PARALLAX PANORAMAGRAMS MADE WITH A LARGE DIAMETER LENS

By Herbert E. Ives

Parallax panoramagrams—pictures showing stereoscopic relief through a wide range of distances and angles of observation—have heretofore been made by any one of several kinds of camera, in which the object, the photographic lens, the opaque line grating and the sensitive plate are given a relative motion during the progress of the exposure. Details of these cameras, and of the characteristics of the pictures made by them may be obtained by reference to an earlier publication.[1] In all cases, whether separation of the grating and plate is depended on to cause the development of the panoramic strips by parallax, or a relative motion is given to plate and grating, a common characteristic is the motion of the lens with respect to the object, whereby different points of view are successively projected upon the grating and plate. This note is for the purpose of describing a method in which the moving lens is dispensed with, making possible a parallax panoramagram camera containing no moving parts whatever.

The essential feature of this method is the use of a photographic lens of very large diameter—where by "very large" is meant large compared to the distance between the eyes.[2] The lens should, in the ideal case, subtend as large an angle from the object as does the moving lens heretofore used, at its extreme positions. The relative functions of the moving lens and the large diameter lens are shown in Fig. 1, *a* and *b*. It is clear that each element of the large lens forms an image, similar to the image from the moving lens when occupying the position of the element. The image is however formed by rays which intercept the plane of the grating and plate from the opposite side of the normal that they do when projected from the moving lens. An important consequence of this inversion will be discussed shortly. Disregarding it for the present the significant thing to note is that by a single exposure from the large lens an infinity of strip images may be produced on a sensitive plate behind and slightly separated from an

[1] Journal Optical Society & R.S.I., *17*, 6, p. 435; 1928.

[2] The idea of using a large lens for this purpose, is, I find, disclosed in a French patent to Bessière (#590, 853, 1925). Inasmuch however as Bessière's procedure would fail to give satisfactory relief pictures, as pointed out below, I have felt warranted in describing in detail my own analysis of the problem which has been experimentally confirmed.

opaque line grating. One way of grasping the action of the large diameter lens is to remember that, as has long been known in photography, such a lens has the property of "looking around" a solid object. In ordinary photography however there is no means provided for properly utilizing this property; it results chiefly in poor definition outside the focal plane, or poor depth of focus. When, however, an opaque line grating having wide opaque and narrow clear spaces (say in the ratio of 10:1) is placed between the lens and the plate the rays striking the plate at various angles are separated from each other, and can then be picked up on viewing through a similar grating, properly placed, when the eye is in the same position with respect to the image that the acting (unobstructed) lens element was to the object.

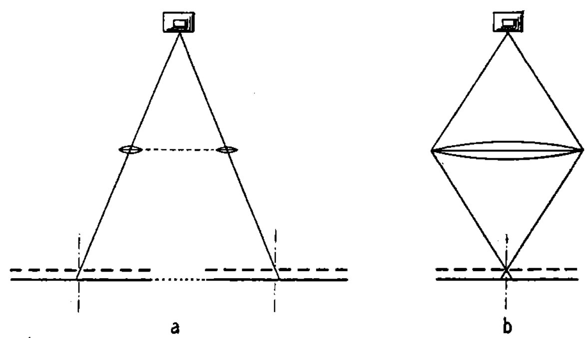

FIG. 1. *Two methods of making parallax panoramagram negatives. (a) A moving lens exposing a sensitive plate behind a grating slightly separated from it; lens, grating and plate being maintained in line during the exposure. (b) A large stationary lens, projecting an image on a stationary plate through a grating slightly separated from it.*

A contact print made from a negative according to the scheme shown in Fig. 1b appears on microscopic examination like a regular parallax panoramagram—a series of parallel strips each varying in intensity from side to side. If, however, this is placed behind an opaque line grating exactly like that used in taking, and separated by the same distance, it does not yield a stereoscopic but a *pseudoscopic* image. This is due to the inversion of direction of the incident light beams above noted. As is well known, in making stereoscopic pictures by a twin lens camera, the print must be cut in two, and the pictures transposed, or, putting it another way, each picture must be separately rotated about an axis perpendicular to its plane. Inverting prisms are sometimes used in stereoscopic apparatus to obviate this transposition of the image. Now in the structured image as formed in Fig. 1*b* the multiple constitutent images are related to each other as the twin images from a stereoscopic camera before cutting apart, and there is no way, comparable to the use of inverting prisms, by which the images may be properly oriented. The recovery of a stereoscopic from this pseudoscopic image becomes, therefore, a crucial problem.

I have found it possible to overcome this occurrence of pseudoscopic where stereoscopic vision is desired by utilizing a fact which has doubtless been noticed frequently by critical observers of parallax stereograms and panoramagrams. This is that if the stereogram or panoramagram is looked at *from the back,* i.e., if the grating is viewed through the structured picture, the stereoscopic picture is transformed into a pseudoscopic one. The application to the pictures made by means of a large diameter lens is immediate. *Let these be mounted for viewing with the grating on the side away from the eye* and then the relief will be correct. The sections shown in Fig. 2 *a* and *b* show the paths of the light beams to the two eyes in each case.

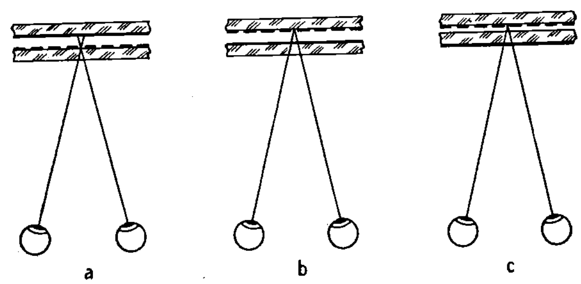

FIG. 2. *Different methods of viewing a parallax panoramagram positive transparency. (a) The picture is viewed through the grating. (b) The grating is viewed through the picture. (c) The grating is viewed through the picture, but the picture is inverted by placing the sensitive emulsion nearest the eye.*

There are two complications which must be taken care of before this scheme of observation can be employed with success, both readily grasped if the paths of representative beams from the large lens are followed, as in Fig. 3. Here R and L are two beams corresponding to the right and left eyes. They form infinitesimal linear elements r and l of a constituent picture strip after passing through a clear space O_1 in the grating G_1 which is separated from the sensitive plate P_1 by the distance d (here shown enormously exaggerated for clearness). Now let us make a contact print from P_1 upon a second sensitive plate P_2, and imagine P_1 removed so that the sensitive surface of P_2 occupies the position originally occupied by the negative emulsion layer. Also let us place a new grating G_2 at the same distance *behind* the positive photographic layer that G_1 was in front of the negative layer. Next suppose the two eyes be placed so as to observe the picture and grating from the approximate position of the lens, but on the other side of the optic axis from the rays originally striking the plate, as shown at R' and L'. If we now trace the rays from R' and L' to the grating space O_2 (the grating G_1 being removed) we see that, to a close approximation (but see below) the ray from the right eye passes through r, and that from the left eye through l. The complete image is moreover correctly disposed right and left, by virtue of being viewed from the lens side. In short, each eye is receiving the proper view in the proper direction for stereoscopic relief. The image is, however, wrong side up. This defect is quite simply remedied by turning the positive over about a horizontal axis in its own plane, so that its emulsion side is toward the eye instead of its glass side,[3] as shown in Fig. 2c.

This necessity for observing from the film side or its equivalent in order to place the picture right away around constitutes one of the complications above noted. The other is also illustrated in the figure. It is that *the view grating G_2 must be larger (of courser spacing) than the taking grating*, in the ratio of the distance of O_2 from the vertical axis to the distance of O_1 from the vertical axis. This enlargement of the viewing grating depends, of course, on the separation which is chosen between the grating and the sensitive plate, which in turn is governed by the size of the lens L. The separation should be such that the strips of photographic action behind the clear grating spaces juxtapose so as to completely utilize the whole area of the plate. If (Fig. 4) we designate the distance between the large lens and the taking grating by F, the magnification of spacing required for the viewing grating is seen to be, by reference to Fig. 3,

$$M = \frac{F+2d}{F}$$

[3] When this is done the relief picture has an exposed film surface, which requires an extra covering glass to prevent injury. The same optical result may be attained while avoiding this inconvenience by inserting the negative plate backward and exposing through the glass. In either of these procedures there is the theoretical objection that a refracting layer is introduced at one stage, not present in the other, whereby the more oblique light beams are distorted. An optically ideal solution is to use a 45° mirror in taking or viewing. (It is indifferent whether this inverts right and left or up and down.) In practice however this inversion may obten be omitted since the mirror image obtained without inverting is usually quite satisfactory.

If we designate the diameter of the large lens by D, and the distance between line centers in the taking grating by s, we have, when the panoramic strips are exactly juxtaposed, (assuming their width, p, to be practically identical with s)

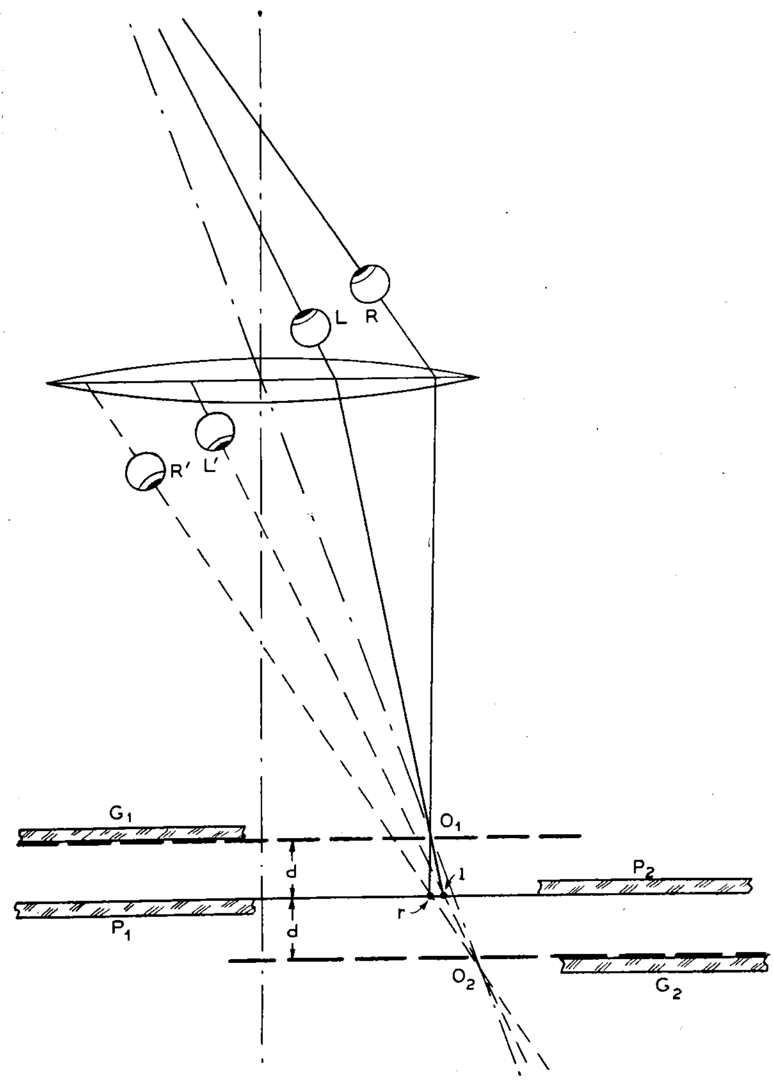

FIG. 3. *Paths of light beams in taking and viewing parallax panoramagrams made with a large diameter lens.*

$$\frac{d}{s}=\frac{F}{D}$$

Substituting this value of d, we get for the magnification,

$$M=1+\frac{2s}{D}$$

which shows that the spacing needed in the viewing grating is independent of any changes in the working distance of the large lens, such as would be caused by focussing for near or distant objects; provided the separation d has been properly adjusted for such changes. The numerical value of M in practice is quite small. For instance, with a 12 inch diameter lens, and a grating of 50 lines to the inch we have,

$$M=1+\frac{2/50}{12}=1.003.$$

This amounts to one lens grating line every six inches across the grating, but remembering that without this change of spacing there would be interference bands across the picture every six inches, the necessity for this grating magnification is evident.

In the discussion of the paths of the light beams in connection with Figure 3, it was stated that, to a close approximation, both the taking and viewing right and left eye beams passed through the same points r and l of the panoramic image strip. This is substantially the case for small angles of incidence, but progressive deviation from this condition occurs as the angle of observation increases. A more complete analysis is shown in Figure 5. Here the symbols are as before, except that rays from both sides of the axial ray are drawn, the additional rays being designated by script letters. In this analysis there is introduced the normal nn' to the axial ray, which is inclined to the plane of the sensitive surface. It is clear that the points of intersections of taking and viewing beams inclined at the same angles to the axial ray occur on the normal nn', and not on the sensitive surface as assumed in Figure 3. Depicting the intersections of the taking rays with the sensitive surface by the solid dots, and those of the viewing rays by small circles, we see that in general all the viewing rays intersect the surface too close to the vertical axis (of Figure 3). What is required to correct for this is a slight shift of the grating space O_2, still further from the vertical axis than is called for by the simple formula above developed. This correction, which is roughly proportional to the cosine of the angle between nn' and the sensitive surface, and so is of importance only for

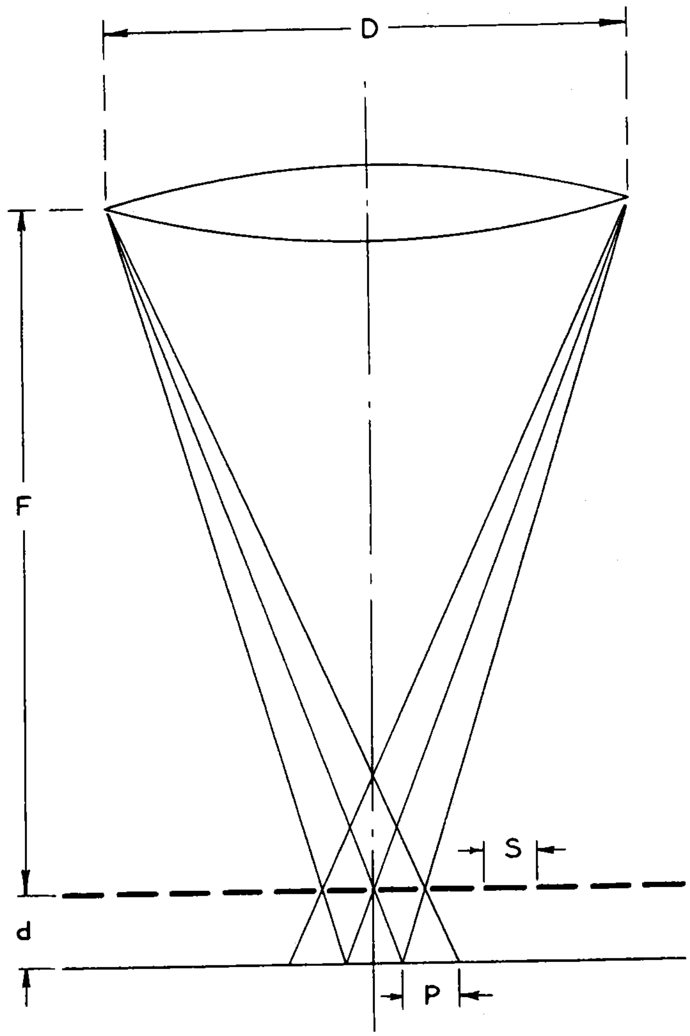

FIG. 4. *Determination of separation of grating and plate as function of grating spacing, lens diameter and focal distance.*

large angles, also varies with the angle of observation. A diameter of taking lens and size of picture can theoretically be attained such that this second order correction will fail. The slightly greater magnification of the viewing grating called for over the amount given by the formula above developed is one that can only be determined empirically.

In order to test this method of making relief pictures, I have made use of a 24 inch focus $f/2$ lens which was available from another prob-

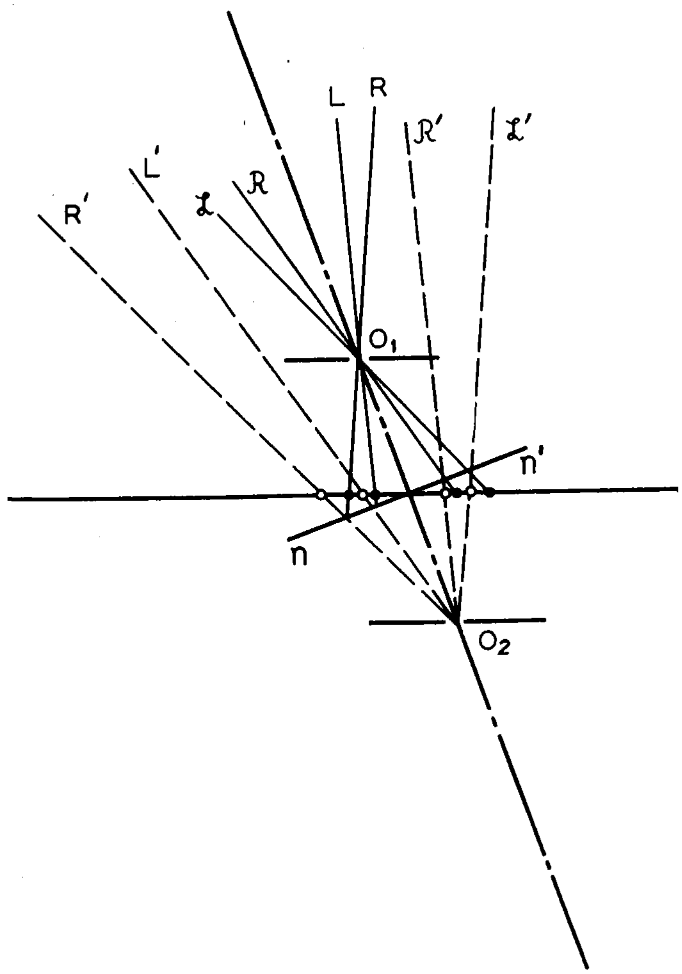

FIG. 5. *Exact analysis of paths of taking and viewing beams.*

lem. This was furnished with a special diaphragm consisting of a horizontal slot 1 inch high, so that the exposures from all parts of the lens, considered as a series of horizontal elements, would be alike. Exposures were made on objects to be reproduced in approximately natural size on $10'' \times 12''$ plates, through a grating of fifty lines to the inch. Under these conditions the 12 inch diameter lens was approximately four feet from the plate, and a separation of grating and plate of one-twelfth inch was suitable.

When we wish to view the contact transparency prints made from these negatives, it is necessary, as discussed above, to have gratings of slightly larger line spacing than the taking gratings. The spacing called for—less than $\frac{1}{2}$ per cent greater than in the taking grating for the practical case quoted—is not of the sort that is readily obtained on any ordinary dividing engine. Photographic copying by means of a lens is practically out of the question, for the photographically copied grating is an almost ideal test object for showing up the defects of the best lenses, by the curved interference patterns produced when it is laid over the original. A projection printing process using no lens has however been found which is entirely satisfactory. The procedure is similar to contact printing except that the printing grating and the sensitive plate are separated by a small distance instead of being in contact. The method is illustrated in Figure 6. Here G_C is a complementary grating, (transparent spaces ten times the width of the opaque) such as would ordinarily be used for making viewing gratings by contact printing. The sensitive plate G_E is placed behind this at a distance $2d$, that is, *twice* the separation between grating and plate used in making the negative, (or a little greater if the lens and picture are of such size that the additional magnification discussed in connection with Figure 5 is needed). At L is a point light source, at a distance F, equal to the distance between large lens and grating in taking the negative. It will be clear that the divergence of the light beams in the space between grating and plate provides the necessary magnification. (It is of course not necessary to adhere to the F and d used in taking, as long as the ratio of d to F is kept constant). Although the viewing gratings thus made differ from the taking by only about two lines across their whole width, this difference is absolutely necessary, as is shown by the occurrence of moiré patterning if a taking grating is tried for viewing purposes.[4]

Pictures made by this method exhibit very satisfactory relief. The angle through which the relief holds is, of course, limited by the size of

[4] Bessière specifies that the viewing grating shall be *identical* with the taking grating. He also states, erroneously, that it is indifferent whether the viewing grating is used in front of or behind the picture. In a later patent (618, 880, 1927) he corrects this latter statement, but says that when the picture is placed between the grating and the eye, as it must be to give correct relief, the picture is indistinct. In consequence, he abandons the large lens in favor of a series of small lenses each furnished with an inverting prism.

the lens used in taking. With the pictures made in this study the width of the zone within which the head must be placed cannot exceed 12 inches at four feet viewing distance. When the eyes move outside

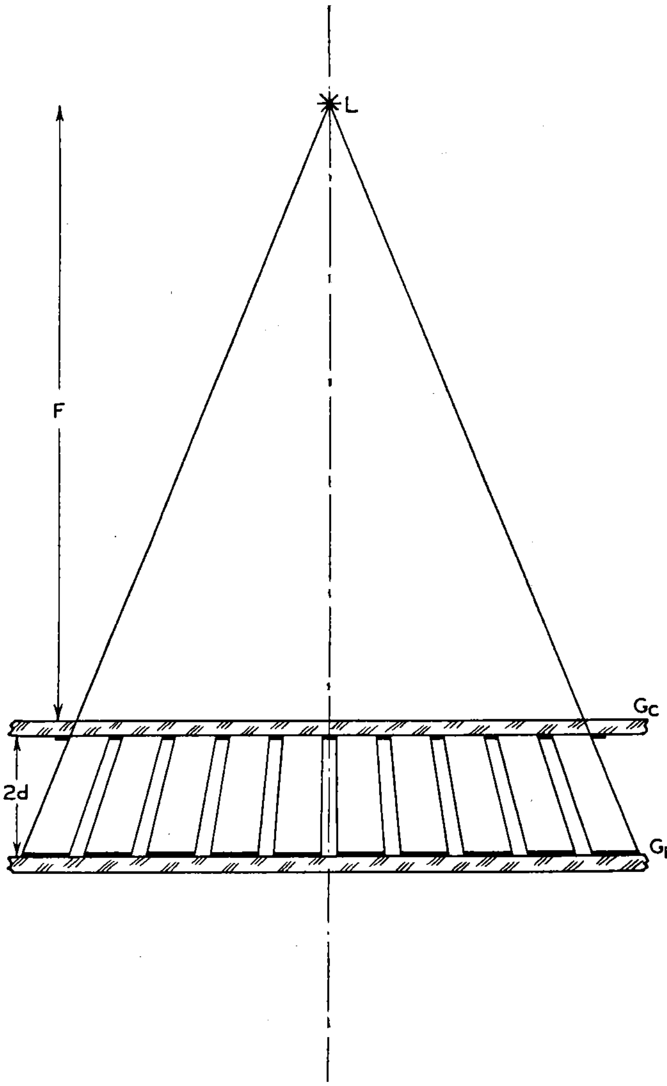

FIG. 6. *Method of making enlarged viewing gratings by the use of a point source of light and separation of master complementary grating and sensitive plate.*

this zone the picture repeats itself, after passing through a narrow zone of confusion, where vision is either monocular or pseudoscopic, depending on the width of the dead space between strips. In a sense, these pictures are more like lateral series of parallax stereograms, for which the position of the eyes is not so critical as with ordinary stereograms, than true panoramagrams, which latter would present only one relief picture visible through a wide angle. The use of a still larger lens of the same focal length would, of course, make the similarity to a true panoramagram closer. Since the lens consists merely of a horizontal strip section it is not unreasonable to believe that the technical problem of designing a suitable one of as high an aperture as F/1 would present no insuperable difficulties. It is possible that a composite refracting unit similar to the Fresnel lighthouse lens could be worked out to provide an even larger aperture. A limitation to useful increase in lens aperture will, however, be met ultimately, due to the non-coincidence of the taking and viewing beams illustrated in Fig. 5.

A great advantage of this method of relief picture making is the simplicity of the apparatus, and of its manipulation. A valuable feature is that as all of the elementary exposures are made simultaneously the total exposure time is greatly shortened. With the apparatus described above, the necessary exposure in strong artificial light is about one second. Partially offsetting these advantages is the fact that the method is less flexible than the moving lens scheme, in that it does not lend itself to the deliberate production of exaggerated relief in controlled amount which is often desirable for producing striking effects.

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