No. 835,648.

PATENTED NOV. 13, 1906.

R. STRAUBEL.

REFLECTOR.

APPLICATION FILED MAR. 13, 1906.

2 SHEETS—SHEET 1.

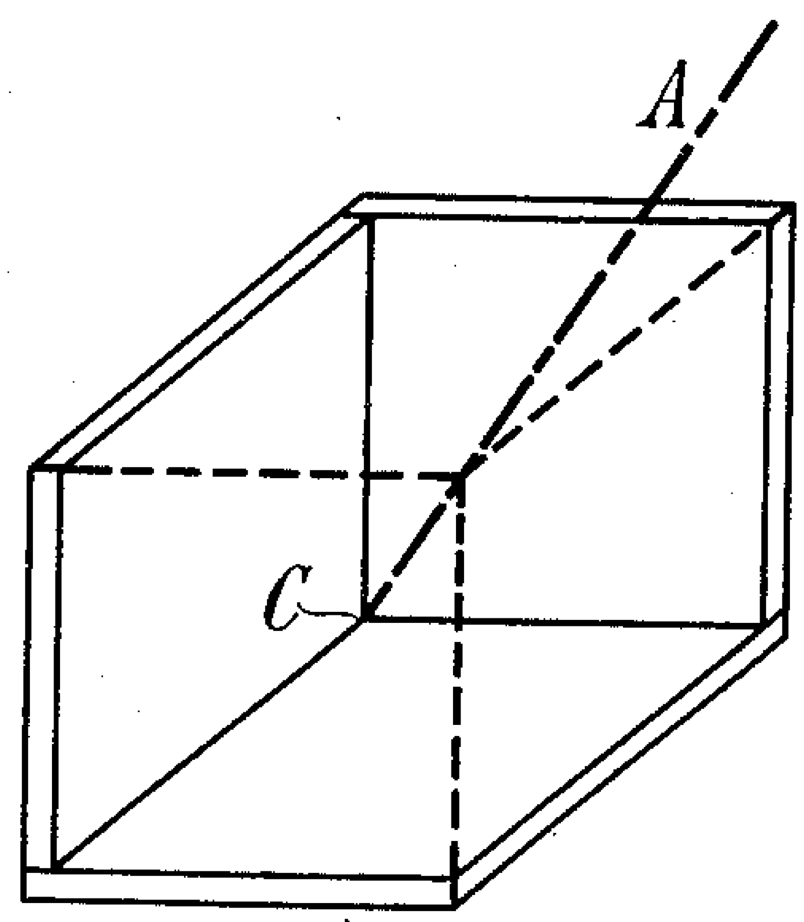

Fig. 1

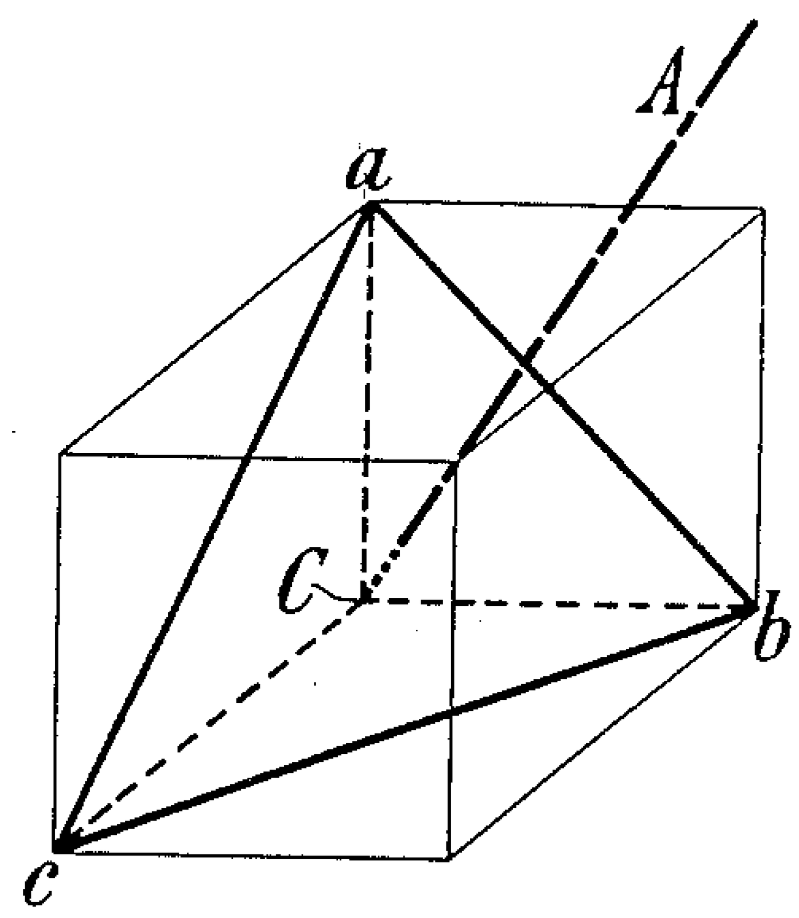

Fig. 2

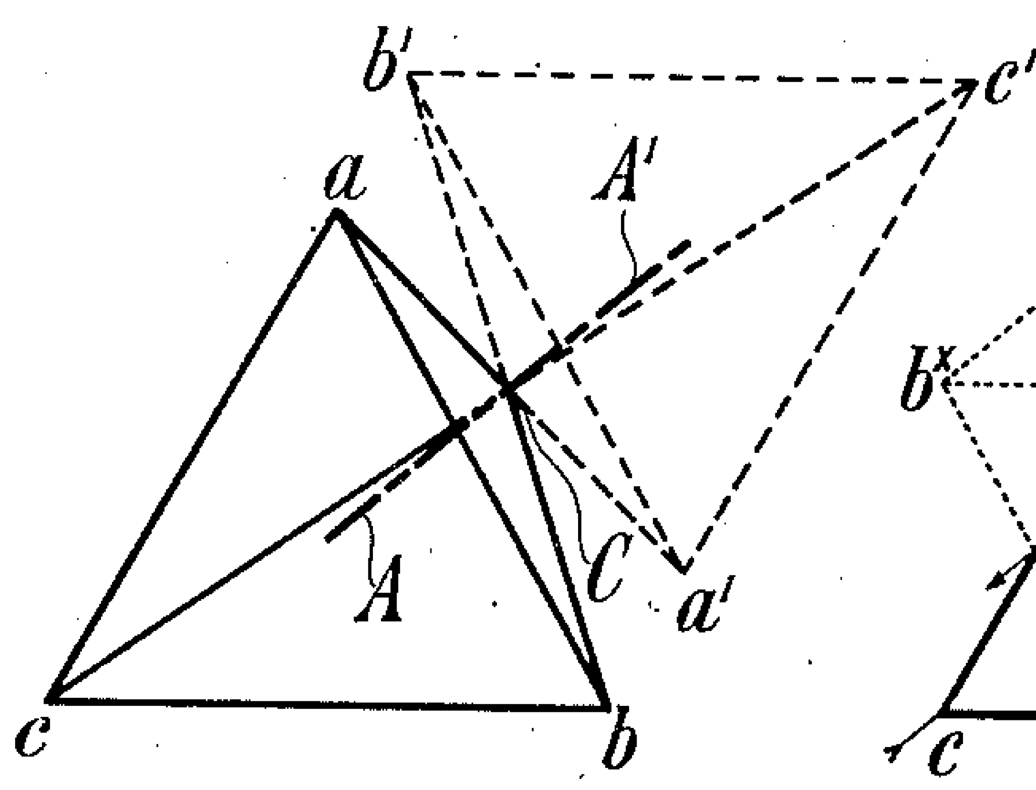

Fig. 3

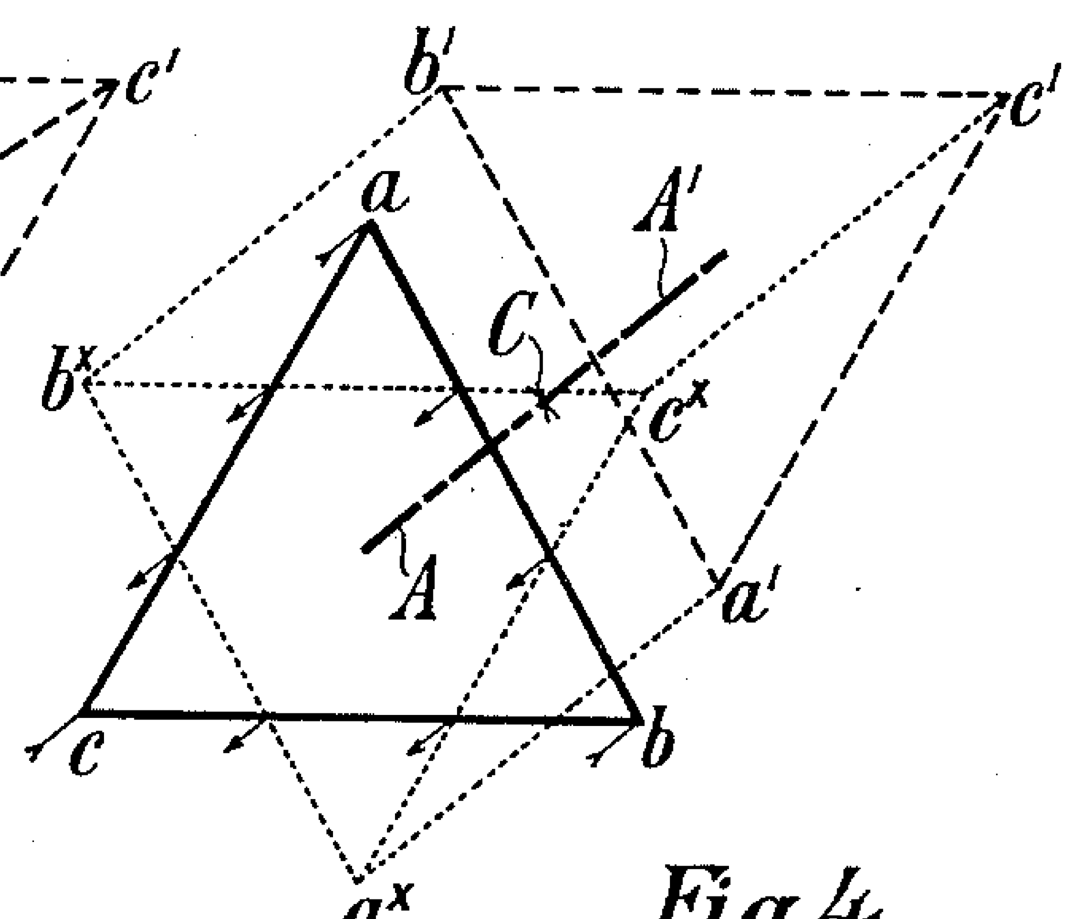

Fig. 4

Witnesses

Paul Krüger

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2 SHEETS—SHEET 2.

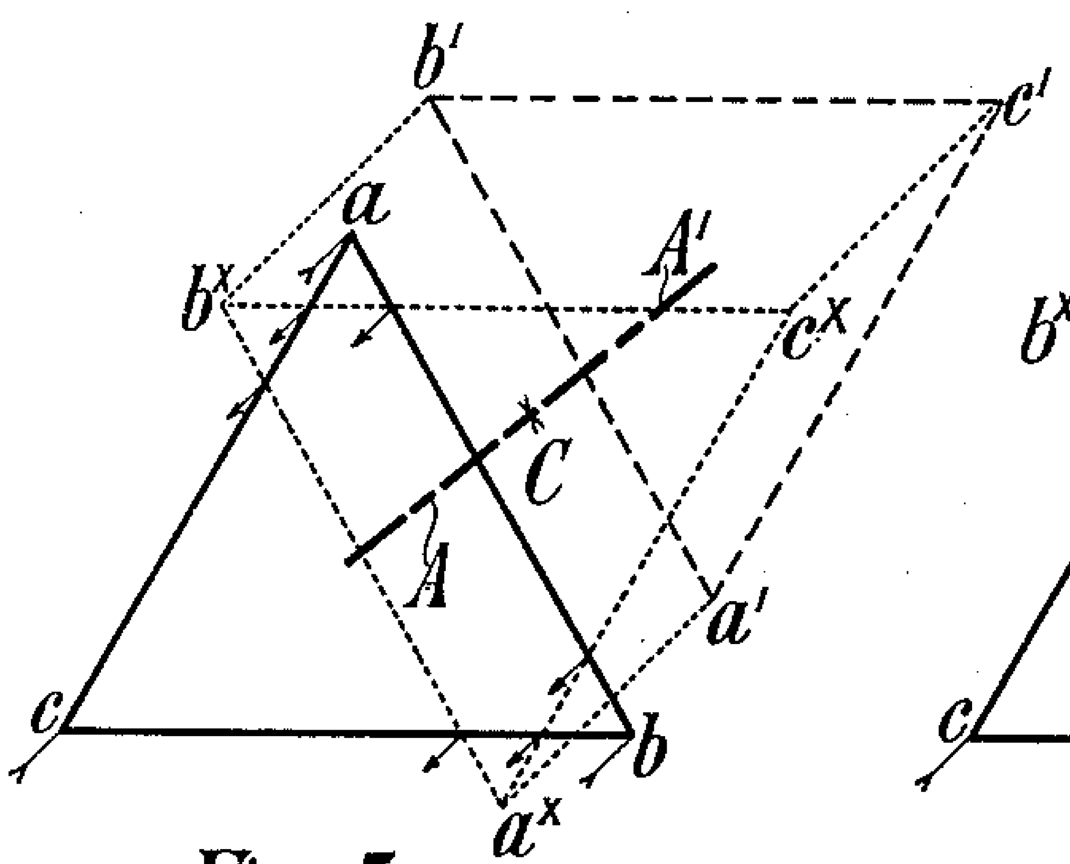

Fig. 5.

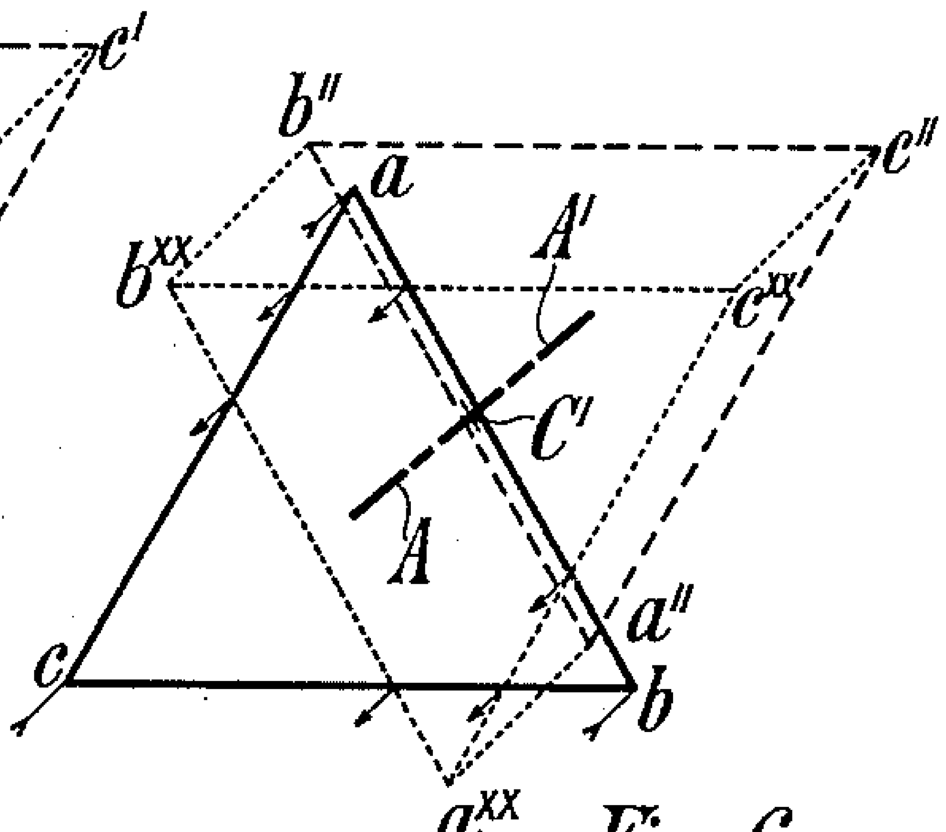

Fig. 6

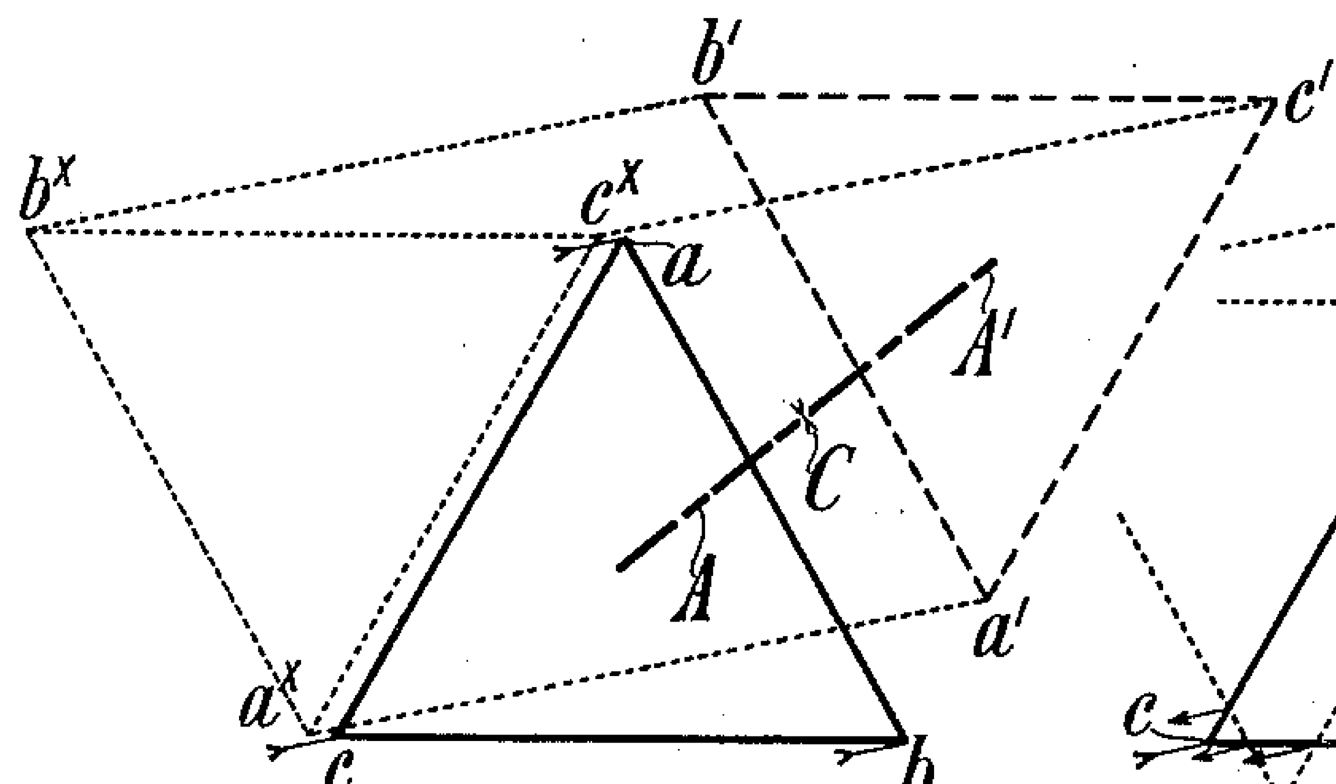

Fig. 7

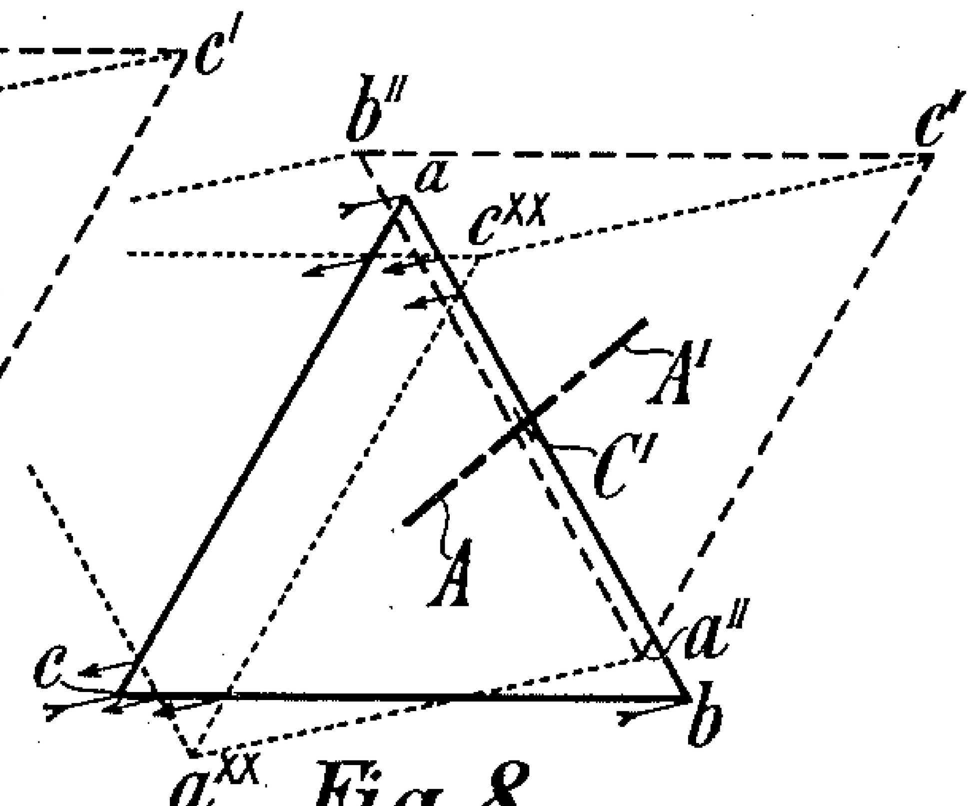

Fig. 8

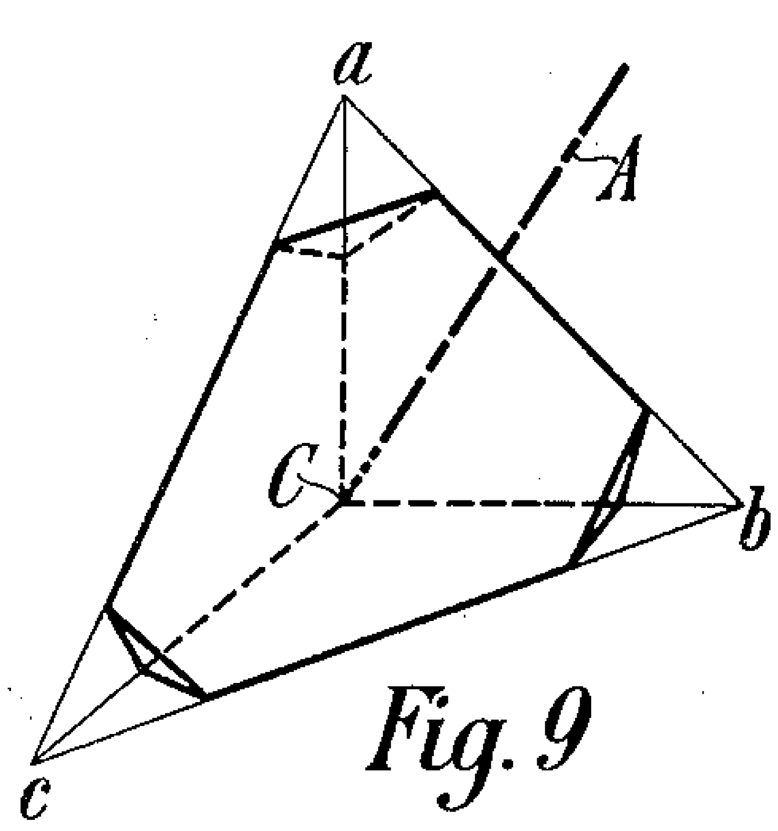

Fig. 9

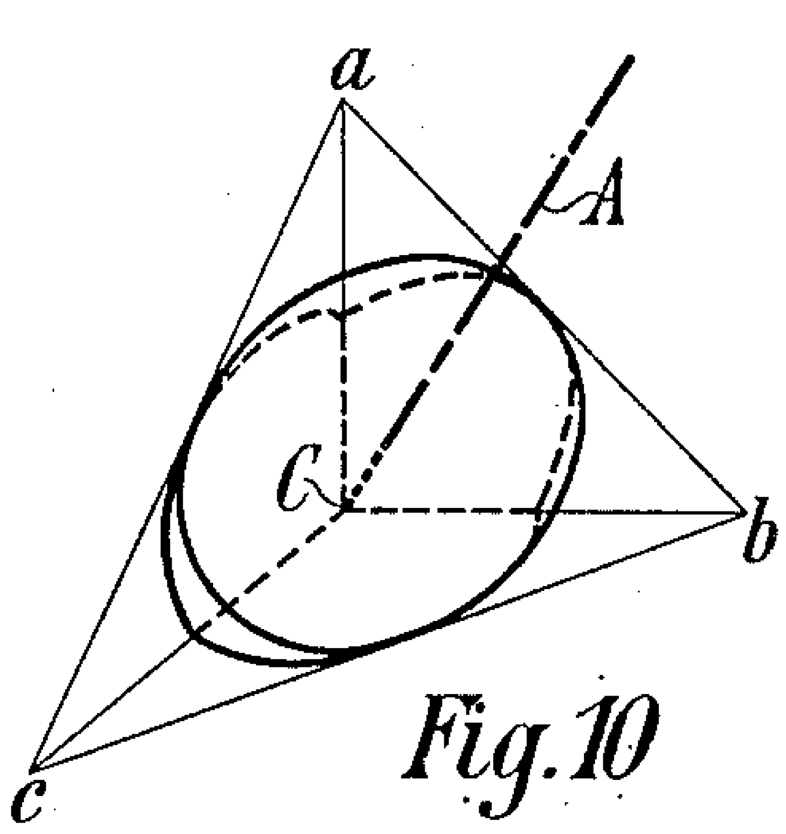

Fig. 10

Witnesses.

Paul Krüger

Fritz Sander

Inventor:

Rudolf Straubel

UNITED STATES PATENT OFFICE.

RUDOLF STRAUBEL, OF JENA, GERMANY, ASSIGNOR TO THE FIRM OF CARL ZEISS, OF JENA, GERMANY.

REFLECTOR.

No. 835,648. Specification of Letters Patent. Patented Nov. 13, 1906.

Application filed March 13, 1906. Serial No. 305,874.

To all whom it may concern:

Be it known that I, RUDOLF STRAUBEL, doctor of philosophy, a citizen of the German Empire, residing at Carl-Zeissstrasse, Jena, in the Grand Duchy of Saxe-Weimar, Germany, have invented a new and useful Reflector, of which the following is a specification.

The invention consists in the improvement of a reflector system described by Beck in the 1887 volume of the *Zeitschrift für Instrumentenkunde*, pp. 385–9, and designated by him "Tripelspiegel," (triple reflector.) The object of the invention is to lessen the loss of rays peculiar to this reflector and to amplify its scope of action without modification of the reflector system proper. The triple reflector consists of three plane-mirrors placed in such mutual relation one to another that the three lines of intersection of the reflecting-planes are not parallel, but intersect each other in one point—the center of the reflector.

A special form of the triple reflector named by Beck "Zentralspiegel" (central reflector) will best serve to elucidate the invention. In this special form not only the effects of the subject-matter of the invention resolve themselves into the simplest, but also the triple reflector has in this form and in those approximating to it its greatest importance. The reflecting-surfaces of the central reflector are all three at right angles to each other. It forms, consequently, when made of contiguous square mirrors, the half of a hollow cube. The diagonal of the cube drawn through the center of the reflector is designated as the "axis" of the reflector. The property to which the central reflector owes its name consists in that on one side the object and on the other side the reflected image of it (more correctly, the six reflected images of it being coincident) have a situation which is symmetrical about the center of the reflector. From this it follows that in general each entering ray which impinges upon one of three reflecting-surfaces with any one inclination to the axis of the reflector and in any orientation to the reflector leaves the reflector in a parallel but opposite direction and in a plane determined by the entering ray and the center of the reflector and so far removed from this point that the central point lies midway between the entering and the exit ray. This is at all times the case when the ray comes to be reflected from all three reflecting-surfaces in succession.

While Beck dealt with the applicability of the central reflector for the determination of certain errors of measurement in astronomy, Grubb has recently, in the English specification No. 21,856/03, called attention to the fact that the central reflector presents other important possibilities when it is used to reflect light of a distant source toward the place or in the proximity of the source of light. In some of these new applications abundant use is made of that one property of the central reflector according to which the angle which the axis of the reflector forms with the direction of entrance of the rays of light can vary from zero to one of considerable size—thirty-five degrees and more, according to the orientation of the reflector to the direction of entrance—without the light failing to return toward its source. According to the degree the rays deviate from the direction parallel to the axis of the reflector the image produced loses in intensity, because a part of the rays no longer meet the third successive reflecting-surface, and in certain orientations and with a large inclination to the axis of the reflector a slighter part does not even meet the second reflecting-surface. This loss is therefore the maximum when the direction of entrance of the rays has reached the limiting angle—thirty-five degrees or more—of the return of the rays, as determined by the orientation for the time being of the reflector. To lessen such loss—that is, to acquire more rays than formerly—and at the same time to widen the limiting angles—that is to say, to create the return of the rays within a range of angle hitherto unavailable—is the twofold aim of the means now proposed. This means, which forms the subject-matter of the invention, consists in filling up the hollow space of the reflector with a transparent body which is optically more dense than the air hitherto in contact with the reflecting-surfaces. The filling is to be limited by a plane or approximately plane entrance and exit surface which is appropriately placed at right angles to the axis of the reflector. Thus originates, when the added optical medium is a solid body—for instance, glass—a tetrahedral prism, which itself can be the carrier of the reflecting-film, so that the hitherto reflecting-bodies are dispensed with. If the film also be dispensed with, so that total reflection occurs at the glass surfaces limited by air, the range of angle of the return of the rays by this means is of course decreased; but yet, nevertheless, this range of angle can be obtained greater than in the central reflector of former construction, because the efficiency of the filling increases as the refractive power of this filling increases and because very highly refractive kinds of glass are procurable. For large central reflectors fluids can be advantageously used as filling. There is thus substituted for the glass prism a body known as the "fluid prism," having thin glass walls. It is also possible, however, to use the free fluid surface as the plane entrance and exit surface of the filling by directing the aperture of the reflector upward. A plane-mirror arranged in an inclined position over the central reflector then throws the rays which ordinarily come from the distant source of light in an approximately horizontal direction toward the central reflector.

In the annexed drawings all figures are perspective views of the same kind.

Figure 1 represents a central reflector. Fig. 2 represents a tetrahedron. Fig. 3 represents a central reflector and its image. Figs. 4 to 8 are diagrams illustrating the loss of light peculiar to the central reflector and the tetrahedron. Figs. 9 and 10 represent tetrahedra, the acute solid angles of which are truncated.

In the central reflector hitherto constructed, as represented in Fig. 1, three plano-parallel plates carry the reflecting-surfaces, which when complemented by three other surfaces (indicated by dotted lines) would form a cube. The diagonal A of the cube proceeding from the center C of the reflector is the axis of the reflector.

If the tetrahedral glass prism be constructed within a like cube, as shown in Fig. 2, its entrance and exit surface or aperture is an equilateral triangle *a b c*.

The central reflector shown in Fig. 3 has the same equilateral triangular aperture *a b c* as the tetrahedron in Fig. 2, but represented as parallel to the plane of drawings. The dotted lines represent the image of the reflector projected by the reflector itself. The symmetrical position of the aperture *a b c* on the one side and of the image *a′ b′ c′* of the aperture on the other about the center C is easily recognized. It will be also seen that the portion of the axis A of the reflector from the center C to the plane of the aperture *a b c*, together with its reflected image A′, is inserted.

The aperture *a b c* in Fig. 4, with its image *a′ b′ c′*, as well as the axis A, with its image A′, have been transferred from Fig. 3. Should a pencil of parallel rays enter into the central reflector parallel to the axis A and completely fill the aperture *a b c*, it must take the form of a triangular prism the edges of which lie, as indicated by the arrow-feathers, at the points *a*, *b*, and *c*. As previously alluded to, the position of the emerging rays appertaining to the entering edge rays and directed parallel to them is given by the center of the reflector lying midway between any two correlated rays. The directions of the reflected edge rays pass, consequently, through the reflected images *a′*, *b′*, and *c′* of the points *a*, *b*, and *c*. In the figure the imaginary reflected prismatic pencil between the image of the aperture *a′ b′ c′* and the plane of aperture is indicated by fine dotted lines. As is evident, the edge rays $a'\ a^\times\ b'\ b^\times$, and $c'\ c^\times$ and partial pencils triangular in section neighboring them cut the plane of aperture outside the aperture *a b c*. This means that they should receive the third reflection from parts of the reflector which have no real existence—that they fall out from the pencil reflected back again. The edges of the real reflected pencil are indicated by arrow-heads. The cross-section of this pencil is a regular hexagon.

Fig. 5 only differs from the foregoing by the pencil admitted through the aperture *a b c*, forming an angle with the axis A. The six arrow-heads in this case indicate the limits of a real reflected pencil, the cross-section of which is an irregular hexagon and smaller than the pencil parallel to the axis, as in Fig. 4, because with inclined incidence still more rays go beyond the limits of the third reflecting-surface.

In Fig. 6 the effect of the subject-matter of the invention is illustrated as applied in the case according to Fig. 5. If it be imagined that in Fig. 3 the space between the three mirrors and the plane of aperture is filled by a prism of glass of ordinary power of refraction—for instance, of a refractive index 1.5—the layer of glass limited by the plane surface of aperture projects an image C′ of the center C of the reflector on the axis A, which image is only $\frac{1}{1.5} = \frac{2}{3}$ so far removed from this surface as the point C itself. From the same reason the image *a′ b′ c′* of the aperture will be produced at two-thirds of the former distance from the plane of aperture—that is, in the position *a″ b″ c″*, Fig. 6—so that this new image of the aperture and the aperture *a b c* are also symmetrical about the image C′ of the center C of the reflector. Consequent upon the closer proximity between the aperture and its image the trace $a^{\times\times}\ b^{\times\times}\ c^{\times\times}$ of the imaginary reflected prism of rays in the plane of aperture has another situation relative to the aperture *a b c* than the trace $a^\times\ b^\times\ c^\times$ in Fig. 5. A considerable portion of the rays hitherto lost have been rendered available.

With Fig. 7 the description returns once more to the central reflector not filled with glass. This figure represents one of the cases where the prism of rays admitted through the aperture *a b c* forms an angle with the axis A, which for the given orientation of the central reflector falls a little beyond the limiting angle of the return of the rays. The cross-section of the real reflected prism of rays had already become zero with a lesser angle of orientation.

The influence of the subject-matter of the invention in the case of Fig. 7 is manifested in Fig. 8. The arrow-heads show what cross-section the real reflected prism of rays has which owes its existence to the employment of a glass tetrahedron.

In Fig. 9 the glass tetrahedron, according to Fig. 2, is again represented. The aperture of Fig. 2 is reduced, however, by plane sections parallel to the axis A to a hexagon. As a comparison with Fig. 4 shows, such a hexagonal opening when regular has the property of reflecting a pencil, filling the aperture and directed parallel to the axis A without loss of rays. At the same time also with incidence of a pencil filling the aperture and inclined to the axis A the loss of rays is relatively trifling. The same may be said of the aperture with circular boundary according to Fig. 10, where the acute solid angles of the tetrahedron are cut off by a coaxial cylindrical surface. Finally, the same holds for every limitation of the aperture which lies symmetrical about the point appertaining to the axis of the reflector of the plane of aperture.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. A triple reflector being approximately a central reflector and having its hollow space filled up by an optical medium, the refractive power of which exceeds that of air and which presents to the luminous rays an approximately plane entrance and exit surface perpendicular to the axis of the reflector.

2. A tetrahedron made of glass and polished on its four surfaces, three of which constitute approximately a central reflector and the fourth of which is perpendicular to the axis of the said reflector.

3. A triple reflector being approximately a central reflector and consisting of a tetrahedral glass body, the plane entrance and exit surface of which is perpendicular to the axis of the reflector and is limited by a figure symmetrical about the point common to the said surface and to the axis of the reflector.

4. A triple reflector being approximately a central reflector and consisting of a glass tetrahedron, the entrance and exit surface of which is perpendicular to the axis of the reflector and the three acute solid angles of which are cut off each by a plane section parallel to the axis of the reflector, so that the said surface is limited by a regular hexagon.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

RUDOLF STRAUBEL.

Witnesses:

PAUL KRÜGEL,
FRITZ SANDER.