PATENT SPECIFICATION

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to Variable Focal Length or Variable Magnification Lens Systems

I, PIERRE ANGENIEUX, a citizen of the French Republic, 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 optical systems with variable focal lengths, also referred to as zoom systems, or with variable magnification.

Such lens systems are known which comprise at the front a fixed convergent member and, just behind this member, an axially movable divergent member giving of the image produced by the front member a virtual image of which the dimensions vary as said divergent member moves along the optical axis. These lens systems comprise, in addition, another axially movable member which is necessary in order to keep in a fixed position the image formed by the complete lens system of a stationary object ; the movements of the two movable members are controlled through a mechanical device such as to adhere to the law governing these movements in order to maintain the fixedness of the final image. As a rule, this type of lens system comprises another fixed member located behind these members or between the movable members or even a third movable member.

It is known that one of the main difficulties to be overcome when endeavouring to make satisfactory images with a lens system of this character lies in the proper calculation and arrangement of the fixed front convergent member, because the position of the inlet pupil moves along the optical axis as the focal length of the lens system is altered.

Therefore, it is the object of this invention to provide a lens system of the type set forth hereinabove, wherein the front member is so constructed as to permit the production of good quality images. This invention relates only to the fixed front member in a lens system of this type

The nature and arrangement of the movable or fixed members located behind the movable divergent members disposed just behind the fixed front member are not within the scope of this invention.

According to the present invention, a variable focal length or variable magnification lens system comprising a fixed front convergent member and at least two axially movable members, the movable member which is disposed next to said fixed front member being divergent, is characterised in that its front member comprises at least three lens elements divided into a front portion and a rear portion, the focal length of said front portion being greater than 120 per cent of the focal length of said rear portion, said front portion consisting of a first front divergent lens element having a concave surface and of a second biconvex element disposed behind said first lens element at a distance varying from zero to a maximum of 5% of the focal length of said front convergent member, the combined effect produced by said concave rear surface of said first lens element and by said convex front surface of said second lens element being divergent, the absolute value of the ratio of the radius of curvature of the rear surface of said second biconvex lens element to that of the front surface of said first divergent lens element being lower than 2, and the radius of curvature of the front surface of the first divergent lens element having an absolute value greater than 2 f, (f designating the focal length of said fixed front member), the rear portion of said

front member having a front surface convex and a rear surface concave, and the radius of curvature of said rear surface being greater than f.

It is worth pointing out that the front portion of the front member is of unusual design due to the moderate refracting power of the front surface of its first lens element. Moreover, this front portion is of relatively moderate power since its focal length is constantly greater than 120 per cent of that of the rear portion.

According to a preferred embodiment of the invention the rear portion of the front member consists of a convergent lens element. However, it would not constitute a departure from the spirit and scope of the invention to divide this lens element into two or more elements.

Preferably, this convergent lens element consists of a meniscus having a concave rear surface with a radius of curvature greater than f. On the other hand, this third lens element is advantageously selected to have its focal length within the range of 1.1 f to 2 f.

According to a specific form of embodiment of the front portion of said front member, the rear surface of the front divergent lens element and the front surface of the second biconvex lens element have the same curvature and therefore these two lens elements may be cemented to each other. In this case the index of refraction of the divergent lens element is compulsorily greater than that of the biconvex lens element.

Finally, according to a preferred embodiment, the radius of curvature of the front surface of the first divergent lens element has a greater absolute value than the radius of curvature of the rear surface of the second biconvex lens element.

Typical embodiments of variable focal length or variable magnification lens systems according to this invention are illustrated in the attached drawing, wherein ;

Figures 1 and 2 are diagrammatic axial sections illustrating two different embodiments of a lens system according to this invention.

Referring first to fig. 1, this example illustrates a variable focal length lens system comprising four members I, II, III and IV wherein member II (divergent) and member III (convergent) are axially movable, the rear member IV being fixed and convergent.

The front member I, which is both fixed and convergent, is constructed according to this invention in that it consists of a first front divergent lens element having a concave rear surface and of a second biconvex lens element, the assembly of these two lens elements constituting a front portion, while the rear portion consists of a third convergent meniscus lens element having its convex surface located at the front.

Figure 2 illustrates an afocal device providing a variable magnification and adapted to be used as a variator when mounted in front of a conventional lens system. This device comprises similarly four members I*a*, II*a*, III*a*, IV*a*. The front convergent member I*a* is fixed and arranged according to this invention, the divergent member II*a* and the rear convergent member IV*a* are axially movable, and the divergent member III*a* is fixed.

In the following tables Example I refers to the form of embodiment illustrated in fig. 1, and Example II refers to the alternate embodiment shown in fig. 2. Examples III, IV and V are alternate embodiments of the front member I which may be substituted for the latter in the construction of Example I. In all these examples the focal lenght of the front member is 100.

In these tables, R1, R2, R3 designate the radii of curvature of each surface of the different lens elements from front to rear, the + sign indicating that the surface is convex to the front while the − sign means that the surface is concave to the front.

e1, e2, e3 designate the relative axial spacing between two adjacent surfaces.

Example I

Focal length of front portion = 651.2
Focal length of rear portion = 119.3

Member	Radii of Curvature	Thicknesses and Spaces	Glass Characteristics	
			Index of refraction nD	Abbe number V
	R1 = + 1 313.07			
	R2 = + 74.14	e1 = 1.63	1.6973	30.2
	R3 = + 78.10	e2 = 0.43	air	
I	R4 = − 256.69	e3 = 11.32	1.6201	60.2
	R5 = + 68.83	e4 = 0.09	air	
	R6 = + 937.46	e5 = 8.93	1.6201	60.2
	R7 = − 162.81	e6 from 4.493 to 47.311	air	
	R8 = + 32.87	e7 = 1.23	1.6204	60.2
II	R9 = − 71.14	e8 = 3.33	air	
	R10 = + 21.73	e9 = 0.92	1.6567	57
	R11 = + 373.75	e10 = 2.53	1.6992	30.2
	R12 = + 53.18	e11 from 44.128 to 1.444	air	
	R13 = − 58.11	e12 = 2.38	1.6588	51.1
III	R14 = + 22.12	e13 = 0.15	air	
	R15 = − 33.39	e14 = 2.92	1.6211	57
	R16 = + 192.63	e15 = 0.84	1.6751	32.3
	R17 = − 27.83	e16 from 3.022 to 2.888	air	
	R18 = + 19.56	e17 = 6.04	1.6500	33.8
IV	R19 = + 126.19	e18 = 2.01	air	
	R20 = − 17.51	e19 = 4.03	1.6567	57

The focal length varies from 21.55 to 79.31.

Example II

Focal length of front portion = 653.8
Focal length of rear portion = 119.6

Member	Radii of Curvature	Thicknesses and Spaces	Glass Characteristics	
			Index of refraction nD	Abbe number V
I	R1 = + 1 307.42	e1 = 1.63	1.6985	30.2
	R2 = + 73.83	e2 = 0.43	air	
	R3 = + 77.77	e3 = 11.27	1.6202	60.2
	R4 = − 255.59	e4 = 0.08	air	
	R5 = + 63.10	e5 = 8.89	1.6202	60.2
	R6 = + 400.62	e6 from 6.24 to 51.54	air	
II	R7 = − 153.05	e7 = 0.82	1.6202	60.2
	R8 = + 30.90	e8 = 3.47	air	
	R9 = − 67.19	e9 = 1.69	1.6574	57.2
	R10 = + 20.43	e10 = 4.64	1.6985	30.2
III	R11 = + 384.42	e11 from 47.38 to 2.08	air	
	R12 = − 155.94	e12 = 1.13	1.6985	30.2
	R13 = + 115.28	e13 from 2.40 to 1.15	air	
IV	R14 = + 64.74	e14 = 3.69	1.6906	54.0
	R15 = − 77.36		air	

The magnification ranges from 0.475 to 2.099.

Example III

Focal length of front portion = 311.8
Focal length of rear portion = 149.6

Member	Radii of Curvature	Thicknesses and Spaces	Glass Characteristics	
			Index of refraction nD	Abbe number V
I	R1 = + 916.91	e1 = 1.43	1.7314	28.4
	R2 = + 66.34	e2 = 14.54	1.6234	56.9
	R3 = − 155.47	e3 = 0.10	air	
	R4 = + 58.71	e4 = 7.52	1.6234	56.9
	R5 = + 150.76	e5 from 3.609 to 46.427	air	

Example IV

Focal length of front portion = 269.6
Focal length of rear portion = 156.9

Member	Radii of Curvature	Thicknesses and Spaces	Glass Characteristics	
			Index of refraction nD	Abbe number V
I	R1 = + 239.31	e1 = 1.41	1.7313	28.40
	R2 = + 82.97	e2 = 14.32	1.6202	60.2
	R3 = − 306.30	e3 = 0.10	air	
	R4 = + 75.85	e4 = 7.41	1.6202	60.2
	R5 = + 331.32	e5 from 2.228 to 45.046	air	

Example V

Focal length of front portion = 650.0
Focal length of rear portion = 119.4

Member	Radii of Curvature	Thicknesses and Spaces	Glass Characteristics	
			Index of refraction nD	Abbe number V
I	R1 = − 1 579.56	e1 = 1.63	1.6284	35
	R2 = + 74.22	e2 = 0.44	air	
	R3 = + 78.18	e3 = 11.33	1.6202	60.2
	R4 = − 256.94	e4 = 0.09	air	
	R5 = + 68.90	e5 = 8.94	1.6202	60.2
	R6 = + 938.19	e6 from 4.584 to 47.402	air	

WHAT I CLAIM IS:—

1. A variable focal length or variable magnification lens system comprising a fixed front convergent member and at least two axially movable members, the movable member which is disposed next to said fixed front member being divergent, said lens system being characterised in that its front member comprises at least three lens elements divided into a front portion and a rear portion, the focal length of said front portion being greater than 120 per cent of the focal length of said rear portion, said front portion consisting of a first front divergent lens element having a concave rear surface and of a second biconvex element disposed behind said first lens element at a distance varying from zero to a minimum of 5% of the focal length of said front convergent member, the combined effect produced by said concave rear surface of said first lens element and by said convex front surface of said second lens element being divergent the absolute value of the ratio of the radius of curvature of the rear surface of said second biconvex lens element to that of the front surface of said first divergent lens element being lower than 2, and the radius of curvature of the front surface of the first divergent lens element having an absolute value greater than 2 f, (f designating the focal length of said fixed front member), the rear portion of said front member having a front surface convex and a rear surface concave, and the radius of curvature of said rear surface being greater than f.

2. A lens system, according to claim 1, characterised in that the rear portion of the front member consists of a single convergent lens element.

3. A lens system according to claim 2, characterised in that said convergent lens element has a focal length in the range 1.1 f to 2 f.

4. A lens system, according to any one of the preceding claims, characterised in that the radius of curvature of the rear surface of the first divergent lens element of the front portion of said front member and that of the front surface of the second biconvex lens element of said front portion are equal, these two lens elements being cemented to each other.

5. A lens system, according to any one of the preceding claims, characterised in that the radius of curvature of the front surface of the first divergent lens element of the front member has a greater absolute value than the radius of curvature of the rear surface of the second biconvex lens element of the same front member.

6. A variable focal length or variable magnification lens system substantially as described hereinabove with reference to the accompanying drawing.

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945,652 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig : 1

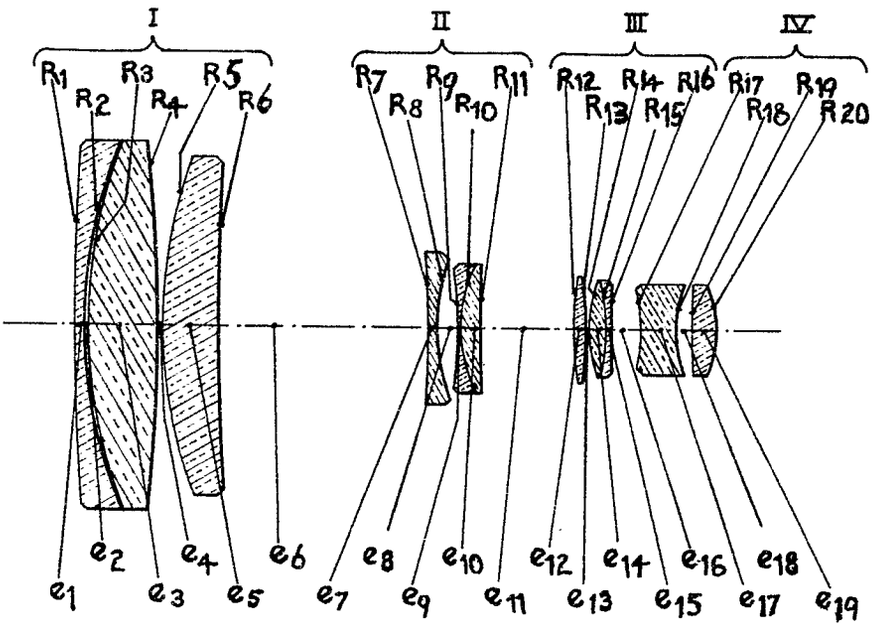

Fig : 2