PHOTOGRAPHIC OPTICS; INCLUDING THE DESCRIPTION OF LENSES AND ENLARGING APPARATUS

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PHOTOGRAPHIC OPTICS.

PREFACE.

To show clearly the principles on which the optical instruments used by photographers are constructed is the object of this little volume. Treatises on physics—nay more, treatises exclusively on optics—are silent about these instruments, and about terms—such as *chemical focus*, *depth of focus*, *distortion*, &c.—which are in daily use among photographers. This is because modern optics has been hitherto confined to the study of telescopic and microscopic lenses, which never, like photographic lenses, receive pencils very oblique to their principal axis. The consequence is, that the aberrations which must be destroyed in these objectives, namely, *spherical aberration* and *chromatic aberration*, have alone been studied. At most, the other aberrations,—namely, *distortion*, *curvature of the field*, and *astigmation*,—have been made by a few authors, such as Airy and Gauss, who have studied them in connexion with *eye-pieces*, the subject of some rare memoirs, of which, moreover, no mention is made in any work on physics or optics.

This volume is divided into two books; the first (and this is the principal one) the optics of photographic objectives, the second that of enlarging apparatus.

The first book is divided into chapters in which we describe the principles of general optics. We dwell particularly on points imperfectly known, or directly related to photography,—such as the chemical action of light; the images produced by small apertures; the absorption of light by transparent media; the reflecting power of mirrors; the position of maximum chemical action in the spectrum on substances sensitive to light; photographic achromatism; the manufacture of lenses; the law of conjugate foci, and the size of images at the foci of lenses; the determination ofthe absolute focus of simple lenses and of optical combinations of several lenses, &c.

The five aberrations of most interest have been the object of our especial care.

A radiating point (of homogeneous colour) being placed at infinity, and in the axis of a convergent lens, emits parallel rays, which on emerging from the lens do not meet at one point in the axis; and therefore the image of the point is surrounded by a circle of diffused light, called the *circle of spherical aberration.* If the point is placed some degrees out of the axis, the circle of aberration becomes elliptical; and if the point is very obliquely placed, its image takes the form of a comet. We have carefully examined the conditions necessary to reduce this spherical aberration to the minimum by the employment of the diaphragm, or better by joining to the convergent lens a divergent lens, with appropriate radii of curvature, which makes the combination *aplanatic*, that is, free from spherical aberration along its axis.

If the radiating point is not of homogeneous colour—if, for instance, it is white—for one ray incident on the lens there are several refracted rays of different colours which cut the axis at different points,—a phenomenon which has received the name of *chromatic aberration*, and which is corrected by joining to the convergent lens a divergent lens formed of another kind of glass, and with suitable radii of curvature. But a lens *achromatic* for incident rays parallel to its axis, cannot be so for rays oblique to this axis; and the optician has therefore to solve the problem of reducing the chromatic aberration to the minimum for the latter while annulling it for the former, a problem which we shall examine in detail.

If instead of a radiating point placed at infinity, we take, for example, *a plane* situated at infinity, and if we reduce the lens to its optical centre, we shall find that the image, at the focus of the lens, cannot be received on a plane surface—a *curved surface* being necessary to receive it: this is the *aberration of form*, or the *curvature of the field*. Further, the two meridians of the lens have, for pencils oblique to its axis, different focal lengths, and thence *two* different *fields of curvature*—an aberration which has received the name of astigmation.

Lastly, another aberration results from the thickness of the lens, and from the position of the diaphragm, the effect of which is to render the straight lines of the object to be reproduced curved in the image,—an aberration which has received the name of *distortion*.

All these aberrations are called *positive* when they are applied to single convergent lenses, and *negative* to single divergent lenses. All are corrected in an optical combination of divergent and convergent lenses (which in practice is always convergent); but the corrections may be excessive or insufficient, and then the aberrations may be, in a convergent optical combination, either positive or negative.

The study of aberrations is followed by that of photographic lenses, which we divide into two classes,—*aplanatic objectives*, which give sharp images over a small field with their entire aperture; and *non-aplanatic objectives*, which give sharp images only on the condition of being limited by a diaphragm to a very small fraction of their aperture, but which generally include a large angle, and consequently give a sharp image over a large field.

Many new non-aplanatic objectives have been produced in late years, but we positively condemn their introduction among photographers, and regard them, not as a step in advance, but the reverse, and for the following reasons:—

The practice of photography has established that, when the image at the focus of a lens is wanting in intensity, the photographic reproduction of this image is itself wanting in relief, the foregrounds being too black, the objects situated in the horizon confounded with the sky, and the clouds in the sky replaced by a plain ground of uniform tint: the proof, in a word, is wanting in aërial perspective, and, if it be a portrait, in vigour and relief. For, to give *sharp* images non-aplanatic objectives require very small diaphragms, and generally of from $\frac{f}{40}$ to $\frac{f}{72}$, f being their focal length: hence an insufficient intensity in the image and the defect which we have just pointed out. But, exempt from distortion, and including a considerable angle, they are useful in some special cases, such as the reproduction of *cartes*, buildings situated a very short distance, or landscapes and buildings strongly illuminated by a powerful sun.

Aplanatic objectives, under the head of which rank the *triplet*, include a less angle, but do not require diaphragms exceeding $\frac{f}{36}$; and therefore they give more artistic photographic proofs, in which the foregrounds and the horizons are well brought out, and the skies have clouds. If the light is insufficient, they are employed with a larger diaphragm; and the sharpness of the image is not destroyed as with non-aplanatic objectives, but only limited to a smaller field. They can be used for portraits in the open air, groups, and animated scenes, with their entire aperture,—an advantage which is invaluable in practice. Lastly, the angle they include, being between 50 and 60 degrees, is more than sufficient, because if this angle is more considerable the effect of the perspective is doubtless more astonishing than agreeable.

In our opinion, therefore, the use of non-aplanatic objectives —such as the *single lens*, the *globe lens*, *Mr. Ross's doublet*, and that of *M. de Steinheil*—should be abandoned (except in some special cases which we have enumerated above) for that of aplanatic objectives among which the *triplet* is the best, as being free from distortion.

For portraits the only possible lens is *Petzval's doublet*, but we are able to state that this form itself will soon be abandoned for a combination recently invented by M. de Steinheil of Munich, which is free from spherical and chromatic aberrations both along its axis and obliquely to it, from distortion and from astigmation, and which, further, reduces the curvature of the field to a much smaller quantity.* This lens, the fruit of immense and ingenious calculations, will not fail to attract the attention of all photographers, as in every respect it deserves to do.

It is not enough to be in possession of good objectives, it is necessary to know how to use them,—a thing about which ninety-nine photographers out of a hundred are in ignorance. To use a lens improperly is to produce portraits false in perspective, buildings and houses falling into the street, &c. We point out, in a special chapter, how an objective should be employed and under what circumstances.

The second book of this work treats of enlargements. In it we examine the history of enlarging apparatus, the theory of them, their setting-up, their management, and the application to them of the heliostat and of artificial light.

We therein clearly establish the principle that the origin of the want of sharpness in the images produced by most enlarging apparatus is due to the circle of aberration of the

* The author of this work is in possession of one of these new objectives through the courtesy of M. de Steinheil. These objectives are not as yet on sale.

condensers which illuminate the negative to be enlarged, the effect of this being to cause diffraction-blurrings or multiple lines in all the sharply defined outlines of the enlarged image. By destroying this circle of aberration, either by the employment of condensers of small diameter, or of aplanatic condensers, the production of these diffraction-blurrings is prevented, and the enlarged images then become admirably sharp.

Such are the principal contents of this little volume, which is not, indeed, to be considered as more than the summary of a more complete work; but which, we hope, will be of some use to the amateur, the professional photographer, the physicist, the optician, and all others interested in the progress of modern optics.

D. VAN MONCKHOVEN,

Doctor of Science.