975,309

PATENT SPECIFICATION

DRAWINGS ATTACHED

975,309

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COMPLETE SPECIFICATION

Variable Focal Length Lens System

I, PIERRE ANGENIEUX, of French Nationality, of 27, rue du Cherche-Midi, Paris (Seine), France, do hereby declare the invention for which I pray that a patent may be granted to me and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to variable focal length lens systems of the type comprising at its front end a fixed convergent component followed by a second axially movable divergent component and by a third divergent component and by finally a fourth convergent component, an axial movement in combination with the axial movement of said second divergent component being applicable to either of said third or fourth components in order to keep in a fixed position the image provided by the assembly of these four components all aligned in a common optical axis and forming together preferably but not compulsorily an afocal optical system. Moreover, a corrector component aligned on the same optical axis is provided at the rear, and a diaphragm is disposed preferably between the fourth component and said corrector component.

Devices of this character are already known to those conversant with the art but this invention is concerned primarily with a lens system of this type wherein the amplitude of the axial movement applicable to said second divergent component is sufficient to cause the latter, in the extreme positions of its permissable stroke, to produce an image magnification with a ratio greater than 4:1, and wherein, when said second divergent component is at the front end of its stroke, that is, very close to the first component, the image magnification produced thereby is inferior to .5 (and ranges in practice from .20 to .50), whereas when this second divergent component is at the rear end of its stroke this magnification is greater than 2 (and ranges in practice from 2 to 5). The power of the third component (which is also divergent) is so calculated that the image magnification produced thereby is always inferior to .8 (and ranges preferably from .2 to .8).

It is known that in optical systems of this general character it is necessary to have at least two axially movable components displaceable according to the law giving a fixed position to the final image in relation to the fixed component elements of the system. In a device comprising the characteristics specified hereinabove it was observed that it is immaterial whether the axial movement (combined with the axial movement of the second component) is applied to the third component or to the fourth component, since this axial movement of the third or fourth component consists of a low-amplitude return stroke. The stroke of the second component may exceed twice the focal length of this component.

According to this invention, said fourth component consists of two or more lens elements, of which one is divergent, has a concave front face and is positional very close to and behind a convergent lens element having a convex rear face, the combined power of said concave front face and said convex rear face being negative, the radius of curvature of said concave face ranging from 35% to 140% of the focal length of said component, and the radius of curvature of said convex face ranges from 40% to 160% of the focal length of said component.

According to a preferred form of embodiment of this invention said fourth component comprises only two lens elements, the front lens element being biconvex and the rear lens element being a divergent meniscus. The radius of curvature of the front face of said biconvex lens element being greater than 70% of the focal length of said component, the radius of curvature of its rear face ranging from 40% to 160% of the same focal length. The radius of curvature of the concave front face of said divergent meniscus ranges from

35% to 140% of the focal length of said fourth component, while the radius of curvature of its rear face ranges from 50% to 250% of the same focal length.

Moreover, the second component of the lens system comprises at least three lens elements constituting two members separated by an air gap, the latter being greater than 15% of the focal length of the second component and preferably inferior to 80% of said focal length, the front member being divergent and having a focal length greater than once but less than twice the focal length of said second component, its front face being convex while its rear face is concave and has a radius of curvature ranging from 60% to 200% of the focal length of said second component. The rear member comprises at the front a concave face having a radius of curvature greater than the focal length of the second component and comprises at least one cemented surface between two lens elements, said cemented surface having its convexity directed forwards to provide a convergent effect and having a radius of curvature ranging from 60% to 200% of the focal length of said second component.

According to a further preferred form of embodiment of this invention, said rear member of said second component comprises only two cemented lens elements of which the front one is biconcave and has an index of refraction for the sodium spectrum line lower by at least .08 to that of the lens element associated therewith.

As to the front member of said second component, it is advantageous to have it comprised of a single lens element in the form of a divergent meniscus wherin the convex front face has a radius of curvature greater than twice the focal length of said second component, the concave rear face of this meniscus having a radius of curvature from 60% to 200% of said focal length.

Regarding the third component, it may consist of a simple lens element without inconvenience.

The accompanying drawing illustrates diagrammatically in axial section a typical form of embodiment of a variable focal length lens system constituted according to the teachings of this invention.

In the drawing, C1, C2, C3 and C4 designates from front to rear the first, second, third and fourth components forming together an afocal optical system. C5 designates a convergent element permitting, in combination with said afocal optical system, the obtaining of a real image. The reference numerals 1, 2, 3, ... 13 designate the different lens elements, t1, t2, t3, ... t13 indicate the lens thicknesses, s1, s2, s3 . . . . s10 show the air-gaps provided between any two adjacent lens elements, and finally R1, R2, R3, ... R24 designate the radii of curvature of the lens surfaces. The diaphragm is disposed between components C4 and C5, and the numerical characteristics of the various component elements of the system are given in the following Table :

	Lens Element	N	ν	Radii in mm.	Thicknesses of the lens elements or air spaces in mm.
C_1	1	1.7313	28.4	R 1 = +684.15	
					t_1 = 1.15
				R 2 = + 50.49	
	2	1.6229	53.1		
				R 3 = −150.11	t_2 = 11.65
					s_1 = 0.08
	3	1.6229	53.1	R 4 = + 49.33	
					t_3 = 6.04
				R 5 = +197.90	
					s_2 from 0.46 to 33.55 and to 45.61
C_2	4	1.6906	54.0	R 6 = +156.48	
					t_4 = 1.21
				R 7 = + 16.87	
					s_3 = 4.95
				R 8 = − 31.80	
	5	1.5164			t_5 = 0.65
				R 9 = + 19.24	
	6	1.7313	28.4		t_6 = 4.24
				R 10 = + 89.79	
					s_4 from 47.15 to 14.06 and to 2
C_3	7	1.6202	60.2	R 11 = − 53.19	
					t_7 = 1.21
				R 12 = +158.43	
					s_5 from 0.40 to 5.35 and to 0.40
C_4	8	1.6202	60.2	R 13 = + 43.75	
					t_8 = 2.82
				R 14 = − 28.12	
					s_6 = 0.45
	9	1.7313	28.4	R 15 = − 21.34	
					t_9 = 0.80
				R 16 = − 29.33	
					s_7 from 6.95 to 2 and to 6.95
C_5	10	1.7199	50.3	R 17 = + 18.86	
					t_{10} = 7.44
				R 18 = −291.18	
					s_8 = 3.56
	11	1.7313	28.4	R 19 = − 21.14	
					t_{11} = 3.02
				R 20 = + 19.47	
					s_9 = 2.17
	12	1.6202	60.2	R 21 = + 163.52	
					t_{12} = 3.23
				R 22 = − 23.96	
					s_{10} = 0.11
	13	1.6202	60.2	R 23 = + 49.33	
					t_{13} = 2.48
				R 24 = − 30.80	

The focal length varies from 10 to 75.31. It has a value of 32.17 at the position of the second component where the third component changes its direction of movement whilst the second component continues to move in the same direction.

The intermediate values given in the above table for S_2, S_4, S_5 and S_7 similarly correspond to the position where the third component changes its direction.

In this Table as in the drawing the lens elements are designated in the front to rear direction in Col. I, the indices of refraction N for the Sodium spectrum line and the conventional dispersive powers (Abbe numbers) are given in Col. II and III, and the radii of curvature R of the lens surfaces, the thicknesses *t* of the lenses elements and the air gaps *s* are given in Col. IV and V.

In this Table the air gap s2 between the first and second components corresponds to the focusing of the lens system to infinity, but component C1 is adapted to be displaced axially forwards for focusing on near objects.

The focal length of component C1 is 77.93 mm, that of component C2 is 18.97 mm, that of component C3 is 64.07 mm, that of component C4 is 37.46 mm and that of component C5 is 29.45 mm. The focal length of the front member of the second components is 27.48 mm. The lens system is adjusted to its minimum focal length, that is 10 mm when s2=.46 mm, 34=47.15 mm, s5=.40 mm, s7=6.95 mm, the magnifications produced by the second and third components being $g^2=0.3644$ and $g^3=0.4479$. Moreover, it is adjusted to produce a focal length of 32.17 mm when s2=33.55 mm, s4=14.06, s5=5.35 mm and s7=2 mm, the magnifications produced by the second and third components being then $g^2=1$ and $g^3=0.5251$, and its maximum focal length is 75.31 mm when s2=45.61 mm, s4=2 mm, s5=.40 mm and s7=6.95 mm, the magnifications produced by the second and third components then being $g^2=2.744$ and $g^3=0.4479$.

In this example, while the divergent component C2 moves axially, component C4 moves likewise axially, in harmony with the law determining the position of these two components with a view to obtain a fixed position of the final or resultant image.

It may be pointed out that in this example component C4 could be kept in a fixed position and that an axial movement could be applied to component C3, whereby the latter, in combination with component C2, would also permit of maintaining the fixedness of the final image. In this alternative, the characteristics of the lens system given in the above Table would remain the same, except for the air gaps s4, s5 and s7 which would become:

s4=from 47.15 to 7.07 and to 2,
s5=from .40 to 7.39 and to .40, and
s7=2.

The lens system is adjusted to its minimum focal length which is 10 mm when s2=.46 mm, s4=47.15 mm, s5=.40 mm, s7=2 mm. This focal length is adjusted to 34.13 mm when s2=33.55 mm, s4=7.07, s5=7.39 mm, s7=2 mm, and the maximum focal length is 75.31 mm when s2=45.61 mm, s4=2 mm, s5=.40 mm and 37=2 mm.

WHAT I CLAIM IS:—

1. A variable focal length lens comprising a first convergent front component moved only for focusing a second axially movable divergent component, a third divergent component and a fourth convergent component, either of said third and fourth components being axially movable in combination with the axial movement of said second component in order to keep in a fixed position the image provided by the complete optical system constituting said lens, all of said four components being aligned on a common axis, said fourth component consisting of at least two lens elements, one of said lens elements being divergent and having a concave front face disposed very near to and behind a convergent lens element having a convex rear face, the combined power of said concave front face and said convex rear face being negative, the radius of curvature of said concave face ranging from 35% to 140% of the focal length of said fourth component and the radius of curvature of said convex face ranges from 40% to 160% of the focal length of said fourth component, said second component having an axial stroke such that when it has completed its rearward stroke the image magnification produced thereby is greater than four times the image magnification produced when it has completed its forward stroke and is positioned near the front component, said second component comprising at least three lens elements forming two members separated by an air gap of a value ranging from 15% to 80% of the focal length of said second component, the front member of said second component being divergent and having a focal length greater than once but less than twice the focal length of said second component, its front face being convex and its rear face concave with a radius of curvature ranging from 60% to 200% of the focal length of said second component, the rear member having at the front a concave face with a radius of curvature greater than the focal length of said second component, said rear member comprising at least one cemented surface between the two lens elements, said cemented surface having its convexity directed forwards and a convergent effect, with a radius of curvature ranging from 60% to 200% of the focal length of said second component, said third component having a power such that the magnification produced by said third component is always inferior to .8.

2. A variable focal length lens system as set forth in claim 1, wherein said second component produces a magnification inferior to .50 and greater than .20 when it has completed its forward stroke, and a magnification greater

than 2 and inferior to 5 when it has completed its backward stroke.

3. A variable focal length lens system as set forth in claim 1, wherein said fourth component comprises only two lens elements, the front lens element being biconvex and the rear lens element having a divergent meniscus configuration, the radius of curvature of the front face of said biconvex lens element ranging from 70% of the focal length of said component to infinity, and the radius of curvature of its rear face ranging from 50% to 250% of the same focal length.

4. A variable focal length lens system as set forth in claim 1, wherein the front member of said second component consists only of a divergent meniscus-shaped lens element having a convex front face with a radius of curvature greater than twice the focal length of said second component.

5. A variable focal length lens system as set forth in claim 1, wherein said fourth component is fixed and said third component is axially movable.

6. A variable focal length lens system as set forth in claim 1, wherein said third component is fixed and said fourth component is axially movable.

7. A variable focal length lens system as set forth in claim 1, wherein the rear member of said second component consists of two cemented lens elements, one of said two cemented lens elements being disposed at the front and having an index of refraction for the sodium spectrum line lower by at least .08 than that of the lens element associated therewith.

8. A variable focal length lens system as particularly described herein with reference to the accompanying drawing.

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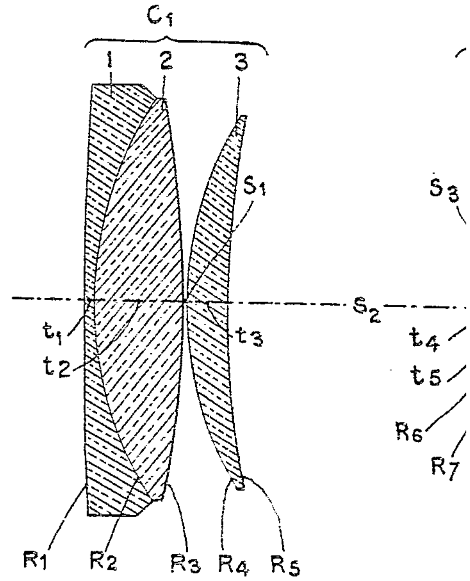

C1
1
2
3
S1
S3
S2
t1
t2
t3
t4
t5
R6
R7
R1
R2
R3
R4
R5

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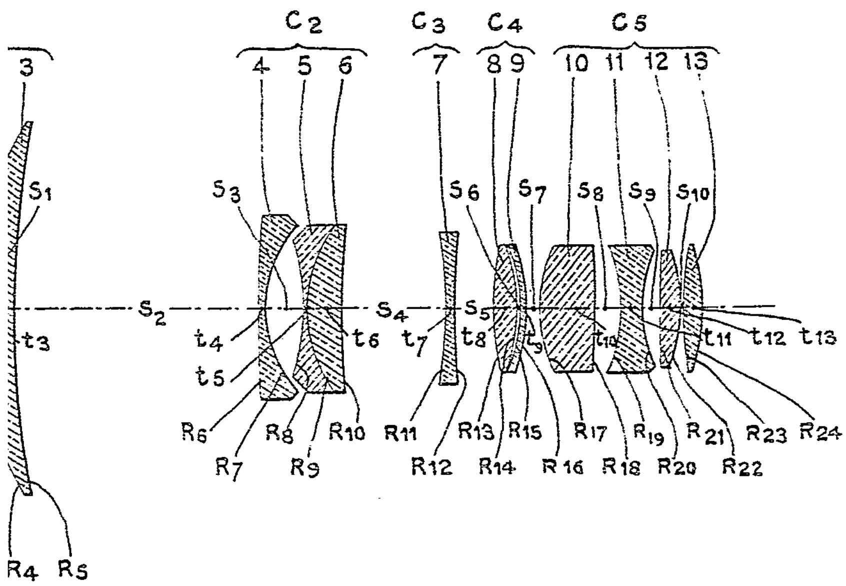
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*



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