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COMPLETE SPECIFICATION.

Improved Double Objective for Photographic and the like purposes.

We, CARL PAUL GOERZ and EMIL VON HOEGH, both of 45/46, Rheinstrasse, Friedenau, near Berlin, Germany, Opticians, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:—

Our invention relates to a double objective for photographic purposes.

It is a well known fact that the anastigmatic flattening and at the same time the neutralisation of the spherical aberration in a system of three lenses is attained by two spherical contact-surfaces of two succeeding mediums; one of them acts as a collector, the other as a disperser for the luminous rays.

Proceeding from the consideration that the efficiency of an objective of this kind depends on the value of the difference of refractive indexes between the two media in juxtaposition, we concluded that further improvements and especially a considerable increase in the sharpness of the picture would be obtained by replacing the contact-surfaces between two different glasses by such between glass and air. By this arrangement the difference between the refractive indices will be increased six or seven times. Researches in this line led us to the construction of the objective which forms the object of the application, and which is formed of two single lenses separated by a layer of air. It is an objective of the very simplest construction which in spite of its simplicity eliminates in a very high degree all defects of the image produced, *i.e.*: spherical and chromatic aberration, astigmatism, convexity of the image, coma, distortion. In addition to this, however, we have succeeded in considerably increasing the general sharpness of the picture by diminishing the so-called "intermediate error" as compared with the astigmatically corrected cemented three lense systems hitherto used for the same purpose.

This two new lense system consists of a bi-concave lense L^1 of low refractive index and of a bi-convex lense L^2 of a high refractive index as shewn in Fig. 1.

The present system is the final result of very careful scientific researches on the following plan:—

Equations were established for the elimination of the spherical aberration and for producing a constant proportion of the sines for axial rays. Different values were introduced for the focal-length of the first negative lense, and for the distance of the two lenses from one another. The solution of the resulting equation of the fourth degree had as a product the resp. focal lengths of the second lenses, and the forms for both lenses most apt for doing away with the two errors.

Subsequently all these forms were controlled by trigonometrically calculating a ray near the circumference taking into account the suitably selected thickness of glass. These calculations showed that the calculation of the correct thickness of the glasses, which was originally left out of account only slightly influenced the results necessary for the realisation of both conditions.

[*Price 8d.*]

Each combination of lenses thus obtained was then examined for curvature of the image and astigmatism, by projecting mathematically a principal ray intersecting the axis of the system under an angle of 32 degr. The astigmatic points of the image were then calculated. The comparison of the relative situation of these points and of the plane of the image pointed to the way in which the problem was to be solved.

The systems studied in this manner all showed a considerable curvature of both astigmatic curves of the image. The conditions were the most favourable ones in that system in which the focal length of the first lense was smallest. Nevertheless, it would be necessary for a complete removal of this error to shorten the focal length still further. The result would have been a considerable decrease in illuminating power in consequence of the great curvature of each lense. It was therefore decided not to insist on the strict fulfilment of the sine-conditions in the separate lense systems, and only bring the two astigmatic points of the image in the imaginary plane of the image to a coincidence, the spherical aberration in the axis being each time removed by trigonometric testing. This was carried out in the following way:—

From the objectives calculated in the manner previously described we selected one the curvature of whose lenses still admitted of a suitable aperture. By varying the constant values, radius of curvature, thickness of the glass and distance of the lenses, we tried to approach our aim. This experiment succeeded completely although the departure from the strict fulfilment of the sine combination was finally somewhat considerable.

Having found a kind of glass which approximately possessed the calculated amount of refraction and of dispersing power for the spectrum and having made the correction necessary on account of the small difference between the refractive indices of the lenses obtained, and the values taken into calculation the testing of the experimental objective in an apparatus specially constructed for that purpose showed that in the single system the want of sufficient consideration of the sine condition shewed itself in a not quite precise sharpness.

On the other hand the advantages of the new system appear clearly when two single systems are exactly centrally united to form a double objective as shewn in Figure 3. This new double objective is formed to possess the same excellent and astigmatic picture plane as the best double anastigmatic lenses hitherto known and this moreover for a still larger opening. This is explained by the compact construction of the composite system and the thinness of the lenses employed. Moreover the considerably increased sharpness of the image of fine line objects is remarkable both in the direction of the axis and in that of main rays intersesting it at any angle.

The constructional elements of a double objective of this kind are as follows:—

Radii R^1 – 71·973 d^1 – 2·246. Thickness of the lense L.
R^2 – 88·944 d^2 – 1·813. Air space of both lenses.
R^3 – 130·924 d^3 – 4·934. Thickness of the lense L^2.
R^4 – 59·309.
Δ – 12·043. Air space between both single systems.

The glass employed has the following optical properties.

$$\text{Refractive index for line D}\begin{cases}\text{Lense } L^1 - 1{\cdot}5356\\ \text{Lense } L^2 - 1{\cdot}6112\end{cases}$$

The relative dispersion, that is the refractive index diminished by 1 divided by the dispersion between the lines C and F of the Spectrum:

$$\gamma = \frac{n_D - 1}{n_C - n_F}\begin{cases}\text{Lense } L^1 - 50{\cdot}8\\ \text{Lense } L^2 - 58{\cdot}6\end{cases}$$

The focal length of the double objective is 240 mm., the effective aperture 32 mm., the effective angle of the image over 80°.

By comparing the system of two lenses as described above to a system composed of three lenses which form one single body, the advantages to the latter will be readily recognised. In Fig. 1 and 2 there are two such systems illustrated side by side, that pattern of the well known astigmatically corrected three lense systems has been chosen, which mostly resembles the object of the present application with regard to the direction of the radii of curvature. This system consists of a positive Meniscus of low refractive index enclosed between two lenses of high refractive index. The figures inscribed on the separate lenses indicate in approximate numbers the refractive indices of the glass employed. As in all astigmatic three-lense-systems, the astigmatic correction is obtained by a contact surface Z, which disperses the light and another S concentrating it.

The two lense system also contains two such contact-surfaces Z or S acting in opposite sense but these are not contact surfaces between glass and glass, but between glass and air. It is obvious that, for a given aperture of a lense system, the distinctness of the image after correction of the spherical aberration for the peripheral ray increases with the increase of the difference between the refractive indices at the contact surfaces. The smaller these differences the deeper is the curvature of said surfaces and the more the intermediate errors increase, that is to say, the spherical deviation of the rays which pass between the centre and the periphery.

These differences of refractive indices consequently in the three lense system amount to:—

On the surface Z: 0·06.
On the surface S: 0·10.

In the case of two lense system on the contrary

On the surface Z: 0·53.
On the surface S: 0·61.

consequently 9 or 6 times more respectively, and therefore the surfaces themselves will possess a considerable flattening as compared with those of the three lense anastigmatics. The very considerably increased clearness of the image is fully explained by this circumstance.

The new two-lense-system can therefore be regarded as a system derived from the three-lense-system by decreasing the power of refraction of the enclosed lense until it becomes equal to the refraction of the air, *i.e.* : = 1., and that it is no longer a glass lense but an air lense enclosed between a bi-concave lense and a bi-convex lense. Obviously the bi-concave lense Figure 4, or the bi-convex lense (Figure 5) or both (Fig. 6) also can be composed of two or more lenses of equal or nearly equal refraction, cemented together. The condition *sine qua non* for getting, for the above stated object, spherical, astigmatic and chromatic corrections with increase in the clearness of the image, is formed by the following criteria.

The back-surface of the first bi-concave lense of low refractive power has to receive a deeper curvature than the front surface of the bi-convex lense of high refraction separated from it by a layer of air. If for instance the achromatism of the two systems of lenses can only be approximately attained with the available species of glass we are able to cancel the still remaining error without any difficulty by composing one of the lenses of two lenses of approximately equal refraction but of different dispersion cemented together.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed we declare that what we claim is:—

An improved spherically, chromatically and astigmatically corrected two-lense-system consisting essentially of a simple or composite bi-concave lense of low refracting power and of a simple or composite bi-convex lense of high refraction separated from the former by means of a layer of air, and in which of the surfaces of the two lenses facing one another, that belonging to the bi-concave lense acts as a disperser and has a greater curvature than the surface of the other lense behind it, which acts as a collector; a single spherically, chromatically and astigmatically corrected double objective being composed of two equal or similar halves of the kind set forth.

Dated this 8th day of June 1898.

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GEORZ & *another's* COMPLETE SPECIFICATION. (1 SHEET)

Fig. 1.

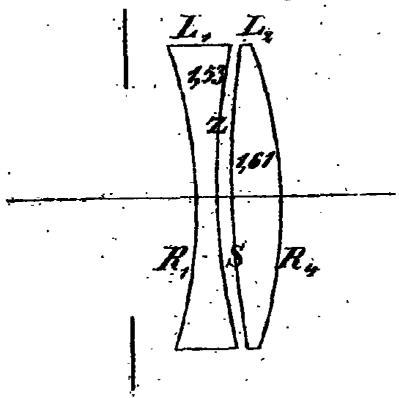


Fig. 2.

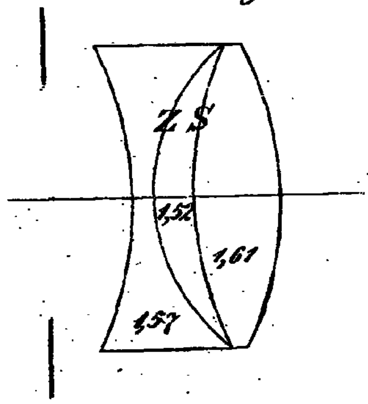


Fig. 3.

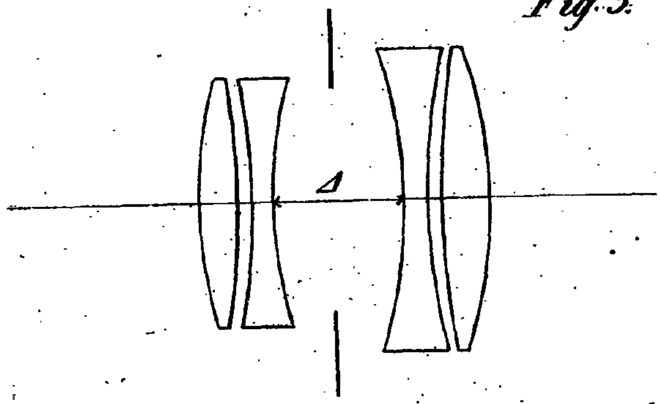


Fig. 4.

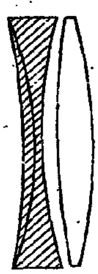


Fig. 5.

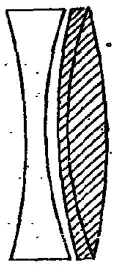
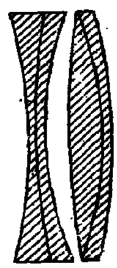


Fig. 6.



[This Drawing is a reproduction of the Original on a reduced scale]

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