PHOTOGRAPHY

Skipwith W. Athey and Lorin R. Stieff, Baltimore, Md.

Application June 28, 1940, Serial No. 343,038

1 Claim. (Cl. 88—16.6)

This invention relates to stereoscopic photography and to methods and means for photographically producing and presenting an interlined stereogram which may be employed either as a still picture or as a motion picture.

The general problem in stereoscopy is to produce and present different views to each of the two eyes of the spectator. Solutions of the problem in general take the form of presenting more than one view to the spectator and providing means for insuring that his each eye shall see only one such view, employing either of the two approaches, (A) some separating means placed at the projection screen or at the viewed picture, or (B) some such means placed at the spectator's eyes. One of the objects of this invention is to provide means for obtaining pictures which may be presented in either of these ways. More specifically, it is intended to provide a complete system for taking and presenting stereoscopic views for observation through some form of differentiating glasses, but it is not proposed to limit the scope to this form of presentation, as other forms may be used, as suggested herein.

Hitherto it has been proposed to produce stereoscopic views by a great variety of methods, among which may be mentioned the following, with some of their disadvantages which this system proposes to eliminate: (A) The taking of two stereoscopically related views simultaneously on two separate films, which has the disadvantage of requiring an increase over the amount of film normally required; (B) The taking of two separate pictures simultaneously on one film, which involves the same disadvantage as (A); (C) The taking of two pictures on one film from different viewpoints in succession, which gives objectionable time-parallax, in addition to the objections to (A) and (B); corresponding stereoscopic pictures taken with a time interval do not give true stereoscopic effects; (D) The taking of two views in the image space normally occupied by one view, by means of mechanical gratings, so arranged that a composite image is formed, consisting of alternate strips of each of the two images. It is also usual in this latter case to form the two partial images in succession, again causing time-parallax. Such a mechanical grating must be differentiated from our invention.

A further object of our invention is an improvement in photography, particularly with reference to moving picture films, and for photographing pictures on a negative film and projecting the pictures from a positive film.

A further object of our invention is the providing of a film which contains in a single picture space a plurality of views taken simultaneously.

A further object of our invention is to provide means for photographing simultaneously in one picture space a plurality of interlined views.

A further object of our invention is to provide means for photographing simultaneously in one picture space two interlined stereoscopic views.

A further object of our invention is to provide means for producing interlined stereoscopic motion pictures with relatively few changes in existing motion picture equipment.

A further object of our invention is the producing of two stereoscopic images essentially in the same space on a sensitive film in such a way as to enable their being separated later for viewing directly, or by projection in such a way as to enable an ortho-stereoscopic rendering of the original object.

A further object of our invention is to provide an improved means for making a plurality of pictures on a single view so that the respective eyes of a spectator may view them individually without commingling their effect.

A further object of our invention is to provide an improved optical system for producing in partial or complete superposition two images of an object obtained from separate viewpoints.

A further object of our invention is to provide means for obtaining with a lens of small diameter two superimposed images whose viewpoints differ by a distance greater than the diameter of the lens.

A further object of our invention is to provide a plurality of images of different polarization of an object which shall have identical intensity in all possible cases irrespective of fugitive polarization effects.

A further object of our invention is to provide means for producing diversely polarized images of an object which shall have identical intensity in all cases.

A further object of our invention is to provide an interlined stereogram which is free of linear pattern when viewed.

A further object of our invention is to provide means for making an interlined stereogram so that it is free from linear pattern when viewed.

A further object of our invention is to provide a film, or films, for projecting interlined stereographic motion pictures such that successive right or left eye views occupy adjacent strip areas.

With the foregoing and other objects in view, our invention consists of the methods employed, combination and arrangement of apparatus and means as hereinafter specifically provided and illustrated in the accompanying drawings, wherein is shown the preferred embodiment of our invention but it is understood that changes, variations and modifications may be resorted to which come within the scope of the claims hereunto appended.

In the drawings of the herein described embodiment of our invention, Figures 1 and 2 are essentially representations of the same thing, Fig. 1 being a schematic view of all the elements of a system for taking stereoscopic pictures and their geometric relationships, while Fig. 2 is a schematic representation in the same view of the optical action of the system as far as the effects on the paths of light rays are concerned.

Fig. 3 is an enlarged detail of a special linear polarizing filter; Fig. 4 is a section of the linear filter of Fig. 3, taken at 4—4 in Fig. 3, looking in the direction of the arrow; Fig. 5 is an enlarged schematic diagram of the path of a light ray through a transparent optical flat, shown in section not cross-hatched for clarity; Fig. 6 is an enlarged schematic view of the lens assembly as shown in Fig. 1; Fig. 7 is a front elevation of the lens shown in Fig. 6, looking in the direction of the arrow; Fig. 8 is a schematic view of a mounting suitable for optical flats 8 and 9, shown in Fig. 1; Fig. 9 is a rear elevation of the mounting shown in Fig. 8, looking in the direction of the arrow; Fig. 10 is a schematic view of the action of polarizer sets on light rays, especially as applied to polarizers 12 and 13, of Fig. 1. Figs. 11–18 are enlarged diagrammatic views of a method of construction of a special linear polarizing filter; Fig. 11 is a section of a polarizing sandwich; Fig. 12 is a section of a similar sandwich; Fig. 13 is a section of the assembly of Fig. 11 after grooves have been ruled thereon; Fig. 14 is a section of the assembly of Fig. 12, after similar grooves have been ruled thereon; Fig. 15 is a section of the assemblies of Figs. 13 and 14, after they have been placed face to face; Fig. 16 is a section of the assembly of Fig. 15, after some portions have been removed; Fig. 17 is a section of the assembly of Fig. 16, after a transparent sheet has been fastened thereto, and Fig. 18 is a section of the assembly of Fig. 17 after further portions have been removed.

Fig. 19 is a front view of a special double stop; Fig. 20 is a schematic view at 20—20 of Fig. 19; Fig. 21 is a diagrammatic view of a method of viewing interlined stereograms; Fig. 22 is a view of the picture and filter assembly of Fig. 21, looking in the direction of the arrow; Fig. 23 is a diagrammatic view of a system for projecting interlined stereograms as produced by applicants; Fig. 24 is a diagrammatic view of another system for projecting interlined stereograms as produced by applicants; Fig. 25 is a view of another system for projecting interlined stereograms as produced by applicants; Fig. 26 is a diagrammatic view of a parallax system of viewing interlined stereograms as produced by applicants; Fig. 27 is a diagrammatic view of a system for printing separate views from interlined views as produced by applicants; Fig. 28 is a diagrammatic view of another system for printing separate views from interlined views as produced by applicants; Fig. 29 is a diagrammatic view of a system for printing separate views from interlined motion picture views as produced by applicants; Fig. 30 is a diagrammatic view of an arrangement of printing slit 134 and strips of linear polarizer 130, of Fig. 29 that may be used with applicant's photograph; Fig. 31 is a diagrammatic view of a record of a single view obtained from a special form of interlined view, as shown in Fig. 33; Fig. 32 is a diagrammatic view of the record other than that of Fig. 31 obtained from the special form of interlined view shown in Fig. 33; Fig. 33 is a diagrammatic view of a special form of interlined view; Fig. 34 is a diagrammatic view of a modification of the apparatus of Fig. 1, adapted to obtaining special interlined stereoscopic views of the form of Fig. 33, and Fig. 35 is a diagrammatic elevation of assembly 137 of Fig. 34.

Similar numerals refer to similar parts throughout the several views.

In Fig. 1, 1 is a lens assembly of two elements, 1^1 and 1^{11}. We have shown a simply constructed lens, though in practice lenses of fewer or more elements may be used. This lens is provided with an iris diaphragm 6 and fitted with an additional light controlling device 7 which is a narrow strip of opaque material placed in the lens between the elements in such a manner that it lies as close as possible to the plane of the iris 6, and is oriented with its long dimension vertical, dividing the lens horizontally into two approximately semi-circular pupils, 14 and 15. This is the preferred construction for the light controlling mechanism, but the same effect may be accomplished by any type of double stop as shown in Figs. 19 and 20.

On the object side of the lens is positioned a reflecting system consisting of reflecting means 2, 3, 4 and 5, all lying with reflecting surfaces vertical. 3 and 4 lie on opposite sides of the lens axis 20, forming equal angles therewith, and with reflecting surfaces facing lens assembly 1 and, meeting if extended, in a line passing vertically through the axis 20. 2 and 5 lie respectively parallel to 3 and 4, equidistant respectively therefrom and on corresponding sides of the axis 20, respectively, with reflecting surfaces facing 3 and 4 respectively. It is not necessary for the above to be in the exact locations enumerated which have been expressed for clearness; we do not wish to be limited to any disposition of these mirrors that come within the scope of the claims hereunto appended, as a wide latitude may be had as to their location.

On the object side of this reflecting system are placed the two polarizers 12 and 13, whose special nature and orientation will be discussed later. On the image side of the lens are positioned transparent optical flats 8 and 9 with their surfaces vertical and at equal angles to the optical axis 20, their front surfaces intersecting if extended in a line passing vertically through the axis 20. The latitude of placement of these flats is in substance the same as that of the reflectors, and we do not wish to be limited to these details as to placement.

Behind this assembly in the image space is placed a special linear polarizing filter 10, and in contact therewith on the side away from the lens, a film 11. 18 and 19 are projections of the effective centers of lens pupils 14 and 15, while 16 and 17 are the effective positions of the reflected virtual images of these pupils when considered from the object space. 21 and 22 are the theoretical positions of the lens axis 20 after reflection in the reflectors 2, 3, 4 and 5. This is the special case as shown in the diagrams, but it is not to be considered as necessary, since various other relative displacements of lens and image may take place.

The expressions "horizontal" and "vertical" refer to the normal position of the camera, and to the plane of the paper in the drawings, but are not to be construed to imply that the complete apparatus may not be oriented in any desired position in use.

Referring to Fig. 2 in further illustration of the operation of our invention, **23** is a plane which may be any sort of image-receiving surface, as a ground glass, screen or film. **24** and **25** are the limiting rays of the light cone received by pupil **14** via reflectors **2** and **3**. **26** and **27** are limiting rays of the cone received by pupil **15**, via reflectors **4** and **5**. **28** is a representative light ray from an object **30** entering pupil **14**, and **29** is a similar ray entering **15**, these rays being broken off in the view for lack of space.

The structure of the linear filter **10** is shown at Figs. 3 and 4, which are enlarged details of the same. Fig. 4 is a sectional view at **4—4**, looking in the direction of the arrow in Fig. 3. **33** is some transparent base material, such as glass, or a synthetic resinous plastic, or any other suitable material, to which are fastened by methods to be described later, strips of sheet polarizing material, such as that consisting of microscopic overlapping crystals of herapathite or quinine-iodosulfate disposed in a cellulosic film matrix, so that the optical axes of the crystals are essentially parallel. This material may be obtained in the open market, under the trade name of "Polaroid." In the preferred embodiment of our invention, alternate strips have their axes of polarization at right angles to each other; as, **34** has its axis parallel to that of **36**, **38** and **40**, and at right angles to that of **35**, **37**, **39** and **41**, etc., **35** has its axis parallel to that of **37**, **39**, etc., and at right angles to that of **36**, **38**, etc.; but we do not propose to limit ourselves to this arrangement and order of strips, and may employ such different angles and degrees of polarization as may be desirable. However, for the particular modifications and uses described in this specification, one particular arrangement is assumed, since it limits the number of essentially similar cases which must be considered. The arrangement assumed is that in which every other polarizer strip has its axis parallel and alternate strips have their axes at right angles to each other, as described immediately above.

Describing the operation of our invention, we shall refer first to Fig. 2 and only to those elements of the system shown therein, later referring to Fig. 1 which contains the additional elements of the polarizers **12** and **13**, linear filter **10** and film **11**. Fig. 2 shows those elements of the system which affect only the paths of the light rays, while the added elements of Fig. 1 affect only the composition and nature of these rays, and it is necessary to differentiate these two functions.

Referring to Fig. 2, when the apparatus is directed at an object, rays of light from the object are received by the reflectors **2** and **5**, are respectively reflected onto **3** and **4**, are again reflected and emerge respectively parallel to their original direction. They are then received by the lens assembly **1**, being refracted therein, passing through pupils **14** and **15**, respectively, are then displaced laterally slightly by flats **8** and **9**, and finally imaged on the plane **23**. **28** and **29** are two representative rays from an object **30**, one received by each of the lens pupils **14** and **15**, following the paths described through the apparatus and being imaged at **31** and **32**, respectively, on the plane **23**. Looking into the front of the apparatus from the object side, pupils **14** and **15** would seem to lie in the positions **16** and **17**, respectively, and the two images received by plane **23** are therefore those that would be seen by eyes or cameras placed at these positions. The construction is such that the separation of these pupillary images is approximately that of normal human eyes.

A film placed at the plane **23** would now record two simultaneous images, and the developed result would show a double exposure. It would be impossible to separate the two views, as would be necessary for presenting the views with true stereoscopic effects. To enable this separation we add to the apparatus of Fig. 2 two polarizers, **12** and **13**, and a linear polarizing filter **10**, as shown in Fig. 1.

The two images are diversely polarized by polarizers **12** and **13**; in the preferred embodiment of our invention, they have their axes of polarization at right angles to each other. The strips of polarizer in the filter **10** have their axes of polarization so oriented that one set of these strips has its axis parallel to the axis of one of the polarizers **12**, **13**, and hence parallel to that of one of the images. The other set of these strips has its axis parallel to that of the other one of the polarizers **12**, **13**, and hence parallel to that of the other image, while the two systems of strips, front polarizers and images have their axes of polarization mutually at right angles. Hence, one set of the strips of the filter will admit one image, and the other set will admit the other, each excluding the light of opposite polarization. For example, strips **34**, **36**, **38**, **40**, etc. may have their axes parallel to that of polarizer **12** and of the image admitted by pupil **14** and all portions of the film **11** lying behind these strips will, therefore, record the image of pupil **14**. Since polarizer **13** would in this case have its axis of polarization at right angles to that of strips **34**, **36**, **38**, **40**, etc., the image admitted through it would not affect the film lying behind these strips. In this case, strips **35**, **37**, **39**, **41**, etc. would have their axes parallel to the axis of polarization of polarizer **13**, and of the image admitted through pupil **15** and at right angles to that of polarizer **12**. The film lying behind these strips would therefore record only the image of pupil **15**. The finished film contains, therefore, an interlined record of alternate strips of image received by pupils **14** and **15**, hence, alternate strips of right and left eye stereoscopic view for this particular application, and is therefore an interlined stereogram. No part of the image recorded contains a double exposure, and it is therefore possible to separate the two images by means to be described.

The optical flats **8** and **9** may be omitted without in any way affecting the essential operation of the apparatus described, and it is not intended to limit the scope to their use. However, they have a very practical function which we shall now describe.

If a stereographic film obtained by the apparatus described is presented in such a way that the lateral relationship between the two images are unchanged, object points whose two images on the film coincide will seem to lie, in stereoscopic viewing, on the surface which is used for presenting them, whether this surface is paper print.

transparency, or projected image. Since, without flats 8 and 9, the taking system would form the two images of a point at infinity in coincidence on the film, such a point would seem to lie on the presenting surface when viewed stereoscopically. This means that all points closer than infinity would lie in front of the presenting surface, and since this is seldom desirable, flats 8 and 9 serve to separate such coincident points so that they may be made to appear, on viewing, at or near infinity. The action of these flats is shown in Fig. 5, where 42 is a ray of light entering a flat 43 at an angle *i*, and emerging parallel to its original direction but displaced laterally by an amount 44. The whole image is displaced by an equal amount, and therefore the distance 44, calculated for a ray perpendicular to the plane of the image, gives the actual amount of this displacement for the whole image. This may be shown to be dependent on the angle which the flat makes with the optical axis, which is in this case also perpendicular to the plane of the image used, the index of refraction of the flat, and the thickness 45 of the flat.

Detail of one construction of the stop mechanism is shown at Figs. 6 and 7. Fig. 6 shows a section of lens assembly 1 with an iris diaphragm 6 and an opaque strip 7, the strip being placed as close to the iris as practical. The front view Fig. 7 shows this strip in place. The function of the strip is to divide the lens into two stops and to equalize the light. If it were omitted, the junction of the mirrors 3 and 4 would divide the lens in two parts, but the effective position for this division as referred to the theoretically correct pupillary plane, that in which the iris is placed, would vary for various parts of the image. Thus the position of one side of each pupil, and hence the area of the pupil, would vary for various parts of the image. The middle strip 7 cuts off the light which is affected by this variation, hence removing the variation.

One method of construction for the mounting of flats 8 and 9 is shown at Figs. 8 and 9, where 46 is a round thick disc in which is cut a rectangular hole 47. Flats 8 and 9 are held in this hole by lugs 48. Means may be provided for holding this assembly in place on the lens assembly, such as an outer casing 49 which fits over the back of the lens barrel.

It should be noted that as the iris diaphragm 6 is changed in size to adjust for intensity of light, the effective centers of pupils 14 and 15 move relative to each other. The effective centers of these pupils are the centers of mass for thin sheets of their shape, and as the radius of the iris opening changes, these centers change in position. Hence, the centers of virtual pupil images 16 and 17 also move and the effective "interocular" distance changes. However, this is a relatively small percentage change and is generally negligible.

For special applications it may be desirable to obtain "model size" effects, and this may be easily accomplished with the apparatus described by removing the reflector system and employing the greatly reduced interocular afforded in that case, with stops of the type shown in Figs. 19 and 20.

It is necessary in polarizing two images diversely to eliminate what is known as "retinal rivalry." If there are any fugitive polarization effects in a scene, caused by reflection, dispersion, or otherwise, diversely oriented polarizers may transmit different amounts of light from these effects. Hence, some means must be provided to produce diversely polarized beams which are equal to each other in intensity no matter what the nature of the incident light. In some cases, "retinal rivalry" may be disregarded, and polarizers 12 and 13 then become simply single polarizers with axes of polarization respectively at right angles to each other. In most cases, however, this "rivalry" is a serious defect.

Fig. 10 shows a schematic plan view of one system of accomplishing this end. The diagram assumes the vibratory nature of light and uses vector notation as a simplified picture of the action of polarization. 50 and 51 are two beams of ordinary or partially polarized light as indicated, the end view of the light vectors lying in haphazard planes. The squares of hatching beside the polarizers 52 and 53, 59 and 60, indicate their axes of polarization. An end view, 56, is shown of vectors 54 and 55 of the emergent beams from polarizers 52 and 53, and the beams are equal in intensity since the action of the two polarizers is identical. The action of any polarizers can be considered that of resolution of incident light into two components at right angles lying respectively parallel to and at right angles with the axis of polarization. The act of polarization then consists in absorbing the one of these components at right angles to the axis of polarization. Light vectors 54 and 55 (indicated by 56) are resolved into two component parts 57 and 58 on entering polarizers 59 and 60, since, as the hatching shows, polarizers 59 and 60 have their axes oriented parallel respectively to 58 and 57. Polarizer 59 then absorbs component 57, and polarizer 60 absorbs 58. The emergent beams may then be shown by vectors 61 and 62, of which end views are shown. Since, vector 56 is at 45° with both 57 and 58, the resolved vectors 57 and 58 are equal in length, and hence the emergent beams, shown both by these vectors and vectors 61 and 62, are equal in intensity.

In application of this method to the taking apparatus of Fig. 1, polarizers 52 and 59 together replace polarizer 12, and polarizers 53 and 60 together replace polarizer 13. Thus, it may be seen that the emergent beams are equal in intensity no matter what the incident light, and the two images received from the polarizer sets have equal intensity throughout. Hence, there can be no "retinal rivalry" due to differences in the two pictures.

The picture produced on the film by the system described consists of alternate strips of different images, and in viewing some reproduction of this picture it is necessary to insure the absence of this pattern of strips. Most of the applications to be described involve viewing each picture as alternate strips of image and darkness, and therefore we provide means in these cases for making these strips so small that they are below the resolving power of the eye in size and the picture gives the impression of continuity. It is generally recognized that the eye cannot resolve two parallel lines whose center separation subtends an angle of less than 1' at the eye. To attain true stereoscopic effects it is necessary to view a stereoscopic picture so that it subtends at the eye the same solid angle that it did at the camera lens. Hence we calculate that the center to center distance of optimum strips must subtend 1' at the camera lens, and the width of the strips must subtend ½ this angle owing to alternation of strips. We therefore calculate that the optimum width of the strips is

.00014 × lens focal length. For example, for a lens of 2" focal length, this would imply strips .0003" wide, or 3300 strips to the inch, which has been found satisfactory. For lenses of short focal length, as in motion pictures, the linear filter must be made of extremely small strips of polarizer, and a special technique must be used in its construction, which we now describe. However, there are certain applications of our invention in which this fineness of construction is unnecessary which will be described later.

Referring to Fig. 11, **63** is a layer of synthetic resin such as a phenol-formaldehyde polymer, fastened with a cement **64** such as a solution of polystyrene in benzene or similar aromatic hydrocarbon solvent, to a layer of sheet polarizer **65** such as that formed of microscopic polarizing crystals oriented in a cellulose acetate matrix. The other surface of the polarizer is cemented to a further layer of phenol-formaldehyde polymer **66** with a cement **67** of an acrylate resin in an aliphatic hydrocarbon solvent. Fig. 12 shows a similar construction, **68** being a layer of phenol-formaldehyde polymer, **67** being the acrylate resin cement, **69** a layer of the cellulosic polarizer, **64** being the polystyrene cement, and 70 a further layer of phenolic polymer. Note that cement **67** is lowermost in Fig. 11, and uppermost in Fig. 12, while cement **64** is uppermost in Fig. 11 and lowermost in Fig. 12.

The sandwiches described are now ruled, as in Figs. 13 and 14, with grooves **71** and **72**. This may be performed in such a machine as is employed for the manufacture of half-tone screens or diffraction gratings. The grooves may be extremely close together, as such machines are particularly adapted to such rulings. The depth and angle of cut is so regulated that dimension **73** is slightly smaller than **74**, **75** slightly smaller than **76**, **77** slightly smaller than **78**, and **79** slightly smaller than 80; the difference in these dimensions being due to the thickness of cement **67** (Fig. 15).

The direction of the grooves is calculated so that when the ruled assemblies **81** and **82** are placed face to face, as in Fig. 15, the axis of polarization of the polarizer of one assembly **81** is at right angles with that of the polarizer of the other assembly **82**. The two assemblies, **81** and **82**, are now cemented together with the acrylate resin cement **67**, as in Fig. 15, and pressed until the polarizers **65** and **69** lie in the same plane. The whole construction is now placed in the aromatic hydrocarbon solvent used in cement **64**, and as the polystyrene cement **64** dissolves, the entire layer above this cement is carefully peeled away, leaving the assembly shown in Fig. 16. None of the other elements are affected by this solvent. If the base resins **66** and **68** are transparent, the existing assembly **83** of this figure may be employed as the linear filter. However, a more satisfactory and durable product is produced by the following operations. Assembly **83** is cemented to a transparent flat **84**, Fig. 17, which may be a transparent resin, glass or other suitable material, with the polystyrene cement **64**. The assembly **85** (Fig. 17) is then placed in the aliphatic hydrocarbon solvent used in the acrylate resin cement **67**, which dissolves the cement **67**, leaving the result shown in Fig. 18, since none of the other elements are soluble in such a solvent. In the diagrams proportions are exaggerated for clarity.

The above method of construction is to be considered as merely descriptive, as the principles involved, such as differential solubility, are widely applicable to this technique in general, and the case cited is not to be considered as limiting. Nor do we limit ourselves to the orientation and disposition of the polarizers and other elements as stated, nor to the nature of the polarizers as stated, or the shape and method of ruling of the grooves as stated. The interlined stereograms obtained by the camera system described may be presented as interlined stereographic positives in such a way as to produce true stereoscopic effects. One method of accomplishing this according to our invention is shown in Figs. 21 and 22, where **86** is an interlined stereographic positive in contact with which is placed a linear polarizing filter **87**, which has its polarizing strips registered with the picture strips of the stereogram (a top view of the assembly being shown in Fig. 22). The two sets of polarizer strips of the linear filter have their axes of polarization at right angles with each other and parallel respectively to the axes of polarization of the lenses **88** and **89** of spectacles worn by the spectator, whose eyes **90** and **91** are shown in Fig. 21. The left eye spectacle lens **89**, for example, may have its polarizing axis parallel to the polarizing axis of strips **90**, **92**, **94**, **96**, etc., of the linear filter, and these strips are registered with left eye picture strips **97**, **99**, **101**, **103**, etc. of the stereogram. In this example, right eye spectacle lens **88** would have its axis of polarization parallel with that of strips **91**, **93**, **95**, etc. of the linear filter, which are registered with right eye picture strips **98**, **100**, **102**, etc. of the stereogram. The left eye spectacle lens polarizing axis is thus parallel to that of the light from left eye picture strips and crossed with that of the light from right eye picture strips, and conversely for the right eye spectacle lens. Hence, each eye receives light only from those picture strips which contain the view which that eye should see, and since the two views are stereoscopic, stereoscopic effects are obtained. The stereogram **86** (Fig. 21) may be in any of several forms, that is, it may be a paper print, transparency, or an image projected on a screen.

It should be noted that if **86** is a non-depolarizing screen, the system may be easily applied to existing motion picture theaters and projectors, in that an interlined stereographic film may be projected onto such a screen from the viewing side through a large linear polarizing filter placed at the screen. The strips of the projected picture are registered with the filter strips as described, and the light from any picture strip passes through a polarizer strip and returns to the eyes through the same strip without being hindered.

In order to avoid the use of a large polarizing filter for large projected images, the stereogram may be projected as two diversely polarized images onto a non-depolarizing screen for viewing with polarizing spectacles as described above. This may be done by causing the light passing through the two sets of picture strips of the stereogram to be polarized in the projector, either before or after passing through these picture strips.

According to a modification of our invention, one method of accomplishing this result is shown in Fig. 23, in which **104** is a light source, **105** a linear polarizing filter in contact with the emulsion side of a stereographic film **106**, and **107** a lens imaging the filter and film on a non-depolarizing screen **108**. The strips of the filter **105** are registered with the picture strips of the film **106**, in the manner described above. Thus the picture at the screen consists of alternate strips of differently polarized image and each eye sees only those strips which record the image that eye is supposed to see.

In some cases shrinkage of the image-bearing material prevents registry of the filter strips and picture strips in the method just described. A further modification of our invention may be used to avoid this difficulty. In this case, an optical image of the linear filter may be substituted for the filter itself, and the size of the image may be varied until the strips of the filter fit the picture strips on the film. Illustrating this system, Fig. 24 shows a light source 109, a linear polarizing filter 110, a lens 111 imaging this filter on an interlined stereographic film 112, and another lens 113 imaging the film and filter image on a non-depolarizing screen 114. The filter image strips are registered with the picture strips in the manner described above, and since all the light in any filter strip image has come from the filter strip itself and is polarized along the axis of the filter strip, the light which passes through the picture strip registered with that filter image strip is similarly polarized. The net action is therefore identical with that just described in which the filter is actually in contact with the film.

A further modification may be made with essentially similar results by substituting an image of the film for the film itself, as shown in Fig. 25, where 115 is a light source, 116 a stereographic film, 117 a lens imaging the film on a linear filter 118, and 119 another lens imaging film image and filter on a non-depolarizing screen 120. In this case the light from each film strip passes through its image at the linear filter and hence through the filter strip with which the image is registered. The result is again the same as that in the systems described above.

In all these cases, some mechanical means may be provided for insuring automatic registration and fit of strips for any condition of the film, particularly in the case of motion picture films.

A further well-known modification can be applied to single positive interlined stereograms as produced by the taking method described in the first part of this specification. This is what is called parallax stereography, and consists, as shown in Fig. 26, in viewing an interlined stereogram, such as 121, which may be a paper print, transparency, or projected image, through a grating 122, composed of alternate transparent and opaque strips. The action is clearly shown in Fig. 26, the letters L and R standing respectively for left and right eyes, and left and right eye images on the stereogram. The grating is so constructed that each eye sees only its proper image strips and a stereoscopic effect is produced.

For some applications it is desirable to produce separate records of the two interlined views of the stereogram. This may be done by a special form of printing in which only one set of picture strips is transferred at a time to a positive film. An unexposed sensitive film may be placed in contact with the stereographic film, and the image received thereon by illuminating only those picture strips which record one of the views. That is, light is only allowed to fall on, say, the left-eye picture strips of the interlined stereographic film, and hence the sensitive film records alternately left-eye picture strips and blank strips. By shifting the illumination, the right eye strips may be recorded on another sensitive film. One modification of our invention contemplates the use of a linear polarizing filter, as described above, to provide the necessary "striped" illumination for the above purpose. We now describe various ways in which this may be accomplished.

Illustrating one such method, Fig. 27 shows a light source, 123, which sends light through a polarizer 124, a linear filter 125 and the base material of a stereographic film 126 onto the emulsion of that film. The strips of the linear filter 125 are registered directly above the picture strips of the film 126, as described above. In contact with the emulsion side of the film 126 is placed an unexposed sensitive film 127. If the polarizer 124 is now oriented so that its axis of polarization is at right angles with that of one set of strips of the linear filter 125, and hence parallel with that of the other set of strips, light will only be admitted through one set of filter strips. Hence, light will pass through only one set of picture strips of film 126, and only that one set of strips will record on sensitive film 127. In this manner, one view can be recorded, and by rotating the polarizer 124, the other set of picture strips can be illuminated and the second view recorded on another sensitive film. This method is only useful when the thickness of the base of film 126 is relatively small with respect to the width of the strips of linear filter 125, in order that the shadows of the strips whose axis is crossed with that of the polarizer 124 shall be sharp on the emulsion of film 126. In addition, film 126 is apt to shrink from any predetermined size, and any one linear filter would fit for only one degree of shrinkage. Hence, in further modifications of our invention, the same device mentioned under modifications for projection, that of substituting an optical image of the filter for the filter itself, may be employed. The size of the optical image of the filter may be changed to fit differently shrunk films.

Illustrating one such modification, see Fig. 28, in which 128 is a light source, 129 a polarizer, 130 a linear polarizing filter imaged by a lens 131 through the back of a stereographic film 132 onto the emulsion of this film, and 133 is an unexposed sensitive film in contact with the emulsion side of film 132. In the operation of this assembly, polarizer 129 is oriented so that "shadows" of one set of strips of linear filter 130 fall on the film 132, and these shadows are registered with the picture strips of the film as described above, and as a result, the picture strips not covered by shadows record on sensitive film 133. By rotating polarizer 129, either set of strips of the image of filter 130 may be turned into shadows, and hence either of the two interlined views may be extracted from film 132 and recorded on separate films. The described modification is directly applicable to still pictures or to stepwise printing of moving pictures, in which one frame is exposed at a time, but for continuous printing of moving pictures, a simpler method is shown in Fig. 29, where a slit 134 is placed in contact with filter 130. As shown in Fig. 30, the length of the slit should be at right angles to the length of the polarizer strips of the linear filter, and hence the slit image at 135 also has its length at right angles to picture strips of film 132. The two films are advanced past the slit image in the direction of the arrows, Figs. 29 and 30. In some cases, the slit may advantageously be placed at 135 near the film 132, instead of at the linear filter 130.

In motion picture applications of our invention, it is possible to eliminate much of the linear pattern which is apparent if any size of strip larger than the optimum determined by resolving power is used in making the original picture. Thus, it is possible to eliminate some of the delicacy of construction inherent in a process which must handle strips of a width of the order of .0003''. Illustrating the general effect produced by the technique to be described, Fig. 31 shows the successive pictures on a film containing a record of left eye images, and Fig. 32 shows a similar right eye film, while Fig. 33 shows the successive appearances of the projection screen as such films are simultaneously projected thereon. The letters L and R indicate left and right eye strips, respectively, while the hatched areas indicate those portions of the two films of Figs. 31 and 32 on which images are recorded. Thus, it may be seen that any strip 136 of the screen shows alternately left and right eye views and that, for any two successive pictures, the whole screen has been used for each of the two eye-views. One eye, say the left, sees each screen strip illuminated half the time by a part of the view, and dark the other half, thus receiving an impression of continuous illumination of each strip through persistence of vision.

Illustrating one method of producing films for accomplishing this result, Fig. 34 shows a simplified diagrammatic view of a taking apparatus such as that described in the first part of this specification, and illustrated in Fig. 1. Polarizers 12 and 13 of Fig. 1 are removed and for them is substituted an assembly 137 of which Fig. 35 is a front view. This assembly consists of sections of polarizer 138, 139, 140 and 141, which are lettered V and H for clarity to indicate that their axes of polarization are respectively vertical and horizontal. Strips in the linear filter 10 are also lettered V and H to indicate their axes of polarization and their proportions are also exaggerated for clarity. Means is provided for reciprocating polarizer assembly 137 in the direction of the arrows in timed relationship with the intermittent movement of the camera, preferably at half the speed of said movement; see connecting rod 144 and crank 145, as shown in Figures 34 and 35.

In the operation of this modification, for a given exposure, assembly 137 will have the position shown in Fig. 34 and reflector 2 will receive a vertically polarized image, while reflector 5 will receive a horizontally polarized image. Hence, behind the vertically polarized strips of linear filter 10 will be recorded the image from reflector 2, or left eye image, and behind the horizontally polarized strips will be recorded image from reflector 5, or right eye image. As the film is changed and the next exposure made, the assembly 137 moves to the other extreme, and the image of reflector 2, or left eye image, is now horizontally polarized and will record behind the strips of filter 10 whose axes are horizontal. Similarly, the right eye image is recorded behind the vertically polarized strips of the linear filter. For the next exposure, the system resumes the original relationship, and the process is continuously repeated. The film, therefore, contains a record such as shown in Fig. 33. The system for avoiding "retinal rivalry" between the stereoscopic views can be applied to the mechanism just described by employing the assembly 137 for the polarizers 59 and 60 of Fig. 10, and placing further polarizers with axes parallel to each other and at 45° with the horizontal in front of the assembly as indicated by polarizers 52 and 53 in Fig. 10, and by polarizers 142 and 143, Fig. 34. It should be noted that the relation of axes of polarization in the preceding description gives the desired result, but that no change in the result would be caused by rotating all the axes of polarization by the same amount in the same direction, except that the front polarizers of the system for avoiding "retinal rivalry" would suppress different fugitive polarization effects in the object.

If a film obtained by the modified taking process just described is to be projected directly as a single film, a modification of any of the processes shown in Figs. 23, 24 and 25, and described previously, may be employed. For a given exposure, the systems of Figs. 23, 24 and 25 may have the necessary relationships to insure each eye seeing its correct picture. However, as the picture is changed, as from the first frame of Fig. 33 to the second, each set of picture strips will be polarized so that the wrong eye will see them, since, say, a left-eye strip will fall behind a right-eye polarizer, and so forth. To avoid this difficulty, a piece of bi-refringent material which is of the proper nature and dimensions to rotate the axis of polarization of the light by 90°, such as a piece of Cellophane .001'' thick, may be inserted into the optical train somewhere between the linear polarizing filter and the spectator's eyes. This material is inserted and removed for alternate pictures by some mechanical means attached to the projector, so that it corrects the polarization for the wrong case stated above and each eye sees only its proper view.

In a further modification of our invention, separate records of the two interlined views, such as shown in Figs. 31 and 32, may be obtained from a stereographic film such as shown in Fig. 33. This may be accomplished by passing such a film through one of the printer systems shown in Figs. 28 and 29 with the same mechanism arranged so that the polarizers of those systems may be rotated through 90° between each two picture frames. Thus, the "shadows" of the linear filter strips will move sideways by one strip width for succeeding frames, and a record of the type shown in Figs. 31 and 32 will be recorded on the sensitive films.

Having thus described our invention, what we claim and desire to secure by Letters Patent is:

A device for producing interlined stereoscopic pictures, a given strip of which pictures contains strip elements of a plurality of views from different viewpoints in successive picture spaces, comprising an optical system adapted to producing superposed stereoscopic images, means for plane-polarizing said images at right angles to each other, and means for alternately changing these axes of polarization, a sensitive surface for recording said images and a linear polarizing filter in contact with said sensitive surface on the side toward the said optical system, so arranged that a part of said filter cross-polarizes one image alternately, and another part alternately cross-polarizes another image, said alternation being in timed relationship with the changing of successive pictures.

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