UNITED STATES PATENT OFFICE.

PAUL RUDOLPH, OF JENA, GERMANY, ASSIGNOR TO THE FIRM OF CARL ZEISS, OF SAME PLACE.

OBJECT-GLASS.

SPECIFICATION forming part of Letters Patent No. 583,336, dated May 25, 1897.

Application filed February 1, 1897. Serial No. 621,475. (No model.)

To all whom it may concern:

Be it known that I, PAUL RUDOLPH, doctor of philosophy, a subject of the Duke of Saxe-Altenburg, residing at Jena, in the Grand Duchy of Saxe-Weimar, German Empire, have invented a new and useful Object-Glass, of which the following is a specification.

The object of my invention is to provide a photographic objective which, while having a great intensity of light and over a wide field of view being well corrected as to astigmatism—that is to say, producing an anastigmatically-flattened image—meets even exceptional requirements as regards chromatic and spherical correction. This object is attained by rendering the principle of correction embodied in Gauss's telescope-objective serviceable for the purposes of the present invention.

Figure 1 represents the telescope-objective of Gauss. Fig. 2 represents an objective constructed according to the present invention. Fig. 3 represents a doublet objective composed of two object-lenses of the improved kind.

As is well known, Gauss has demonstrated that a double-lens objective enables both chromatic and spherical aberration to be corrected with great accuracy for a comparatively large aperture if such compound object-lens be constructed as illustrated in the section Fig. 1 of the accompanying drawings—that is, if it consists of a convex crown-glass meniscus A and a convexo-concave flint-glass lens B, the two surfaces whereof, which are turned toward each other and are separated by air, differing materially in their curvatures, so that they may not be cemented together. Unlike the types of object-glasses of Fraunhofer, Littrow, and others, in which the faces turned toward each other have practically equal curvatures and are generally cemented together, the type of objective devised by Gauss is liable to undergo on the basis of a proper distribution or arrangement of the curvatures a correction of the spherical aberration for two different colors, so that the so-called "chromatic" difference of the spherical aberration is done away with and both aberrations are effaced over an area corresponding to a large aperture. Objectives of this description have been repeatedly and successfully applied to astronomical telescopes, both the arrangements of lenses that are practicable—viz., crown first and flint first—having been tried; but before the present invention no advantageous application of this type of compound lens to photographic objectives has to my knowledge been either made or deemed feasible. Such application is attained in the first place by imparting to Gauss's objective the property of producing an anastigmatically-flattened image, (which is so desirable for photographic-lens systems, but which has hitherto not been realized in the said objective,) and, secondly, by achromatizing such anastigmatic objective in a novel manner satisfactory for photographic purposes. In attempting to attain this result considerable difficulty has been experienced, owing to the narrow range of suitable sorts of glass.

It has been found that in an objective of great aperture a perfect anastigmatic flattening of the image may be secured only with lenses either of considerable thickness or placed at a great distance apart. Furthermore, a sufficient chromatic correction, while attainable in the astronomical objective with any given pair of crown and flint glass, which need not produce an anastigmatically-flattened image and which has hitherto been constructed with lenses of but little thickness and placed at a short distance from each other, in an anastigmatic objective of a comparatively large aperture may be insured only where the dispersive power of the flint-glass, as expressed by the formula $\frac{\Delta n}{n-1}$, has a comparatively great value—viz., about double the value of the dispersive power of the crown-glass. Such a pair of lenses, however, is unsuited for photographic purposes, inasmuch as it would have to comprise a very heavy flint-glass. According to the present invention this drawback is obviated in the following manner.

In the lens system shown in Fig. 1 either one lens, A, or the other lens, B, or both, consist each of a positive (biconvex) lens and of a negative (biconcave) lens cemented to the first and formed of glass having the same, or nearly the same, refractive power as the glass of the positive component, but different dispersive power. A lens so composed will, as regards all the effects dependent upon refracdistance between the main parts of the lens system; L′ L^2 L^3, the lenses themselves, and D the diameter of the lenses.

In the following tables radii, thicknesses, and diameter of the lenses are expressed in relative numbers, the focal length of the complete objective being taken as a unit. By simply multiplying these numbers by the focal length required in any given case the dimensions of an objective possessing the requisite focal length will be found.

In order to characterize the different sorts of glass employed, there are given the refractive indices n^D and $n^{G'}$, relating, respectively, to the D line of the solar spectrum and to the Hγ line of the hydrogen spectrum. Besides, for each kind of glass the value of the dispersive power $\frac{\triangle n}{n-1}$ is mentioned, $\triangle n$ being calculated for the interval between D and Hγ, while for n the value n^D is adopted.

Example 1: An astigmatically, spherically, and chromatically corrected object-lens with a front diaphragm, as shown in Figs. 2. The relative aperture of the objective is equal to one-ninth of the focal length. The objective consists of two components separated from each other by air, the negative component being a single lens L′, while the positive part is made up of a dispersing-lens L^2 and of a collecting-lens L^3, both cemented together. The refractive indices of both sorts of glass employed in making the lenses L^2 and L^3 are approximately equal, while the glass of which the lens L^2 is formed is the one possessing the higher dispersive power of the two.

Dimensions for a focal length=1
Maximum relative aperture=.111

Radii.	*Thicknesses and Distances.*
$r' = -\ .1164$	$d' = .0320$
$r^2 = -\ .2215$	$d^2 = .0172$
$r^3 = -1.6097$	$d^3 = .0222$
$r^4 = +\ .2708$	$d^0 = .0086$
$r^5 = -\ .1760$	$b = .0197$

Descriptions of Glass.

	n^D.	$n^{G'}$.	$\frac{\triangle n}{n-1}$.
L′:	1.57210	1.58997	.03124
L^2:	1.51158	1.52344	.02318
L^3:	1.51111	1.52127	.01988

Example 2: An astigmatically, spherically, and chromatically corrected doublet objective with an intermediate diaphragm. (Shown in Fig. 3.) Relative aperture one-fourth. The objective is constructed symmetrically in relation to the intermediate diaphragm, each part consisting of two pieces separated from each other by air, the positive piece consisting of the single lens L^3, while the negative piece is made up of the positive lens L^2 and of the negative lens L′, cemented thereto, the refractive indices of L^2 and L′ being approximately equal, but L′ having the higher dispersive power.

Dimensions for a focal length=1
Maximum relative aperture=.25

Radii.	*Thicknesses and Distances.*
$r' = -r'' = -\ .1954$	$d' = .0411$
$r^2 = -r^{2'} = +\ .4370$	$d^2 = .0514$
$r^3 = -r^{3'} = -\ .3599$	$d^3 = .0308$
$r^4 = -r^{4'} = -1.5424$	$d^0 = .0026$
$r^5 = -r^{5'} = -\ .3147$	$b = .0514$

Descriptions of Glass.

	n^D.	$n^{G'}$.	$\frac{\triangle n}{n-1}$.
L′:	1.57631	1.59227	.02769
$L^2 = L^3$:	1.57244	1.58512	.02215

What I claim, and desire to secure by Letters Patent of the United States, is—

A compound objective which gives an anastigmatically-flattened image, consisting of two lenses (separated from each other by a medium of little refractive power), viz: one positive lens and one negative lens, at least one of which lenses is made up of two constituent parts united by cement and formed of two different sorts of glass of unequal dispersive power but nearly equal refractive power, essentially as shown and described.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

PAUL RUDOLPH.

Witnesses:
RUDOLPH FRICKE,
OTTO WOEDERLEIN.

(No Model.)

J. B. SARGENT.

WHIFFLETREE.

No. 583,337. Patented May 25, 1897.

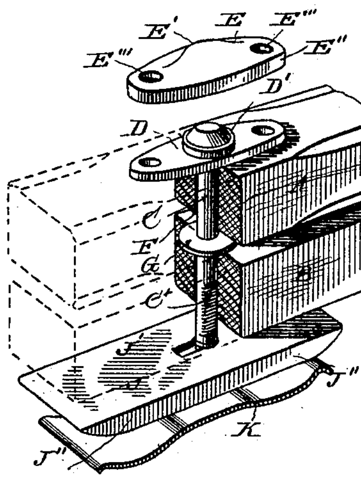


Fig. 1.

Fig. 2.

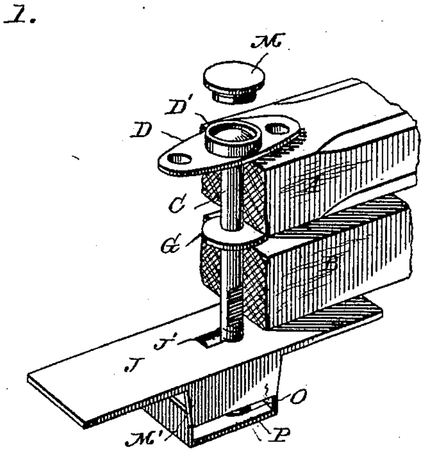


Fig. 3.

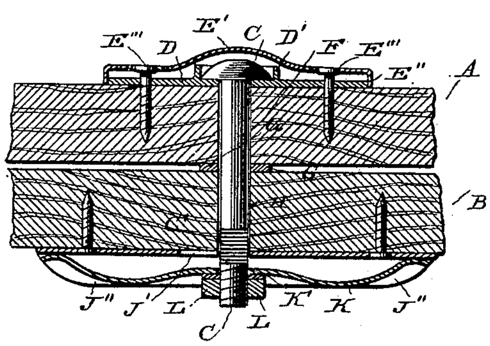
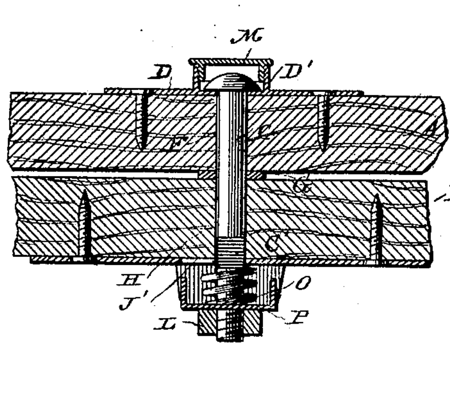


Fig. 4.



WITNESSES:

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