PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Photographic Objective

I, ALBRECHT WILHELM TRONNIER, of German Nationality, of 50a Salinenstrasse, Kreuznach, Germany, 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:—

This invention relates to a spherically, chromatically and comatically corrected objective with anastigmatic flattened field consisting of three components which are separated by air spaces, two of which have positive power and different radii of curvature, and enclose the third dispersive component in the form of an asymmetrical biconcave lens, so arranged that the air spaces between the components are unequal and have likewise a dispersive effect, the arrangement being such that the larger air space is located on the side of the shorter radius of curvature of said biconcave lens, in which air space the diaphragm is generally arranged.

This above-mentioned type of objective is particularly suited for obtaining an anastigmatic flattened field over a comparatively large angle, possessing a good spherical correction also for large apertures, whereby it is possible to keep the longitudinal spherical aberration in general below 0.5% and the differences between the sagittal and the meridional image points and the ideal (Gaussian) image plane below about 1% of the equivalent focal length. The sine-coincidence condition can likewise be satisfied so that the images in the proximity of the optical axis coincide for the various aperture zones not only with respect to position, but also to magnification, in consequence of which they are free from inner axial coma. (It may be explained that the sine condition requires that the differences between the focal lengths for axial rays and marginal rays shall be zero, and that the sine coincidence condition is satisfied if the spherical aberration is equal to the sine deviation.) There often arise, however, indistinctnesses in the lateral parts of the image field in spite of an anastigmatically satisfactory correction, because with larger openings of the lateral pencils the transmission of the image, in general, even if the sine-coincidence-condition has been fulfilled, is affected with coma. The correction of the coma can be brought about in the case of a suitable design of the system for the type of objective in question, either by giving the total system a great length (height of vertices) or by introducing a collective cemented surface which is convex towards the diaphragm into one of the two collective components —preferably that component which is on the image side—the respective component being split into two cemented lenses of opposite power and consisting of glasses with different indices of refraction, the glass of higher refractive power belonging to the collective component. There is known, for instance from German patent specification No. 581,472, an objective of the above mentioned type which can be well corrected for coma, and in which also the other aberrations can be obviated in a measure sufficient for the requirements of photographic objectives.

While with those known objectives the possibility of correcting the coma in the case of a short length of the system is established under conditions which limit the combination to the constructional form having a collective cemented surface in the positive component located on the image side, the present invention permits attainment of the above correction with only three simple lenses which are separated by air spaces, without the length of this system exceeding the admissible limits. The comatic lateral aberration can, with this improved objective, be kept below 1.5 per thousand for an oblique principal ray (on the image side) of 20° and a relative aperture of the coma pencil of f/8.8 in the plane of the entrance pupil, provided that the image plane coincides with the Gaussian focal plane (see the applicant's publication "Die Abweichungen geneigter Büschel endlicher Oeffnung im Meridianschnitt zentrierter Linsensysteme" published in the periodical "Photographische Industrie," Berlin, 1933, Vol. 41, pages 953—956). The effect stated is obtained by a closely approximate fulfilment of the comatic-pupil con-

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dition (see equation 5 in the above-mentioned publication) for that sub-class of the present type of objective in which the collective front lens possesses at least twice the refractive power of the total system, and its combination with the subsequent negative lens possesses at the most (measured in the numerical value) 0.4 of the refractive power of the total lens-system, the aperture of which is equal to, or larger than, 0.20.

In order to define the characteristic features of the invention, the elements of the parallel auxiliary ray are to be used, for which the Schwarzschild equation is valid:

$$\phi = \sum_{i=1}^{K} \frac{n^1_i - n_i}{r_i} \qquad h_i = 1$$

where n_i and n^1_i are the indices of refraction before and behind the radius of curvature r_i, and the height of incidence of the parallel auxiliary ray is denoted by h_i, and the index i is the surface-number from the first (i=1) to the rear (i=6) radius of the system. If the surface effect be denoted by $\bar{\phi}F$, and if the effect of the V−1 surfaces preceding the V surface is denoted

by $\bar{\phi}^{1}V_{v-1} = \bar{\phi}V_v$, then

$$\bar{\phi}^{1}V_v = \bar{\phi}V_v + \bar{\phi}F_v = \bar{\phi}V_v + 1$$

and for the transition from the V surface to the V+1 surface there is valid the equation

$$h_{v+1} = h^1_v = h_v - \delta h_v$$

i.e.,

$$\delta h_v = \bar{\phi}^{1}V_v \cdot \frac{d_{v,v+1}}{n^1_v}$$

In this way the exact definition of the construction of the system is possible, as the individual surfaces are defined by the $\bar{\phi}$– values not only by their refractive indices and their curvatures, but also by their position, so that these values can serve for the representation of the aberration coefficients, for instance of the third order. According to A. Gleichen the transition value from the V surface to the V+1 surface is denoted by C_v and if there is written

$$t_v = h_v(\bar{\phi}F_v m_v - \bar{\phi}V_v) \text{ and } \pi_v = {}^1/t_v + C_v,$$

(m_v being a factor by which the value of $\bar{\phi}F_v$ is to be multiplied) then the Seidel-coefficients will be, in this case, successively as follows:

$$SI_v = \bar{\phi}^{2}F_v\alpha_v + \bar{\phi}^{2}F_v\bar{\phi}V_v\,\beta_v + \bar{\phi}F_v\,\bar{\phi}^{2}V_v\gamma_v + \bar{\phi}^{3}V_v\,\delta_v$$

$$SII_v = SI_v\,\pi_v\ ,\ SIII_v = SII_v\,\pi_v$$

$$SV_v = (SIII_v + P_v)\,\pi_v$$

It is in view of these relations that the new objective within the present sub-type of photographic three-lens objectives is defined in terms of the statement of the relations of the third powers of three $\bar{\phi}$ values with respect to the value of the last surface of the total system. This reference to $\bar{\phi}F_6$ is made in consideration of the influence of this surface and its effect upon the intersection distance p^1_0 between the vertex of this surface and the focal plane, and of the importance of this distance upon the coma correction according to the equations 4) and 6) of the above-mentioned publication.

According to this invention, the object in view is obtained for the present sub-type of the triplets by such a distribution of the effect-values that the ratio

$\bar{\phi}^{3}F_1 : \bar{\phi}^{3}F_6$ lies between the values 22.40 and 11.20, and, besides, the ratio

$\bar{\phi}^{3}V_4 : \bar{\phi}^{3}F_6$ lies between the values 11.20 and 5.60, and finally, the ratio

$\bar{\phi}^{3}F_6 : \bar{\phi}^{3}F_3$ lies between the values 5.60 and 2.80.

The figure of the accompanying drawing shows an objective according to this invention for a focal length of f=200 mm. Figs. 2, 3 and 4 show the correction curves for this example. (At an earlier part of the specification the equations have been furnished for a system whose focal length is equal to unity).

The correction is drawn in the scale used by W. Merté (see the publication of W. Merté in the "Handbuch der wissenschaftlichen und angewandten Photographie," Vol. 1, "Das photographische Objectiv," Vienna 1932). In the Merté scale f=100 mm. There are shown in Fig. 2 the spherical and sine-condition aberrations, in Fig. 3 the aberrations of the sagittal and meridional focal points from the ideal image plane (drawn in full and in dotted lines), and in Fig. 4 the distortion for the image scale N=∞, N being the international symbol denoting the ratio of aberration to front radius. The aberrations in Figs. 2 and 3 are stated in percentages of the equivalent focal length, the distortion in percentage of the image height. The comatic lateral aberration amounts, in the example, for the inclination 18° 38′ 25.6″ on the object side (with the principal ray inclination on the image side of $u^1_6 = 20°\ 14'\ 5.4''$) and as regards the upper and the lower coma ray of + or −5.765 mm. height of incidence in the plane extending through the centre of the entrance pupil +1.18 or −1.20 per thousand of the image height, with the proviso that the image plane coincides with the Gaussian focal plane.

The distance between the Gaussian focal plane and the vertex of the last lens on the image side is denoted by p^1_0. The equivalent focal length of the numerical example is equal to the unit of the various radii and distances given. The refractive indices stated refer to the violet (g) wave length, while the dispersion of the glasses used is characterised by the Abbe number

$$\nu = \frac{n_D - 1}{n_F - n_C}$$

Relative aperture 1:4.5 $p^1_0 = 0.8297$

$R1 = +0.2616$

$d1 = 0.4916$ $n1 = 1.6739$ $\nu 1 = 51.3$

$R2 = +12.017$

$\Delta 1 = 0.03988$ air

$R3 = -0.8346$

$d2 = 0.01038$ $n2 = 1.6481$ $\nu 2 = 35.4$

$R4 = +0.2567$ $b1 = 0.04807$

$\Delta 2 = 0.10925$ air

$b2 = 0.06118$

$R5 = +3.0261$

$d3 = 0.02567$ $n3 = 1.6515$ $\nu 3 = 56.3$

$R6 = -0.5479$

i.e., $\overset{-1}{\phi}V_2 = +2.52381$—therefore more than 2.0

$\overset{-1}{\phi}V_4 = -0.16532$—therefore less than 0.4 abs.

$\overset{-3}{\phi}F_1 : \overset{-3}{\phi}F_6 = 17.789$, and

$\overset{-3}{\phi}V_4 : \overset{-3}{\phi}F_6 = 6.9643$ and at the same time

$\overset{-3}{\phi}F_6 : \overset{-3}{\phi}F_3 = 3.6704$

In the above ratios, $\overset{-3}{\phi}F_1$ is the third power of the effect of the collective front surface of the objective next the object; $\overset{-3}{\phi}F_3$ is the third power of the effect of the front surface of the dispersive component which is concave towards the object and bounds the smaller air space; $\overset{-3}{\phi}F_6$ is the third power of the effect of the rearmost surface of the objective, the radius of curvature of which is equal to R_6; $\overset{-3}{\phi}V_4$ is the third power of the total effect of the three surfaces preceding the outer surface on the image side, of the dispersive component, i.e., $\bar{\phi}V_4 = \bar{\phi}F_1 + \bar{\phi}F_2 + \bar{\phi}F_3$. This surface of the dispersive component bounds the larger air space and is convex towards the object.

The Schwarzschild equation is given in the transactions of the Königliche Gesellschaft der Wissenschaften of Göttingen (Mathematisch-Physikalische Klasse) published in 1906 by the Weidmannsche Buchhandlung, Berlin, see pages 9 and 10 of the third article by K. Schwarzschild.

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

A spherically, chromatically and comatically corrected objective with anastigmatic flattened field consisting of three single components which are separated by air spaces, two of which have positive power and different radii of curvature and enclose the third dispersive component in the form of an asymmetrical biconcave lens, in such a manner that the air spaces between the components are unequal and have likewise a dispersive effect, being arranged in such a manner that the larger space is located on the side of the shorter radius of curvature of said biconcave lens, the collective front lens, preceding this biconcave lens, possessing at least twice the refractive power of the total system, while its combination with the subsequent negative lens possesses at the highest (measured in the numerical value) 0.4 of the refractive power of the total lens-system, the aperture of which is equal to, or larger than, 0.20, the said objective lens being characterised by such a distribution of the $\bar{\phi}$ values that the ratio

$\overset{-3}{\phi}F_1 : \overset{-3}{\phi}F_6$ lies between the values 22.40 and 11.20, and, besides the ratio

$\overset{-3}{\phi}V_4 : \overset{-3}{\phi}F_6$ lies between the values 11.20 and

5.60 and finally the ratio

$\overset{-3}{\phi}F_6 : \overset{-3}{\phi}F_3$ lies between the values 5.60 and 2.80.

Dated the 17th day of July, 1934.

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Fig. 1

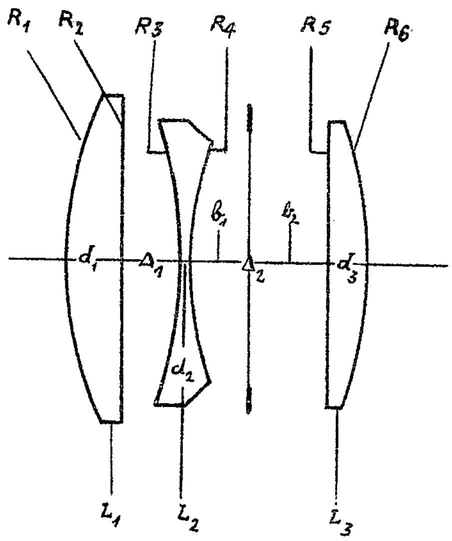

Fig. 3

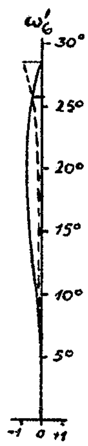

Fig. 2

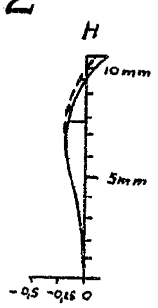

Fig. 4