PATENT SPECIFICATION

Application Date: Oct. 6, 1942. No. 14034/42.

561,943

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Complete Specification Accepted: June 12, 1944.

PROVISIONAL SPECIFICATION

Improvements in or relating to Optical Objectives

We, Taylor, Taylor & Hobson Limited, a Company registered under the Laws of Great Britain, Arthur Warmisham, British Subject, and Charles Gorrie Wynne, British Subject, all of 104, Stoughton Street, Leicester, do hereby declare the nature of this invention to be as follows:—

This invention relates to an optical objective corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two simple divergent components located between two simple convergent components, and has for its object to provide objectives of this kind corrected over a semi-angular field of 15° to 22° for an aperture higher than F/3.5 and up to, say, F/2.5 or F/2.

In the objective according to the invention, the numerial sum of the radii of curvature of the front surface of the front component and of the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, whilst the overall axial length of the objective between such two surfaces lies between 40% and 50% of the equivalent focal length.

Conveniently at least one of the convergent outer components is made of a material having mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0 and preferably less than 58.0. Thus for example both outer components may be made of crystalline magnesium oxide in the form known as β-magnesium-oxide.

The divergent inner components may each be made of a material having mean refractive index between 1.64 and 1.75 and Abbé V number between 34.0 and 27.0. It is especially convenient to make the inner components of an alkaline halide crystal, for example sodium bromide crystal.

By choosing materials for the four components all having substantially the same relative partial dispersion, it is possible to obtain a much higher degree of correction for secondary spectrum than hitherto without sacrificing the corrections for astigmatism, field curvature and distortion. The relative partial dispersion, usually represented by θ, may be defined by the mathematical expression $\dfrac{n_g - n_e}{n_F - n_C}$, where n_C, n_e, n_F and n_g are respectively the refractive indices for the C, e, F and g lines of the spectrum. Thus sodium bromide crystal has relative partial dispersion .985 and good secondary spectrum correction can be obtained if it is used for the divergent inner components in conjunction with magnesium oxide crystal (having relative partial dispersion .989) for the convergent outer components.

Numerical data for two convenient practical examples of objective according to the invention are given in the following tables, in which R_1 R_2 . . . . . . represent the radii of curvature of the individual lens surfaces counting from the front (that is the side of the longer conjugate) the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D_1 D_2 . . . . . . represent the axial thicknesses of the individual elements, and S_1 S_2 S_3 represent the axial air spaces between the components. The tables also give the mean refractive indices n_D for the D-line, the Abbé V numbers and the relative partial dispersions θ of the materials used for the various elements.

[*Price* 1/-]

EXAMPLE I.

Equivalent focal length 1.000 Relative Aperture F/2.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .4765				
	D_1 .1078	1.738	53.5	.989
R_2 ∞				
	S_1 .0843			
R_3 − .6760				
	D_2 .0196	1.651	33.5	1.060
R_4 + 1.0685				
	S_2 .0216			
R_5 + 1.602				
	D_3 .0127	1.651	33.5	1.060
R_6 + .5027				
	S_3 .0980			
R_7 + 2.001				
	D_4 .0735	1.738	53.5	.989
R_8 − .5581				

EXAMPLE II.

Equivalent focal length 1.000 Relative Aperture F/3.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .5026				
	D_1 .1214	1.738	53.5	.989
R_2 − 9.194				
	S_1 .0882			
R_3 − .6430				
	D_2 .0184	1.641	29.9	.985
R_4 + 1.248				
	S_2 .0202			
R_5 + 1.650				
	D_3 .0138	1.641	29.9	.985
R_6 + .5136				
	S_3 .1287			
R_7 + 2.012				
	D_4 .0699	1.738	53.5	.989
R_8 − .5927				

In these examples it will be noticed that the numerical sum of the radii R_1 and R_8 is 1.0346 in Example I and 1.0953 in Example II, whilst the overall length of the objective is .4175 in Example I and .4606 in Example II. Magnesium oxide crystal is used for both convergent outer components in each example, and extra dense flint glass is used for the divergent inner components in Example I, whilst sodium bromide crystal is used for the inner components in Example II.

Example II is well corrected for secondary spectrum and has the further advantage that it can be employed not only with visible light but also with ultra violet light down to 2000 Å units. Since the relative partial dispersion of sodium bromide crystal used for the divergent components is slightly less than that of the magnesium oxide crystal used for the convergent components, the combination gives a small residual secondary spectrum which is the reverse of the usual shape, for the paraxial focussing distance thereby established for the central wavelength chosen for colour correction is a maximum and other wavelengths both longer and shorter give smaller focussing distances. This is favourable for use with violet and ultraviolet rays, for as the wavelength decreases, the secondary spherical aberration becomes increasingly relatively overcorrected and the shortening of the paraxial focussing distance thus makes it possible to arrange a compromise such that the position of the focal plane can remain constant for all wavelengths with slightly softer definition for the shorter wavelengths.

Dated this 6th day of October, 1942.
PULLINGER & MALET,
Agents for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Optical Objectives

We, TAYLOR, TAYLOR & HOBSON LIMITED, a Company registered under the Laws of Great Britain, ARTHUR WARMISHAM, British Subject, and CHARLES GORRIE WYNNE, British Subject, all of 104, Stoughton Street, Leicester, 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 an optical objective corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two simple divergent components located between two simple convergent components, and has for its object to provide objectives of this kind corrected over a semi-angular field of 15° to 22° for an aperture higher than F/3.5 and up to, say, F/2.5 or F/2.

In the objective according to the invention, the numerial sum of the radii of curvature of the front surface of the front component and of the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, whilst the overall axial length of the objective between such two surfaces lies between 40% and 50% of the equivalent focal length.

Conveniently at least one of the convergent outer components is made of a material having mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0 and preferably less than 58.0. Thus for example both outer components may be made of crystalline magnesium oxide in the form known as β-magnesium-oxide.

The divergent inner components may each be made of a material having mean refractive index between 1.64 and 1.75 and Abbé V number between 34.0 and 27.0. It is especially convenient to make the inner components of an alkaline halide crystal, for example sodium bromide crystal.

By choosing materials for the four components all having substantially the same relative partial dispersion, it is possible to obtain a much higher degree of correction for secondary spectrum than hitherto without sacrificing the corrections for astigmatism, field curvature and distortion. The relative partial dispersion, usually represented by θ, may be defined by the mathematical expression $\frac{n_g - n_e}{n_F - n_C}$, where n_C, n_e, n_F and n_g are respectively the refractive indices for the C, e, F and g lines of the spectrum. Thus sodium bromide crystal has relative partial dispersion .985 and good secondary spectrum correction can be obtained if it is used for the divergent inner components in conjunction with magnesium oxide crystal (having relative partial dispersion .989) for the convergent outer components.

A convenient construction of objective according to the invention is illustrated in the accompanying drawing, and numerical data for two practical examples of such construction are given in the following tables, in which R_1 R_2 . . . . . . represent the radii of curvature of the individual lens surfaces counting from the front (that is the side of the longer conjugate) the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D_1 D_2 . . . . . . represent the axial thicknesses of the individual elements, and S_1 S_2 S_3 represent the axial air spaces between the components. The tables also give the mean refractive indices n_D for the D-line, and Abbé V numbers and the relative partial dispersion of the materials used for the various elements.

EXAMPLE I.

Equivalent focal length 1.000. Relative Aperture F/2.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
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	S_2 .0216			
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R_6 + .5027				
	S_3 .0980			
R_7 + 2.001				
	D_4 .0735	1.738	53.5	.989
R_8 − .5581				

EXAMPLE II.

Equivalent focal length 1.000 Relative Aperture F/3.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
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R_2 − 9.194				
	S_1 .0882			
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R_8 − .5927				

In these examples it will be noticed that the numerical sum of the radii R_1 and R_8 is 1.0346 in Example I and 1.0953 in Example II, whilst the overall length of the objective is .4175 in Example I and .04606 in Example II. Magnesium oxide crystal is used for both convergent outer components in each example, and extra dense flint glass is used for the divergent inner components in Example I, whilst sodium bromide crystal is used for the inner components in Example II.

Example II, which incorporates also the invention forming the subject of the present Applicants' British Patent Application No. 13958 of 1942 (Serial No. 561,804), is well corrected for secondary spectrum and has the further advantage that it can be employed not only with visible light but also with ultra violet light down to 2000 Å units. Since the relative partial dispersion of sodium bromide crystal used for the divergent components is slightly less than that of the magnesium oxide crystal used for the convergent components, the combination gives a small residual secondary spectrum which is the reverse of the usual shape, for the paraxial focussing distance thereby established for the central wavelength chosen for colour correction is a maximum and other wavelengths both longer and shorter give smaller focussing distances. This is favourable for use with violet and ultra-violet rays, for as the wavelength decreases, the secondary spherical aberration becomes increasingly relatively over-corrected and the shortening of the paraxial focussing distance thus makes it possible to arrange a compromise such that the position of the focal plane can remain constant for all wavelengths with slightly softer definition for the shorter wavelengths.

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:—

1. An optical objective corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two simple divergent components located between two simple convergent components, in which the numerical sum of the radii of curvature of the front surface of the front component and the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, and the overall axial length of the objective between such two surfaces lies between 40% and 50% of such equivalent focal length.

2. An optical objective as claimed in Claim 1, in which at least one of the convergent outer components is made of material having mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0.

3. An optical objective as claimed in Claim 2, in which the Abbé V number of the material used for the said convergent outer component is less than 58.0.

4. An optical objective as claimed in Claim 2 or Claim 3, in which the convergent outer components are made of crystalline magnesium oxide in the form known as β-magnesium-oxide.

5. An optical objective as claimed in any one of Claims 1—4, in which the divergent inner components are each made of a material having mean refractive index between 1.64 and 1.75 and Abbé V number between 34.0 and 27.0.

6. An optical objective as claimed in any one of Claims 1 to 5, in which the materials of which all four components are made have substantially the same relative partial dispersion.

7. An optical objective as claimed in any one of Claims 1 to 6, in which the divergent inner components are each made of an alkaline halide crystal.

8. An optical objective as claimed in Claim 7, in which the divergent inner components are made of sodium bromide crystal.

9. An optical objective as claimed in Claim 1, having numerical data substantially in accordance with one or other of the tables set forth herein.

Dated this 5th day of October, 1943.

PULLINGER & MALET,
Agents for the Applicants.

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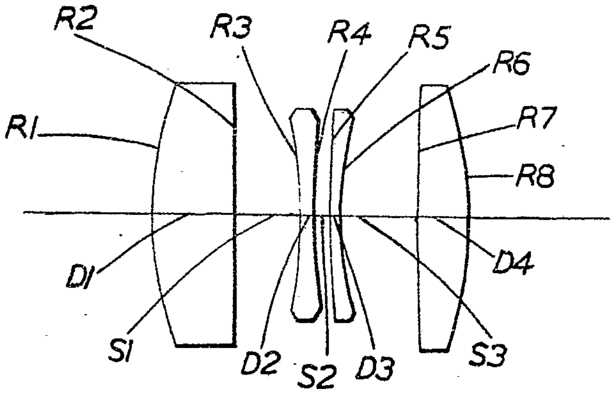
[This Drawing is a full-size reproduction of the Original.]



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