

PATENT SPECIFICATION

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(54) LENS ASSEMBLY

(71) We, KARL VOCKENHUBER, of 118 Pötzleinsdorferstrasse, Vienna 18, Austria and RAIMUND HAUSER, of 2, Goldeggasse, Vienna 4, Austria, both Austrian Citizens, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a lens assembly, in particular a taking lens, with an afocal attachment of variable magnification and a basic lens system of fixed focal length, the attachment comprising two spaced lens systems of positive focal length but fixed with respect to the basic lens system, a negative lens system, adjacent to the front lens system and provided for varying the focal length and a second, negative lens system for maintaining the image position constant, the two negative lens systems being simultaneously and axially movable but at a varying rate between the two positive focal length systems.

Lens assemblies of the kind described hereinabove are focused to near objects by moving the positive lens system on the object side but this kind of close focusing is subject to relatively narrow limits because of the resultant increase of the front lens diameter to a size which exceeds any reasonable dimensions. It has therefore become the practice in obtaining extreme close focusing to move one of the interior lens systems which is adjustable for varying the focal length. However this method of close focusing continues to remain dependent on the appropriate focal length adjustment of the complete lens. One solution to the problem of obtaining extreme close focusing independent of focal length is to subdivide the front lens system into a negative component on the object side and a positive component which follows in the direction of light incidence. Close focusing is obtained by moving the negative component. The ray divergence which

predominates substantially downstream of the aforementioned negative component does not have any detrimental effect on the lens diameter.

In accordance with the present invention there is provided a lens assembly comprising an afocal attachment of variable magnification composed of four lens systems which are spaced from a basic lens system of fixed focal length; the attachment having its first and fourth lens systems positionally fixed with respect to the basic lens system and of positive focal length and the second and third lens systems being axially movable simultaneously but at a varying rate between the first and fourth lens systems and each having a negative focal length the second lens system being used to vary the focal length of the lens assembly and the third lens system being used to maintain the image position of the lens assembly constant; in which attachment the first lens system is provided, for close focusing of objects, with an axially-movable negative lens component disposed in front of a positive lens component, which positive lens component is nearer the basic lens system and comprises two lenses providing an achromatic doublet disposed between two separate positive lenses each having its face of greater curvature disposed nearer the doublet.

By utilising the invention it is possible to provide a lens assembly with a focal length variation ratio greater than five, and which enables extreme close exposures to be taken without any additional aids such as supplementary lenses.

The quasi-symmetrical construction of the lens of the invention offers a number of advantages in terms of correction facilities as well as in terms of manufacturing technology. Distributing the refractive indexes and therefore the coefficients of aberration over the individual lens surfaces enables inexpensive optical glass to be used for the three lenses of the positive component of the front element even for large-

aperture lenses with a distinct wide-angle effect.

- 5 The positions of nodal points is a measure of the symmetrical distribution of the refractive powers within the positive component. The distances between the two nodal points from their associated vertices should not differ by more than 10% from each other. Preferably the distance e_1 of the nodal point on the object side and the distance e_2 of the image side nodal point from the associated vertices of the positive component satisfy the following inequality:

$$0.9 e_1 \leq |e_2| \leq 1.1 e_1$$

- 15 Lenses having a short initial focal length have a distinct wide-angle effect when set to the shortest focal length, namely at $f_{\min} < 1.8 y$, where y is half the length of the image field diagonal, that is to say the shortest total focal length is therefore smaller by more than 10% than the image field diagonal $2y$. As a result and because of the substantial expansion, the diameters of the front lens system have a tendency to increase rapidly. To reduce this effect it is preferred that the two lenses which form the achromatic doublet of the positive component are separated from each other, the inward facing lens radii being of different sizes. The introduction of a thin air film in place of the cemented surface increases the affected radii by at least 50% with the same effect so that the mean thickness of the positive lens of the achromatic doublet is diminished by approximately 30% while the diameter remains unchanged, a circumstance which has a substantial effect on the reduction of the diameter of the negative component.

- 40 The invention will now be explained in more detail, by way of example, with reference to the accompanying diagrammatic drawings, in which:—

- 45 FIGURE 1a shows an attachment of a taking lens with a focal length variation ratio of approximately six with the focal length set to minimum;

FIGURE 1b shows the attachment set for maximum focal length;

FIGURE 1c shows a basic lens system for the attachment illustrated in Figures 1a and 1b; 50

FIGURE 2a to 2c shows in figures corresponding to figures 1a to 1c, respectively, a taking lens with a focal length variation ratio of approximately ten; and, 55

FIGURES 3a to 3c correspond to Figures 2a to 2c but show a third form of taking lens. 60

Figures 1a to c show a taking lens with a focal length variation ratio of approximately six. A lens system I on the object side has a positive focal length f_1 and is stationary relative to a basic lens system V with positive focal length f_v in the same sense as a lens system IV with positive focal length f_{iv} . A lens system II with negative focal length f_{ii} and a lens system III with negative focal length f_{iii} are simultaneously movable but at a different rate between lens system I and lens system IV, lens system II performing the motion required for varying the focal length while a constant image position is obtained by motion of the lens system III. A dividing prism P is illustrated between lens system IV and lens system V for reflecting the light which may be required for example for the optical view finder path. 65

The positive front lens system I comprises a negative lens component L_1 and a positive lens component L_2 . The positive component L_2 is constructed in such a way that a doublet element comprising a negative and a positive lens for the purpose of chromatic stabilisation is disposed between two individual positive lenses whose sides of greater curvature flank the element. 70

Further features of this lens are contained in the table below where r refers to the curvature radii d to the median lens thicknesses, l to the vertex distances and n_d or v_d refers to the refractive indexes or the Abbe numbers of the lenses. 75 80 85 90

			n_d	v_d
L_1	$r_1 + 12,033$	$d_1 = 0,08$	/	1,620 / 60,3
	$r_2 + 2,061$	$l_1 = 0,27$		
L_2	$r_3 - 2,419$	$d_2 = 0,08$	/	1,606 / 43,9
	$r_4 + 2,091$	$d_3 = 0,18$		
L_3	$r_5 + 10,440$	$l_2 = 0,14$	/	1,805 / 25,4
	$r_6 \text{ plan}$	$d_4 = 0,22$		
L_4	$r_7 - 1,990$	$l_3 = 0,01$	/	1,620 / 60,3
	$r_8 + 7,299$	$d_5 = 0,08$		
L_5	$r_9 + 1,412$	$d_6 = 0,37$	/	1,617 / 53,9
	$r_{10} - 5,204$	$l_4 = 1,01$		
L_6	$r_{11} + 1,362$	$d_7 = 0,26$	/	1,614 / 56,4
	$r_{12} + 5,970$	$0,06 \dots f_{\min}$		
L_7		$l_5 = 1,04 \dots f_M$		
		$1,41 \dots f_{\max}$		
L_8	$r_{13} + 3,522$	$d_8 = 0,05$	/	1,620 / 60,3
	$r_{14} + 0,611$	$l_6 = 0,15$		
L_9	$r_{15} - 0,722$	$d_9 = 0,05$	/	1,622 / 53,2
	$r_{16} + 0,967$	$d_{10} = 0,10$		
L_{10}	$r_{17} - 15,921$	$1,46 \dots f_{\min}$	/	1,805 / 25,4
		$l_7 = 0,30 \dots f_M$		
L_{11}		$0,11 \dots f_{\max}$		
	$r_{18} - 0,858$	$d_{11} = 0,05$		
L_{12}	$r_{19} - 2,458$	$0,05 \dots f_{\min}$	/	1,710 / 36,6
		$l_8 = 2,23 \dots f_M$		
L_{13}		$0,05 \dots f_{\max}$		
	$r_{20} - 2,275$	$d_{12} = 0,07$		
L_{14}	$r_{21} - 1,138$	$l_9 = 0,01$	/	1,620 / 60,3
	$r_{22} + 3,401$	$d_{13} = 0,09$		
P	$r_{23} - 2,318$	$l_{10} = 0,09$	/	1,569 / 56,1
	$r_{24} \text{ plan}$	$d_p = 0,37$		

			n_d	v_d
	r_{25} plan	$l_{11} = 0,23$		
L_{14}	$r_{26} + 0,784$	$d_{14} = 0,16$	/ 1,620	/ 60,3
	$r_{27} + 27,665$	$l_{12} = 0,29$		
L_{15}	$r_{28} - 1,005$	$d_{15} = 0,44$	/ 1,805	/ 25,4
	$r_{29} = 0,832$	$l_{13} = 0,03$		
L_{16}	$r_{30} + 1,847$	$d_{16} = 0,17$	/ 1,623	/ 56,9
	$r_{31} - 1,220$	$l_{14} = 0,01$		
L_{17}	$r_{32} + 1,1005$	$d_{17} = 0,15$	/ 1,683	/ 44,5
	$r_{33} - 1,817$	$f_{\min} = 0,34$		
		$f_M = 1,00$		
		$f_{\max} = 1,94$		
	relative aperture	$= 1:1,8$		
	image field diagonal	$2_y = 0,32$		
		$e_1 = 0,29$		
		$e_2 = -0,30$		

5 Figures 2a to c show a taking lens having a focal length variation ratio of approximately ten. The basic construction corresponds to that of the taking lens

already described with a focal length variation ratio of six. The greater complexity of the movable lens system II and III is due to the higher focal length variation ratio.

			n_d	v_d
L_1	$r_1 + 126,428$	$d_1 = 0,21$	/ 1,620	/ 38,1
	$r_2 + 5,765$	$l_1 = 0,84$		
L_2	$r_3 - 5,491$	$d_2 = 0,18$	/ 1,561	/ 45,2
L_3	$r_4 + 4,958$	$d_3 = 0,58$	/ 1,744	/ 44,8
	$r_5 + 23,057$	$l_2 = 0,22$		
L_4	$r_6 + 37,459$	$d_4 = 0,59$	/ 1,658	/ 50,9
	$r_7 - 5,903$	$l_3 = 0,01$		
L_5	$r_8 + 9,940$	$d_5 = 0,21$	/ 1,805	/ 25,4
	$r_9 + 4,582$	$l_4 = 0,11$		
L_6	$r_{10} + 5,544$	$d_6 = 0,66$	/ 1,620	/ 60,3
	$r_{11} - 10,618$	$l_5 = 0,01$		
L_7	$r_{12} + 3,114$	$d_7 = 0,54$	/ 1,618	/ 55,1
	$r_{13} + 8,269$	$0,17 \dots f_{\min}$		
		$1,80 \dots f_M$		
		$3,49 \dots f_{\max}$		

			n_d	v_d
L_8	$r_{14} - 37,459$	$d_8 = 0,09$	/	1,713 / 53,8
	$r_{15} + 2,509$	$l_7 = 0,07$		
L_9	$r_{16} + 2,711$	$d_9 = 0,11$	/	1,713 / 53,8
	$r_{17} + 1,548$	$l_8 = 0,35$		
L_{10}	$r_{18} - 6,088$	$d_{10} = 0,24$	/	1,805 / 25,4
	$r_{19} - 2,217$	$d_{11} = 0,09$		
L_{11}	$r_{20} + 25,291$		/	1,620 / 60,3
		$2,93 \dots f_{\min}$		
		$l_9 = 1,23 \dots f_M$		
		$0,17 \dots f_{\max}$		
L_{12}	$r_{21} - 1,548$	$d_{12} = 0,07$	/	1,623 / 56,9
L_{13}	$r_{22} + 1,548$	$d_{13} = 0,15$	/	1,785 / 26,1
	$r_{23} + 4,955$			
		$0,72 \dots f_{\min}$		
		$0,79 \dots f_M$		
		$l_{10} = 0,16 \dots f_{\max}$		
L_{14}	$r_{24} + 4,777$	$d_{14} = 0,13$	/	1,658 / 57,3
	$r_{25} - 9,957$	$l_{11} = 0,01$		
L_{15}	$r_{26} + 4,777$	$d_{15} = 0,13$		1,658 / 57,3
	$r_{27} - 9,957$	$l_{12} = 0,14$		
P	$r_{28} \text{ plan}$	$d_P = 0,60$	/	1,569 / 56,1
	$r_{29} \text{ plan}$	$l_{13} = 0,46$		
L_{16}	$r_{30} + 1,254$	$d_{16} = 0,25$	/	1,620 / 60,3
	$r_{31} - 76,280$	$l_{14} = 0,28$		
L_{17}	$r_{32} - 2,086$	$d_{17} = 0,56$	/	1,805 / 25,4
	$r_{33} - 1,300$	$l_{15} = 0,12$		
L_{18}	$r_{34} + 3,386$	$d_{18} = 0,29$	/	1,620 / 60,3
	$r_{35} - 1,897$	$l_{16} = 0,09$		
L_{19}	$r_{36} - 1,288$	$d_{19} = 0,29$	/	1,620 / 60,3
	$r_{37} - 18,006$			
		$f_{\min} = 0,45$		
		$f_M = 1,00$		
		$f_{\max} = 4,30$		

relative aperture = 1:1,8
 image field diagonal $2y = 0,52$
 $e_1 = 0,66$
 $e_2 = -0,70$

5 The embodiment illustrated in Figures 3a to c is a further development of the taking lens described with reference to Figures 2a to c, the aim being a simplification to save manufacturing costs as well as for the purpose of reducing the dimensions, more particularly the diameter of the front lens system but with an unchanged range of

focal length and with only a slight reduction 10 of the relative aperture.

The basic construction in which the individual lens groups are replaced by thin lenses, remains unchanged, detailed data of the embodiment being contained in the 15 table below.

			n_d	v_d
L_1	$r_1 + 96,316$	$d_1 = 0,17$	/ 1,618	/ 49,8
	$r_2 + 5,194$	$l_1 = 0,70$		
L_2	$r_3 - 5,738$	$d_2 = 0,17$	/ 1,618	/ 49,8
	$r_4 + 151,176$	$l_2 = 0,30$		
L_3	$r_5 + 50,593$	$d_3 = 0,56$	/ 1,691	/ 54,7
	$r_6 - 6,025$	$l_3 = 0,01$		
L_4	$r_7 + 12,000$	$d_4 = 0,19$	/ 1,805	/ 25,4
	$r_8 + 4,748$	$l_4 = 0,06$		
L_5	$r_9 + 5,128$	$d_5 = 0,67$	/ 1,620	/ 60,3
	$r_{10} - 11,111$	$l_5 = 0,01$		
L_6	$r_{11} + 3,311$	$d_6 = 0,59$	/ 1,641	/ 60,1
	$r_{12} + 16,283$	$0,13 \dots f_{\min}$		
		$1,77 \dots f_M$		
		$l_6 \quad 3,46 \dots f_{\max}$		
L_7	$r_{13} + 151,226$	$d_7 = 0,09$	/ 1,641	/ 60,1
	$r_{14} + 1,333$	$l_7 = 0,37$		
L_8	$r_{15} - 24,770$	$d_8 = 0,30$	/ 1,805	/ 25,4
L_9	$r_{16} - 1,653$	$d_9 = 0,07$	/ 1,620	/ 60,3
	$r_{17} + 3,685$	$3,04 \dots f_{\min}$		
		$1,34 \dots f_M$		
		$l_8 \quad 0,27 \dots f_{\max}$		

7	1,388,081				7
L ₁₀	r ₁₈ - 1,875	d ₁₀ = 0,07	/	1,744 / 44,8	
	r ₁₉ + 12,742	0,75...f _{min}			
		0,81...f _M			
		0,19...f _{max}			
			n _d	v _d	
L ₁₁	r ₂₀ + 3,052	d ₁₁ = 0,26	/	1,487 / 70,4	
	r ₂₁ - 1,979	l ₁₀ = 0,14			
P	r ₂₂ plan	d ₁₂ = 0,61	/	1,569 / 56,1	
	r ₂₃ plan	l ₁₁ = 0,55			
L ₁₂	r ₂₄ + 1,073	d ₁₃ = 0,25	/	1,650 / 39,2	
	r ₂₅ + 8,556	l ₁₂ = 0,27			
L ₁₃	r ₂₆ - 1,600	d ₁₄ = 0,71	/	1,805 / 25,4	
	r ₂₇ + 1,311	l ₁₃ = 0,14			
L ₁₄	r ₂₈ + 2,993	d ₁₅ = 0,22	/	1,620 / 60,3	
	r ₂₉ - 1,681	l ₁₄ = 0,09			
L ₁₅	r ₃₀ + 1,763	d ₁₆ = 0,22	/	1,641 / 60,1	
	r ₃₁ - 4,257	f _{min} = 0,46			
		f _M = 1,00			
		f _{max} = 4,32			
relative aperture		= 1: 2			
image field diagonal		2y = 0,52			
		e ₁ = 0,65			
		e ₂ = -0,65			

In the above three examples of the arrangements shown in the drawings it is to be understood that the tabulated data is subject to a curvature deviation of individual surfaces of up to $\pm 10\%$ of the refractive power of the appropriate element of the thicknesses of up to $\pm 10\%$ of the appropriate element, of the refractive indices of up to ± 0.03 , and of the Abbé numbers of up to ± 5 .

WHAT WE CLAIM IS:—

1. A lens assembly comprising an afocal attachment of variable magnification composed of four lens systems which are spaced from a basic lens system of fixed focal

length; the attachment having its first and fourth lens systems positionally fixed with respect to the basic lens system and of positive focal length, and the second and third lens systems being axially movable simultaneously but at a varying rate between the first and fourth lens systems and each having a negative focal length the second lens system being used to vary the focal length of the lens assembly and the third lens system being used to maintain the image position of the lens assembly constant; in which attachment the first lens system is provided, for close focusing of objects, with an axially-movable negative lens component disposed in front of a

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L_{10}	$r_{18} - 1,875$	$d_{10} = 0,07$	/	1,744	/	44,8
	$r_{19} + 12,742$					
		$0,75...f_{min}$				
		$0,81...f_M$				
		$0,19...f_{max}$				
				n_d		v_d
L_{11}	$r_{20} + 3,052$	$d_{11} = 0,26$	/	1,487	/	70,4
	$r_{21} - 1,979$	$l_{10} = 0,14$				
P	r_{22} plan	$d_{12} = 0,61$	/	1,569	/	56,1
	r_{23} plan	$l_{11} = 0,55$				
L_{12}	$r_{24} + 1,073$	$d_{13} = 0,25$	/	1,650	/	39,2
	$r_{25} + 8,556$	$l_{12} = 0,27$				
L_{13}	$r_{26} - 1,600$	$d_{14} = 0,71$	/	1,805	/	25,4
	$r_{27} + 1,311$	$l_{13} = 0,14$				
L_{14}	$r_{28} + 2,993$	$d_{15} = 0,22$	/	1,620	/	60,3
	$r_{29} - 1,681$	$l_{14} = 0,09$				
L_{15}	$r_{30} + 1,763$	$d_{16} = 0,22$	/	1,641	/	60,1
	$r_{31} - 4,257$	$f_{min} = 0,46$				
		$f_M = 1,00$				
		$f_{max} = 4,32$				
relative aperture		$= 1:2$				
image field diagonal		$2y = 0,52$				
		$e_1 = 0,65$				
		$e_2 = -0,65$				

In the above three examples of the arrangements shown in the drawings it is to be understood that the tabulated data is subject to a curvature deviation of individual surfaces of up to $\pm 10\%$ of the refractive power of the appropriate element of the thicknesses of up to $\pm 10\%$ of the appropriate element, of the refractive indices of up to ± 0.03 , and of the Abbé numbers of up to ± 5 .

WHAT WE CLAIM IS:—

1. A lens assembly comprising an afocal attachment of variable magnification composed of four lens systems which are spaced from a basic lens system of fixed focal

length; the attachment having its first and fourth lens systems positionally fixed with respect to the basic lens system and of positive focal length, and the second and third lens systems being axially movable simultaneously but at a varying rate between the first and fourth lens systems and each having a negative focal length the second lens system being used to vary the focal length of the lens assembly and the third lens system being used to maintain the image position of the lens assembly constant; in which attachment the first lens system is provided, for close focusing of objects, with an axially-movable negative lens component disposed in front of a

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5 positive lens component, which positive lens component is nearer the basic lens system and comprises two lenses providing an achromatic doublet disposed between two separate positive lenses each having its face of greater curvature disposed nearer the doublet.

10 2. A lens assembly according to claim 1, in which the distance e_1 of the nodal point (H) on the object side and the distance e_2 of the image side nodal point (H') from the associated vertices of the positive lens component satisfy the following inequality:

$$0.9 e_1 \leq |e_2| \leq 1.1 e_1$$

3. A lens assembly according to claim 1 or claim 2, in which the two lenses which form the achromatic doublet are separated from each other and the curvature of their adjacent faces is different.

4. A lens assembly as claimed in claim 1, arranged and adapted to operate substantially as described with reference to any one of the accompanying drawings.

5. An attachment for a lens assembly as claimed in claim 4.

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