

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO PHOTOGRAPHIC LENSES

(71) We, PONDER & BEST INC., of 11201 W. Pico Blvd, Los Angeles, California, United States of America, a corporation organized and existing under the laws of the State of California, United States of America, 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:—

This invention relates to photographic lenses, and more particularly relates to lens of relatively long focal lengths and telephoto lens.

Moderately long focal length telephoto objectives such as a three hundred millimeter objective for thirty-five millimeter cameras have traditionally focused on objects no closer than approximately ten times the focal length. One reason for this limitation is focusing for a particular object distance requires an objective lens travel which is proportional to the square of the focal length. For closeup focusing, this results in extensive lens travel, requiring either several turns of the focusing ring or potential imprecise focusing resulting from a large thread pitch angle of the focusing ring. Additionally, with large focusing travel it is difficult to achieve linkage with an automatic diaphragm as utilized on many thirty-five millimeter single lens reflex cameras.

Another difficulty in achieving close focus is poor image quality. In order to achieve compactness in a telephoto objective, the focal lengths of the individual lens components must be considerably shorter than a non-telephoto objective of the same focal length. The change of aberration correction as a function of magnification change is a complicated function which increases rapidly with decreased focal length of the components.

The degradation in image quality as a function of magnification or focusing distance varies from one lens type to another but, for example, if a three hundred millimeter objective is optimized for approximately thirty-five feet object distance, the image quality at

ten feet object distance will be greatly degraded. If a closer object distance were required, image quality could degenerate to the point of being unacceptable even for novel use.

Ordinarily, various lens types are optimized for a pre-determined distance. When the objective is moved the spherical aberration or axial imagery will not change significantly. However, as the lens is focused close, the off-axis imagery will change significantly.

The present invention consists in a lens having an equivalent focal length greater than its front vortex distance when focused to infinity, said lens comprising a housing, a plurality of lens elements coaxially mounted in a said housing, means for moving said lens elements axially in fixed relation to focus said lens, a compensating lens in said housing behind said lens elements in fixed relation to said housing, said compensating lens serving to correct aberrations due to off-axis imagery when said lens is close focused.

By front vortex distance is meant the axial distance, when the lens is focused to infinity, between the image plane and that face of the lens which is furthest away from the image plane.

One lens structure according to the invention permits the lens to be focused more closely without degradation of the off-axis imagery. This is achieved by providing a lens type using a relatively long focal length lens at a fixed position with reference to the film plane. Then, as the lens is focused, only the foremost portion of the lens moves while the rear component remains fixed with respect to the film. Dependent on the particular fronting lens or objective which is used, various fixed back groups may be utilized, such as cemented or air spaced doublet, or negative meniscus. The compensating lens is selected to be of essentially zero or negative power.

In such an arrangement, with the rear lens element fixed in location to the film plane, when the front elements are moved, the spherical aberration or axial imagery will not change significantly. The off-axis imagery,

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however, would ordinarily change significantly. With the proper design of the rear group, the change will have a compensating effect to that which would normally occur without the correcting element, without degradation of the on-axis imagery.

5 The fixed rear element can have negative power. The focal length of the lens as a total unit thus decreases as the front or objective portion is moved for closer focusing.

10 Another lens structure according to the invention corrects off-axis aberration while allowing closer focusing of the lens with respect to an object to be photographed.

15 Another structure according to the invention is a new and improved simplified telephoto lens structure which permits closer focusing of lens of predetermined focal length, without excessive travel of the objective elements.

20 The invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

25 Figure 1 is a longitudinal view, partially in cross section of a lens embodying the invention;

Figure 2 is a representation of the image frame of a camera;

30 Figure 3 is a representation of a 135 mm f/2.3 five element objective lens with a meniscus aberration corrector element.

Figure 4 is a representation of a 135 mm f/2.0 five element objective lens with an air spaced doublet correction lens; and

35 Figure 5 is a representation of a 200 mm f/3.0 five element objective lens with a single meniscus correction lens.

40 A lens assembly 10 embodying the invention generally comprises a housing 11 which includes a barrel 12, a focusing ring or sleeve 13 and a mounting member 14.

45 The mounting member 14 includes mounting means generally indicated by the reference numeral 15 adapted to mount the lens to a camera body indicated in broken line by the reference numeral 16. The camera body 16 will have means defining a film plane 17. Also defined in the camera body will be means defining an image frame which is mounted just before the film plane, generally indicated by the numeral 18 which is also shown diagrammatically in Figure 2.

50 Mounted to the barrel for movement therewith are objective lens elements 20, 21, 22, 23 and 24 and 25. When the focusing ring 13, which is threadably connected to the barrel, is rotated the barrel 12 will move longitudinally with respect to focusing ring 13. A pin

or guide 28 or other suitable means extends between mounting member 14 and depending portion 29 of barrel 12 to prevent rotation of the barrel and insure only linear movement thereof. Mounting member 14 at the forward end thereof has a radially inwardly directed flange 30 and an axially directed lens mount 31. Mount 31 carries therein an aberration correction or compensating lens 32 which is at all times held in fixed relation to film plane 17.

60 Dependent upon the lens parameters, the compensating element may be a singlet element, a doublet or a more complex design, dependent on the relative aperture. Generally, for a relative aperture of about f/3.0 a singlet corrector lens is adequate. For larger relative apertures, a doublet corrector may be utilized. However, this will depend on the overall lens design. For example, an air spaced or cemented doublet corrector can be used for apertures exceeding f/2.0 with magnifications of 0 to 1.0 with very good results.

70 It has been determined that when the front elements 20—25 are moved in barrel 12, the off-axis imagery would ordinarily change significantly. However, with the provision of the correcting element 32, the off-axis or lateral aberration is compensated without degradation of the on-axis image.

75 The correcting element is chosen to have an effective focal length (EFL) equal to or greater than twice the back focal length (BFL) of the overall lens, where the BFL is equal to or greater than .7D, and where D is a diagonal measure of the image frame, as exemplified in Figure 2.

80 With this arrangement the spherical aberration or axial imagery will not change significantly as the objective portion alone is moved. However, the correcting element 32 will compensate for the change in off-axis imagery which would be significant in the absence of the correcting element.

85 The compensating lens 32 is of negative power. In this construction, the focal length of the overall lens would decrease as the front portion is moved for focusing on a closeup object. Because of the relationship between focusing travel and focal length a small change in focal length results in a large difference in focusing travel. Thus a three hundred millimeter lens for a 24 mm×36 mm image frame which would normally focus to ten feet could focus to five feet with the same lens travel.

90 Table I below sets forth the data on the lens of Figure 1.

TABLE I
300 mm f/4.5 (Figure 1)

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
5		R1=86.177			
	20	R2=-4025.350	10.000 m.m.	1.498	66.7
			0.300		
		R3=68.910			
10	21	R4=-177.800	13.300	1.533	45.9
			0		
		R5=-177.800			
	22		6.000	1.613	43.8
15		R6=-plano	1.810		
		R7=3140.932			
	23		6.000	1.847	23.8
		R8=83.236			
20			58.272		
		R9=-322.731			
	24		5.794	1.785	25.6
		R10=-52.222			
			3.796		
25		R11=-40.0201			
	25		6.280	1.816	44.5
		R12=-419.537			
			20.491		
30		R13=132.6794			
	32		3.828	1.516	64.0
		R14=76.992			
			93.39		
		Film Plane			

In the foregoing table N_d is the index of refraction and V_d is the Abbe number.

The lens specified has an FVD of 209.990 mms. may be termed a compact telephoto inasmuch as the ratio of the front vortex distance (FVD) to the equivalent focal length is less than 0.7.

The lens shown in Figure 1 is a three hundred millimeter f/4.5 lens for a 24 mm×36 mm image frame (35 mm) camera. This lens utilizes a negative meniscus 32 as the aberration correction element. The meniscus 32 has an EFL=-363 mm, and the overall lens has a vertex-to-vertex distance of 126.23 mm.

The equivalent focal length of the corrector

lens 32 is -363 mm, more than twice the BFL (93.39 mm) of the overall lens, and the BFL is greater than 0.7 of the diagonal D of the image frame. The space between elements 25 and 32 varies from 1.22 mm to 20.491 mm for focusing from seven feet to infinity. The corrector element 32 as well as the mechanical design of the lens housing in this lens permits focusing as close as five focal lengths without unacceptable lateral aberration for most purposes.

Figure 9 illustrates a 135 mm f/2.3 lens for 24 mm×36 mm image frame camera using a single meniscus L6. The data on this lens is shown in Table II.

TABLE II
135 mm f/2.3 (Figure 3)

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
70	L1	R1=45.6583 mm			
		R2=-3538.80	12.15 mm	1.6228	56.9
			0.34		
		R3=45.5236			
	L2		11.13	1.5168	64.2
75		R4=77.8311			
			4.64		
		R5=-145.2645			

TABLE II (Cont.)

5	L3	R6=35.1509	3.51	1.80518	25.5
			19.22		
		R7=95.1885	6.93	1.64769	33.8
10	L4	R8=-44.2681	4.58		
		R9=-37.3576	2.00	1.6223	53.1
		R10=-95.1509	*		
15	L5	R11=62.1185	2.00	1.54814	45.8
		R12=44.4264	59.67		
		Film Plane			

- 20 N_d is the index of refraction and V_d is the Abbe number.
- 25 The back focal length of the lens is 59.67 mm. The space between lens elements L5 and L6 varies between 0.87 mm and 10.4 for focusing from infinity to 1500 mm. or less than 59 inches.
- 30 The effective focal length of the corrector element L6 is -296.4 mm. The lens L6 is a negative meniscus. The FVD is 127.04 mms. Figure 4 illustrates a 135 mm f/2.0 lens for a 24 mm×36 mm image frame camera. The data on this lens is shown in Table III.

TABLE III
135 mm f/2.0 (Figure 4)

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
35	L1	R1=51.645 mm			
		R2=plano	14.100 mm	1.60729	59.5
			.369		
40	L2	R3=50.030	11.841	1.5168	64.2
		R4=100.33	5.017		
		R5=-233.12	4.050	1.80518	25.5
45	L3	R6=46.807	26.491		
		R7=126.394	5.684	1.71736	29.5
		R8=-59.478	6.934		
50	L4	R9=-37.419	3.645	1.64769	33.8
		R10=-338.400	*		
		R11=-144.915	4.725	1.80518	25.5
55	L5	R12=-70.159	3.921		
		R13=-70.863	2.160	1.71736	20.5
		R14=-149.480	39.92		
60	L6	Film Plane			
65	L7				

N_d is the index of refraction and V_d is the Abbe number.

The back focal length of the lens is 39.92 mm. The space between lens elements L5 and L6 varies between 1.16 mm and 15.82 mm for focusing from infinity to 1688 mm or about twelve and one-half focal lengths or about 66.4 inches.

The effective focal length of the corrector

doublet is +1195 mm.

The corrector elements L5 and L6 are of positive and negative power.

The FVD is 130.017 mms.

Figure 5 illustrates a 200 mm f/3.0 lens or a 24 mm×36 mm image frame camera using a single meniscus L6. The data on this lens is shown in Table IV.

TABLE IV
200 mm f/3.0 (Figure 5)

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
20		R1=56.828 mm			
	L1		12.0 mm	1.56873	63.1
		R2=3586.0	.5		
25		R3=62.384			
	L2		11.3	1.51680	64.2
		R4=428.03	5.46		
30		R5=-254.83			
	L3		4.13	1.80518	25.5
		R6=64.06	29.21		
		R7=-1567.0			
35	L4		5.61	1.80518	25.5
		R8=-54.70	5.24		
		R9=-38.14			
	L5		1.85	1.71270	43.3
40		R10=-157.93	*		
		R11=71.98			
	L6		2.0	1.57957	53.7
		R12=47.56	77.5		
45		Film Plane			

N_d is the index of refraction and V_d is the Abbe number.

The back focal length of the lens is 77.5 mm. The space between elements L5 and L6 varies between 3.2 mm and 15.0 mm for focusing between infinity and 2372 mm or about 93 inches.

The effective focal length of the corrector element is -240.4 mm.

The lens L6 is a negative meniscus.

The FVD is 158.00 mms.

The present invention provides lenses with movable objectives while maintaining a compensating lens in fixed relation to the film plane. With this arrangement where the power of the compensating lens is essentially zero or negative, the lens will deliver optimum performance from infinity to closer distances heretofore obtainable.

The corrector lens may have positive power so long as its power is so small that it is essentially zero. The power is for all practical purposes is essentially zero when the focal

length of the corrector is at least eight times the overall EFL of the lenses including the corrector. In this instance attention is invited to the EFL of the corrector of Figure 3. (Table II).

Generally, the EFL of the corrector will only be positive when the magnitude of the focusing travel is not a primary concern.

It may thus be seen that the objects of the invention set forth as well as those made apparent from the foregoing description are efficiently attained. While preferred embodiments of the invention have been set forth for purposes of disclosure, modification to the disclosed embodiments of the invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the scope thereof.

WHAT WE CLAIM IS:—

1. A lens having an equivalent focal length

N_a is the index of refraction and V_a is the Abbe number.

The back focal length of the lens is 39.92 mm. The space between lens elements L5 and L6 varies between 1.16 mm and 15.82 mm for focusing from infinity to 1688 mm or about twelve and one-half focal lengths or about 66.4 inches.

The effective focal length of the corrector

doublet is +1195 mm.

The corrector elements L5 and L6 are of positive and negative power.

The FVD is 130.017 mms.

Figure 5 illustrates a 200 mm f/3.0 lens or a 24 mm x 36 mm image frame camera using a single meniscus L6. The data on this lens is shown in Table IV.

TABLE IV
200 mm f/3.0 (Figure 5)
Axial Distance
Between Surfaces

	Lens	Radius		N_a	V_a
20		R1=56.828 mm			
	L1		12.0 mm	1.56873	63.1
		R2=3586.0	.5		
25		R3=62.384			
	L2		11.3	1.51680	64.2
		R4=428.03	5.46		
30		R5=-254.83			
	L3		4.13	1.80518	25.5
		R6=64.06	29.21		
		R7=-1567.0			
35	L4		5.61	1.80518	25.5
		R8=-54.70	5.24		
		R9=-38.14			
	L5		1.85	1.71270	43.3
40		R10=-157.93	*		
		R11=71.98			
	L6		2.0	1.57957	53.7
		R12=47.56	77.5		
45		Film Plane			

N_a is the index of refraction and V_a is the Abbe number.

The back focal length of the lens is 77.5 mm. The space between elements L5 and L6 varies between 3.2 mm and 15.0 mm for focusing between infinity and 2372 mm or about 93 inches.

The effective focal length of the corrector element is -240.4 mm.

The lens L6 is a negative meniscus.

The FVD is 158.00 mms.

The present invention provides lenses with movable objectives while maintaining a compensating lens in fixed relation to the film plane. With this arrangement where the power of the compensating lens is essentially zero or negative, the lens will deliver optimum performance from infinity to closer distances heretofore obtainable.

The corrector lens may have positive power so long as its power is so small that it is essentially zero. The power is for all practical purposes is essentially zero when the focal

length of the corrector is at least eight times the overall EFL of the lenses including the corrector. In this instance attention is invited to the EFL of the corrector of Figure 3. (Table II).

Generally, the EFL of the corrector will only be positive when the magnitude of the focusing travel is not a primary concern.

It may thus be seen that the objects of the invention set forth as well as those made apparent from the foregoing description are efficiently attained. While preferred embodiments of the invention have been set forth for purposes of disclosure, modification to the disclosed embodiments of the invention, as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the scope thereof.

WHAT WE CLAIM IS:—

1. A lens having an equivalent focal length



greater than its front vortex distance when focused to infinity, said lens comprising a housing, a plurality of lens elements coaxially mounted in a said housing, means for moving said lens elements axially in fixed relation to focus said lens, a compensating lens in said housing behind said lens elements in fixed relation to said housing, said compensating lens serving to correct aberrations due to off-axis imagery when said lens is close focused.

2. A lens according to claim 1 where said compensating lens is of negative power.

3. A lens according to claim 2 where the absolute value of the equivalent focal length of the compensating lens is no greater than three times the equivalent focal length of the overall lens.

4. A lens according to claim 1 where the power of the compensating lens is positive

and the compensating lens is an air spaced doublet.

5. A lens according to claim 4 wherein the equivalent focal length of the compensating lens is over eight times greater than the equivalent focal length of the overall lens.

6. A lens according to claim 2 where the compensating lens is a negative meniscus having its concave surface on the image side.

7. A lens according to claim 1 wherein said movable lens elements define a first positive group of at least two lens elements, a second group of negative power having its major power contribution on its image side surface, followed by an aperture stop, and a third group of positive power.

8. A lens according to claim 1, 2, 3 or 4 defined by the data substantially as set forth in the following table:

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
40		$R1=86.177$			
	L1	$R2=-4025.350$	10.000	1.498	66.7
			0.300		
45		$R3=68.910$			
	L2	$R4=-177.800$	13.300	1.533	45.9
			0		
		$R5=-177.800$			
50	L3	$R6=-\text{plano}$	6.000	1.613	43.8
			1.810		
	L4	$R7=3140.932$	6.000	1.847	23.8
55		$R8=83.236$			
			58.272		
	L5	$R9=-322.731$	5.794	1.785	25.6
		$R10=-52.222$	3.796		
60		$R11=-40.0201$			
	L6	$R12=-419.537$	6.280	1.816	44.5
			20.491		
65		$R13=132.6794$			
	L7	$R14=76.992$	3.828	1.516	64.0
			93.39		
		Film Plane			

70 Where L1—L7 represents the lens elements progressively from the front objective to the rearmost element, R1—R14 being the radii of the lens surfaces, the axial distance is measured axially between lens surfaces, N_d is the index of refraction of each lens element,

and V_d is Abbe numbers of the lenses L1—L7.

9. The lens of claim 6 defined by data substantially as set forth in the following table:



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	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
5	L1	R1=45.6583 mm			
		R2=-3538.80	12.15 mm	1.6228	56.9
			0.34		
10	L2	R3=45.5236			
		R4=77.8311	11.13	1.5168	64.2
			4.64		
15	L3	R5=-145.2645			
		R6=35.1509	3.51	1.80518	25.5
			19.22		
20	L4	R7=95.1885			
		R8=-44.2681	6.93	1.64769	33.8
			4.58		
25	L5	R9=-37.3576			
		R10=-95.1509	2.00	1.6223	53.1
			*		
30	L6	R11=62.1185			
		R12=44.4264	2.00	1.54814	45.8
			59.67		

Film Plane

Where L1—L6 represent the lens elements progressively from the front objective to the rearmost element, R1—R12 being the radii of the lens surfaces, the axial distances is measured axially between lens surfaces, N_d is the index of refraction of each lens element, and V_d is the Abbe number of the lenses L1—L6, and the space * between elements L5 and L6 varies for focusing. 10. The lens of claim 1 or 5 defined by data substantially as set forth in the following table:

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
40	L1	R1=51.645 mm			
		R2=plano	14.100 mm	1.60729	59.5
			.369		
45	L2	R3=50.030			
		R4=100.33	11.841	1.5168	64.2
			5.017		
50	L3	R5=-233.12			
		R6=46.807	4.050	1.80518	25.5
			26.491		
55	L4	R7=126.394			
		R8=-59.478	5.684	1.71736	29.5
			6.934		
60	L5	R9=-37.419			
		R10=-338.400	3.645	1.64769	33.8
			*		
65	L6	R11=-144.915			
		R12=-70.159	4.725	1.80518	25.5
			3.921		
70	L7	R13=-70.863			
		R14=-149.480	2.160	1.71736	20.5
			39.92		
		Film Plane			



- Where L1—L7 represent the lens elements progressively from the front objective to the rearmost element, R1—R14 being the radii of the lens surfaces, the axial distance is measured axially between lens surfaces, N_d the index of refraction of each lens element, and V_d is the Abbe number of the lenses L1—L7, and the space * between elements L5 and L6 varies for focusing.
11. The lens of claim 1, 2, 3 or 6 defined by data substantially as set forth in the following table:

	Lens	Radius	Axial Distance Between Surfaces	N_d	V_d
15	L1	R1=56.828 mm R2=3586.0	12.0 mm .5	1.56873	63.1
20	L2	R3=62.384 R4=428.03	11.3 5.46	1.51680	64.2
25	L3	R5=-254.83 R6=64.06	4.13 29.21	1.80518	25.5
30	L4	R7=-1567.0 R8=-54.70	5.61 5.24	1.80518	25.5
35	L5	R9=-38.14 R10=-157.93	1.85 *	1.71270	43.3
	L6	R11=71.98 R12=47.56	2.0 77.5	1.57957	53.7
		Film Plane			

- Where L1—L6 represent the lens elements progressively from the front objective to the rearmost element, R1—R12 being the radii of the lens surfaces, the axial distance is measured axially between lens surfaces, N_d is the index of refraction of each lens element, and V_d is the Abbe number of the lenses L1—L6, and the space * between elements L5 and L6 varies for focusing.
12. A photographic lens constructed;
- arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

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