AUTOSTEREOSCOPY AND INTEGRAL PHOTOGRAPHY BY PROFESSOR LIPPMAN'S METHOD

P.P Sokolov, 1911.
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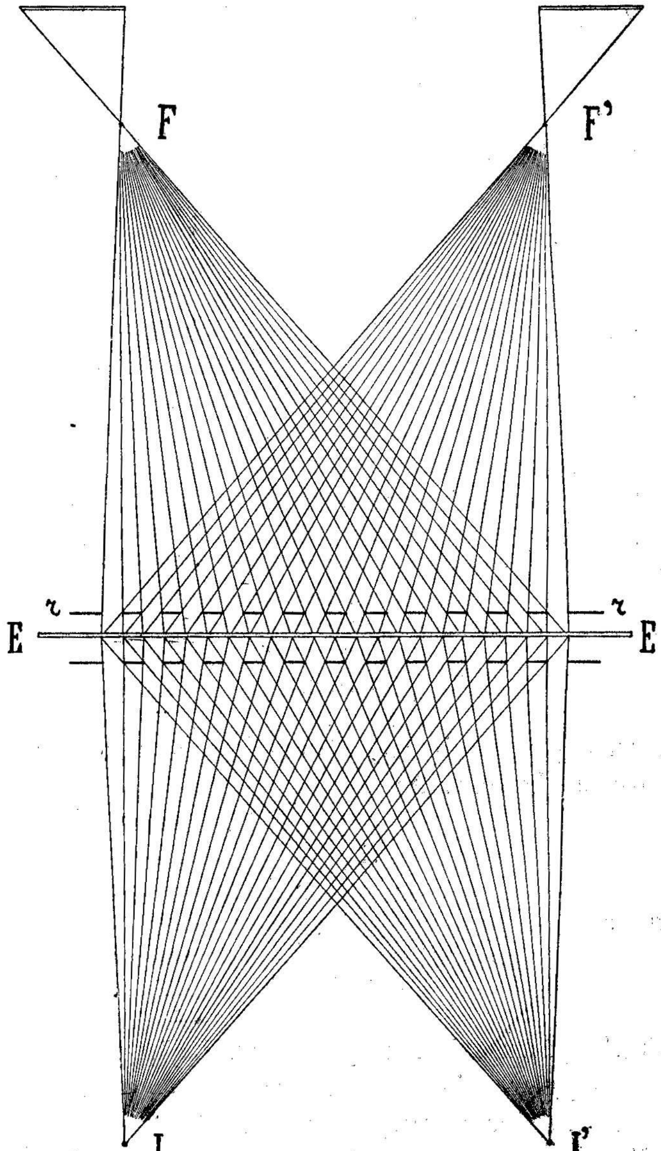
Stereoscopic photography has been winning more and more favor with both amateur photographers and the scientific community. We will not discuss what a powerful impression stereoscopic photographs produce upon close examination thanks to the illusion of relief and reality that they create. From a practical point of view, we will only say that no photograph produced by conventional means using a single lens is capable of conveying such a clear idea of the shape and size of the object of interest. Moreover, the fine details which escape attention when one examines a conventional photograph stand out clearly and cannot go unnoticed in a stereoscopic photograph. It follows from the above what an important role stereoscopic photography plays in science and technology.



Фиг. 1.

The sole disadvantage of stereoscopic photography is that when examining stereoscopic images one needs a special apparatus, called a stereoscope. As is widely known, the purpose of such apparatuses is to separate for each eye its respective image and to help the eyes to blend two planar images into a single spatial one. We will not describe here these apparatuses which are well-known to everyone, and of which exist a great variety, including reflective stereoscopes as well as more common refractive ones.

The inconvenience which comes from the necessity of always having a stereoscope at hand has led to numerous attempts to eliminate the need for it. In 1906 L'Estanave proposed the "lattice method"[1)] for this purpose.

[1)] Comptes Rendus d.s. de l'Ac.d.sciences. T. CXLIII p. 644. T. CXLVI p. 319

The method is as follows. Let us place a lattice rr with equal light and dark spacing in front of a semi-transparent screen and use two lanterns F and F’ to project onto the screen the images which correspond to the right and left eyes, respectively. The distance between the lenses should be about 7 cm [Editor’s note: 7 cm refers to the average interpupillary distance]. Having passed through the lattice, the rays will produce striped images of both the right-hand and the left-hand photographs, perpendicular to the plane of the drawing in Fig.1. By changing the distance from the lattice to the screen we can locate a position in which the stripes will not overlap, but will follow one another in the appropriate sequence. Fig. 1 shows the direction of the rays for the case when the distance between the lattice and the screen is chosen correctly. This correct distance is determined by the following relationship (Fig. 2):

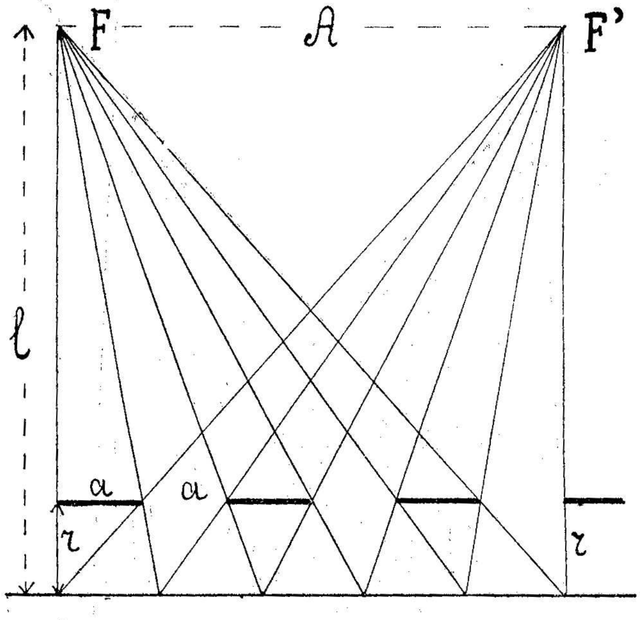


Рис. 2.

$$\frac{A}{a}=\frac{l}{r},$$

From which we get:

$$r=\frac{al}{A},$$

Where A is the distance between F and F’,

l is the distance between these points and the screen,

a is the mesh width of the lattice.

If we now place an identical lattice on the other side of the screen symmetrically to the first one, and assume that the image is observed from points J and J’, which correspond to the left and right eyes, respectively, we will see with the right eye only the stripes of the image that correspond to the right eye, while with the left eye we will see only those that correspond to the left eye. Perceptually, both images will blend into one, and if the lattice is fine enough (mesh width=1/5 mm), the results will be fairly good.

It is clear that if we use a photosensitive plate instead of the screen, we can obtain a striped slide which can only be examined through the lattice. Moreover, the lattice can be photographically deposited on the other side of the slide plate. The thickness of the glass plate should be calculated using the above relationship.

Furthermore by placing the lattice horizontally, while simultaneously positioning the lantern lenses vertically (i.e. taking a side view of the drawing in Fig. 1), and by replacing the stereoscopic photographs by two other different photographs, we will obtain a slide with two different images.

When examining the same photograph from points J and J’ we will see two different images. Of course, these images will be ordinary, planar ones, but they both can be made stereoscopic if we use a square grid instead of the striped lattice.

The inconvenience of L’Estanave’s method is twofold: first, half of the surface of every image is lost because of the lattice, and second, correct identification of the lattice position requires particular skill.

Another method of producing autostereoscopic photographs[1)] proposed by the author is to corrugate a light-sensitive surface. To derive the contour of this surface, let us discard the lattice used in L’Estanave’s method and only leave the rays which represent lines of sight. The above rays intersecting near the surface, outline a number of teeth (Fig 3), whose right-hand slopes can only be seen by the right eye, and whose left-hand slopes can only be seen by the left eye. Therefore, if we corrugate the light-sensitive paper in this way and manage to print the right image on the right-hand side and the left image on the left-hand side, both images will blend into a single one upon examination, and we will create the illusion of relief.

1) Вѣстникъ фотографiи. 1908 г. стр. 315.

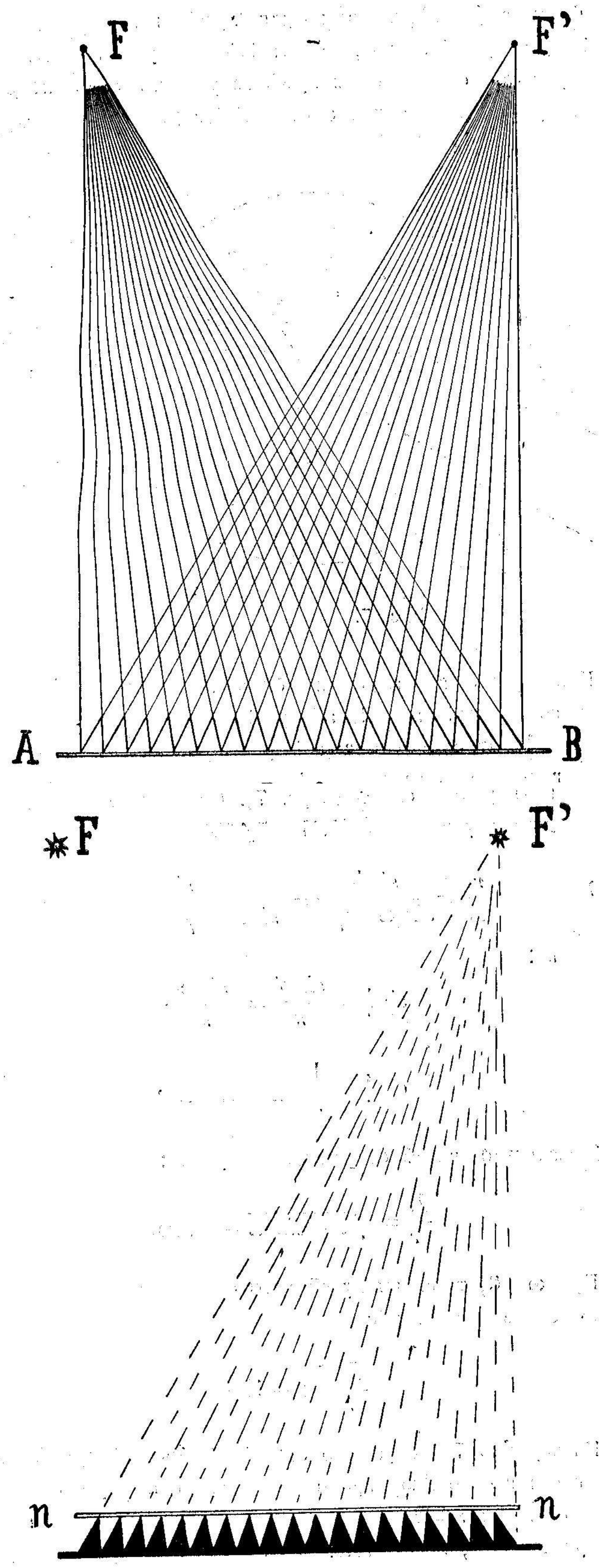


Рис. 4.

The negative can be printed on such a surface in the following way. Let us superimpose (Fig.4) the negative on the corrugated surface, and illuminate it with the rays emanating from the point in space relative to which the corrugation was performed and where the right eye is supposed to be located while viewing the photograph. One can see from the figure that the whole surface of the negative will be projected onto the right-hand sides of the teeth. Let us do the same with the left negative but illuminate it with the rays emanating from the point at a distance of 7 cm from the right one.

It is noteworthy that the tooth calculated for the distance providing the best vision for normal eyes, (i.e. for 20 cm), is very high and thin, and given the necessary great number per unit length, a surface of this kind is difficult to manufacture.

Even though the above two methods create the illusion of relief without resorting to bulky auxiliary equipment, they still do not produce the same effect as that achieved by means of the stereoscope because of the apparently reduced angular dimensions of the photographed objects.

In 1908 Professor Lippman [1] proposed a method to prepare slides which not only meet the stringent requirements of stereoscopy, but act as a window.

Let us imagine that we are approaching a window to admire the view from it. As we come closer, the panorama in view expands, while the perspective and the angular dimensions of objects change. After coming close to the window we can see the panorama of the surrounding area encompassing almost 180˚. A stereoscopic slide should meet these auxiliary requirements in order to act as a window. The theory of such a slide is as follows:

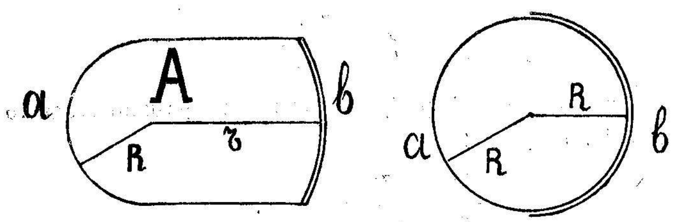


Рис. 5.

[1]) Comptes Reudus. T. CXLVI p. 446.

Let us take a glass cylinder A (Fig. 5) with spherical bases a and b. The curvature of these bases can be calculated in such a way that one of them, e.g. a, plays the part of the lens whose main focal surface is the opposite spherical surface b. If the cylinder is very small (1/4 mm in diameter), all the objects, even those close to it (e.g. at a distance of 1 meter) will be encompassed by the main focal surface. By coating this surface with a light-sensitive emulsion we can produce a microscopic photograph by means of the lenses stationed in front of the cylinder.

The theory of refraction of the central rays near the spherical surface gives the following relationship (Fig. 6):

$$\frac{1}{f_1}+\frac{n}{f_2}=\frac{n-1}{R}$$

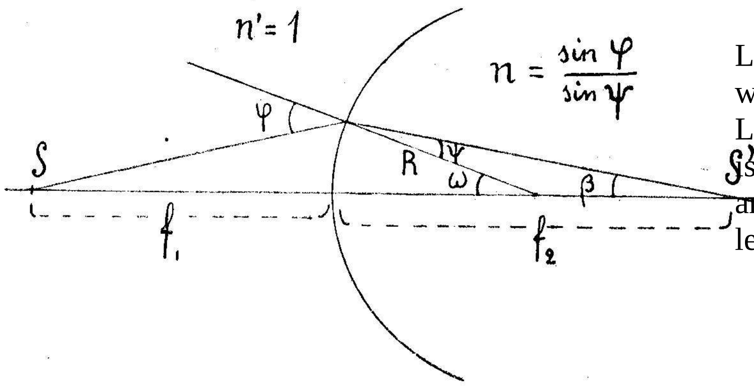


Рис. 6.

In our case f2 =∞, hence:

$$f_2=\frac{Rn}{n-1}.$$

Having constructed the ratio of the front and back base radii, we will obtain the following:

$$\frac{R}{r}=\frac{R}{f_2-R}=n-1.$$

This is the relationship Lippman presented in his paper. The refraction factor should be chosen for violet rays which are the most actinic.

If the refraction factor is equal to 2, we will obtain

$$r=R,$$

It means that a sphere should be used instead of the cylinder, which is much more technically feasible.

Formula (1) is only true for the central rays. However, the aberration effect is pronounced for the rays, incident at a certain angle to the main optical axis, even if the lens surface is diaphragmed.

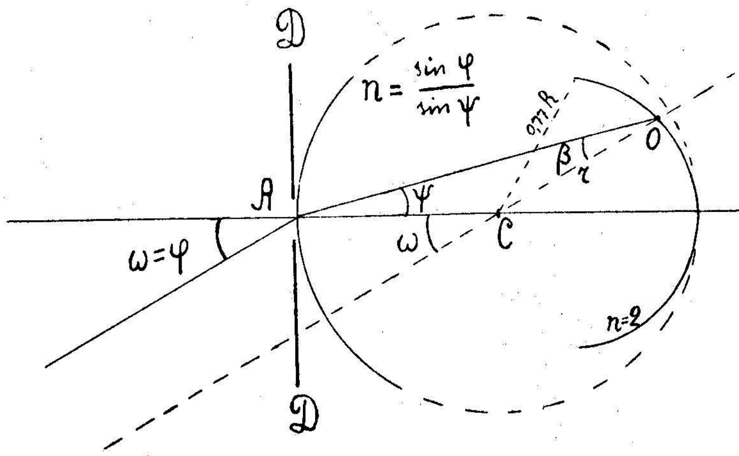


Рис. 7.

Let us now see what the surface should be like when the aberration effect is taken into account. Let us assume that a narrow beam of parallel rays is incident onto a diaphragmed lens surface at an angle of ω = φ (Fig. 7). It is evident that r=f (ω); let us find this dependence. From ΔAOC we have:

$$\frac{r}{R}=\frac{\sin\psi}{\sin(\omega-\psi)}=\frac{\sin\psi}{\sin\omega\cos\psi-\cos\omega\sin\psi};$$

$$\sin\psi=\frac{\sin\varphi}{n}=\frac{\sin\omega}{n},$$

$$\cos\psi=\frac{1}{n}\sqrt{n^2-\sin^2\omega},$$

Hence, after reducing the expression we will obtain the following:

$$\frac{R}{r}=\sqrt{n^2-\sin^2\omega}-\cos\omega,$$

For ω =0, that is for the central rays, we obtain the above relationship

$$\frac{R}{r}=n-1.$$

Fig. 7 shows the cross-section of the main focal surface produced by the plane passing through the main optical axis if n=2. If ω = 60˚, r = 0.77.R.

For simplicity, we will replace the cylinders with spheres. We will take a large number of such small spheres, place them on a flat surface and join them to each other in some way. We will coat one side of this integral plate made up of spheres with a light-sensitive emulsion and try to photograph something with the help of this plate. It is clear that one does not need a camera for this type of photography; to place the plate at some distance from the object being photographed would suffice. Let us take only one radiant point for simplicity (Fig. 8).

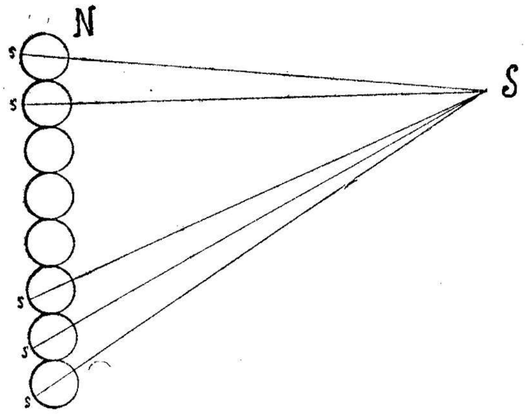


Рис. 8.

Every sphere will produce a microscopic image of this point, and these minute images will be encompassed by the main spherical surface of each sphere, because due to the small size of the spheres the distance between the radiant point and the spheres can be regarded to be infinitely large. It follows from the laws of optics that if, conversely, the rear, emulsion-covered side of the plate is illuminated, the images of the point will send beams of parallel rays from each sphere into space in the same direction relative to each ball, in which these same beams entered the spheres. Apparently, the number of such beams will be equal to the number of the spheres in the plate.

All these fairly narrow beams should intersect in some point in space, namely, in the same place and at the same distance from the plate as location of the radiant point when the photograph was taken.

To sum up, the point in which the rays emanating from the plate intersect will be the negative image of the photographed point. To produce a slide, let us place an identical integral plate made up of minute spheres at a particular distance in front of the negative illuminated from the back (Fig. 9).

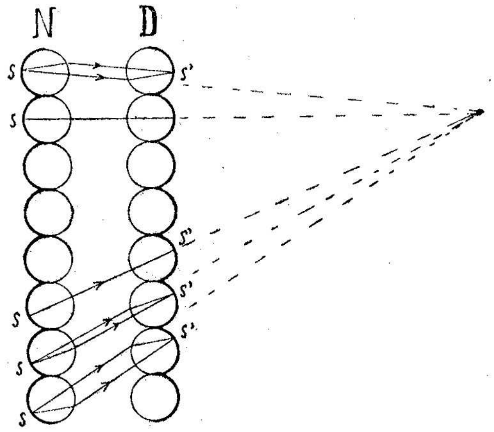


Рис. 9.

Beams of parallel rays emanating from the spheres of the negative will be incident onto this slide plate. When these ray beams, apparently converging in the negative, are incident onto the balls of the positive plate, they will produce positive images of the photographed point in the focal surface of the latter.

If we develop the slide photographically and then illuminate its emulsion-covered side, we will, as previously, obtain beams of parallel rays emanating from it, but these will be divergent, rather than convergent (Fig. 10).

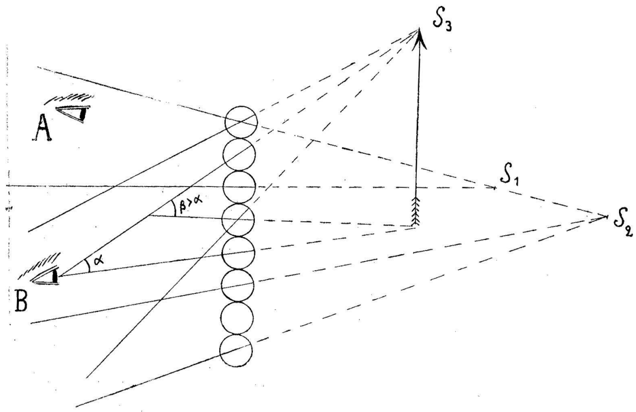


Рис. 10.

Seen by the eye of the viewer, the beams of parallel rays will produce a visible reconstructed image of the photographed point in the space behind the slide. The same is true for any point in space. It can be clearly seen that as the viewing position changes, so does the perspective (Fig.

10). Thus, for example, of the three photographed points, s_1 s_2 s_3, we will not see point s_3 if we view it from point A, whereas one can see all the three points from point B. Because the right and the left eyes will have different perspective, we will get an impression of relief very similar to the one we get in reality. Finally, the angular dimension of the photographed objects will change with the distance from the viewing point, which is shown by the arrow in Fig.10. The numerical value of the angular dimension will be the same as it is in reality.

This flat integrated surface composed of spheres can encompass a 120˚ panorama. Meanwhile, a 360˚ panorama can be fixed on an integral cylindrical plate coated with emulsion from the inside, while a spherical plate can even accommodate all surrounding space.

A surface like this is similar to the visual apparatus anatomy of certain insects.

Professor Lippman very aptly called his method “integral photography”, because the resulting integral image is the sum of individual microscopic images.

As far as the practical realization of this brilliant idea is concerned, we must admit that manufacturing such minute cylinders with a precise pre-set curvature encounters vast technical problems and is not yet feasible.

To prove the validity of the theory the author used the pinhole method to photograph a number of radiant points (electric bulbs).

To produce such a picture, we used a fiber plate 3mm thick and 15X20 cm in dimensions. 1,200 small equally-spaced cone-shaped holes were drilled throughout its surface, except at the margins. (Fig. 11-A).

These holes act as very small cameras in which minute openings at the cone apexes serve as lenses.

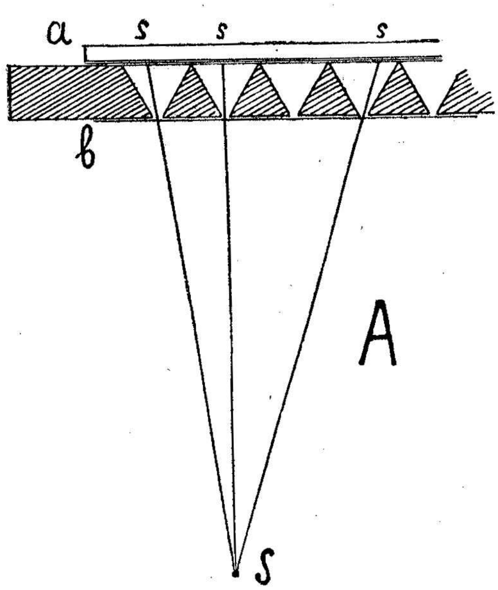


Рис. 11—А.

To provide maximum accuracy and uniformity, these holes were also drilled in a separate copper plate which was then superimposed onto the fiber plate from side b; an ordinary photographic plate coated with emulsion is placed onto side a before the exposure, with the emulsion-covered side in close contact with the holes.

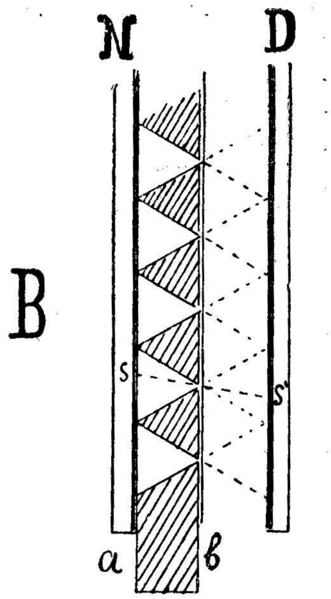


Рис. 11—В.

The direction of the rays is the same as it is in the previous example. The slide was prepared by placing a second plate on the other side of the same lattice. This other plate is symmetrical with the first one and is at a distance of 3 mm from the pinhole openings. For this arrangement the dimensions of certain photographs produced on the slides will be quite consistent with those on the negative (Fig. 11-B).

However, it turns out that by using pinhole cameras one can view the negative directly without producing a slide if the light first passes through the openings. If we follow the direction of the rays in Fig. 12, we will easily see that the negative image of the point behind the plate is in point A.

Viewing the same negative from the opposite side, i.e. from the side of the openings, we will obtain the following.

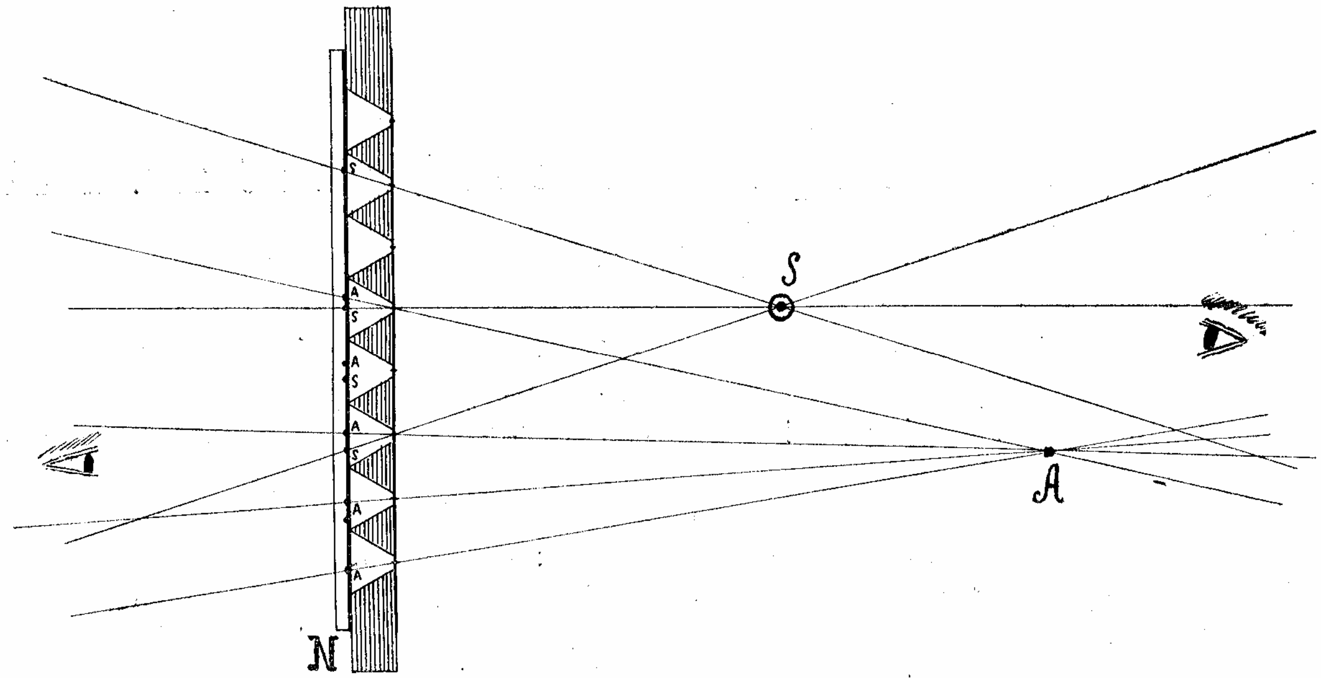


Рис. 12.

Assuming that we move from an infinite distance closer to the negative, which is illuminated from behind by a powerful light source (the negative can be easily transformed into a slide by chemical means), we will find ourselves in the space of the rays emanating from the negative and intersecting in those points of space where the radiant points were stationed previously, relative to the negative. Therefore, if stationed in front of the points in which the rays intersect, we will be able to see them in the space in front of us. If we approach one of these points, its angular dimension will increase and reach its maximum when the position of the eye coincides with that of the point.

The same thing happens when one views Lippman's negative after illuminating its emulsion-covered side.

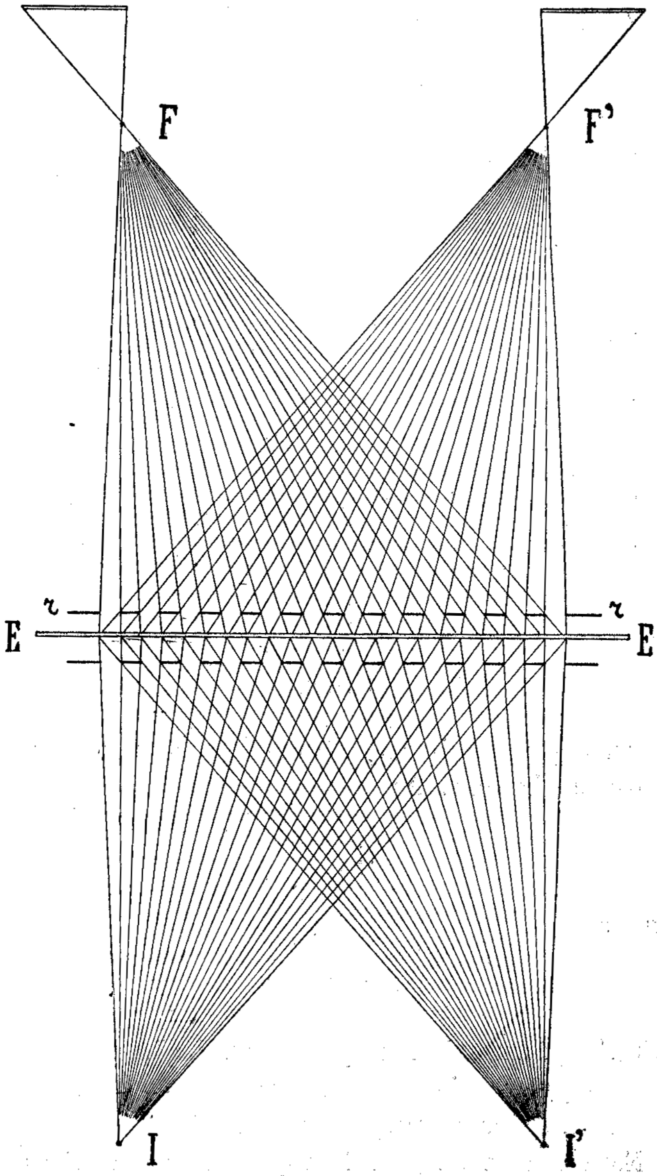
Автостереоскопія и интегральная фотографія по пр. Липману.

П. П. Соколовъ.

Стереоскопическая фотографія съ каждымъ годомъ все болѣе и болѣе завоевываетъ къ себѣ симпатію, какъ со стороны фотографовъ-любителей, такъ и людей науки. Не станемъ говорить о томъ громадномъ впечатлѣніи, которое благодаря иллюзіи рельефа и дѣйствительности остается послѣ разсматриванія стереоскопическихъ снимковъ. Съ практической точки зрѣнія скажемъ, что никакой снимокъ, полученный обыкновеннымъ способомъ съ однимъ объективомъ, не можетъ дать такое ясное понятіе о формѣ и размѣрахъ снятаго предмета, какъ снимокъ стереоскопическій. Кромѣ того, всѣ мелкія подробности, ускользающія отъ вниманія въ обыкновенномъ снимкѣ, выступаютъ рельефно и не могутъ быть незамѣченными при стереоскопическомъ способѣ. Отсюда ясно, какое огромное значеніе долженъ имѣть стереоскопическій методъ фотографированія въ приложеніи къ техникѣ и наукѣ.

Единственнымъ недостаткомъ стереоскопическаго способа является необходимость имѣть при разсматриваніи снимка особый аппаратъ, называемый стереоскопомъ. Цѣль этихъ аппаратовъ, какъ извѣстно, отдѣлить для каждаго глаза соотвѣтственный снимокъ и помочь глазамъ слить два плоскихъ снимка въ одинъ—пространственный. Мы не будемъ описывать эти, всѣмъ хорошо извѣстные аппараты, которыхъ существуетъ очень много и бываютъ или зеркальные, или, болѣе распространенные, состоящіе изъ оптическихъ стеколъ.

Неудобство постоянной надобности имѣть стереоскопъ вызвало попытки освободиться отъ этого прибора и вотъ въ 1906 году L'Estanave предложилъ для этой цѣли «способъ рѣшетки» [1]). Методъ его



Фиг. 1.

[1]) Comptes Rendus d. s. de l'Ac. d. sciences. T. CXLIII p. 644. T. CXLVI p. 319.