

SPECIFICATION

Improvements in zoom lenses

5 This invention relates to zoom lenses. 5

Many zoom or variable focal length lenses have been designed based on a classical telephoto construction. Lenses of this type usually comprise at least three groups and have typically in excess of ten elements. Prior constructions have a front group of positive power, which is followed by a moving negative power group having significant separation at the long focal length position, and a rear group which is often 10 movable with the intermediate group. Attempts to simplify construction so as to reduce costs have not been consistent with obtaining a large zoom ratio while maintaining high image quality unless the numerical aperture is reduced significantly. Further, the attempted simplified lens designs have seldom resulted in relatively compact configurations which use inexpensive optical materials. 10

Zoom lenses have become popular as optical characteristics, image quality, and zoom ranges have 15 improved. Such lenses are being used more frequently in place of single focal length lenses than just a few years ago. However, most of these zoom lens designs have moderate relative apertures which make the lenses less competitive in the existing market of accessory photographic equipment for cameras. 15

The present invention consists in a zoom lens comprising from the object end, a first negative group followed by a second positive group, said groups being movable axially of each other to vary the equivalent 20 focal length of the lens, the absolute value of the equivalent focal length of said group $|F_1|$ being greater than the lower limit equivalent focal length of said lens, and 20

$$3 > |F_1| / F_2 \geq 1.6$$

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where F_2 is the equivalent focal length of said second group, the lower limit equivalent focal length being greater than the diagonal of the image frame of said lens, said first group consisting of two elements, one of which is biconcave.

30 One lens embodying the invention is an improved variable equivalent focal length (EFL) lens of relatively high speed, and range extending from normal into the telephoto region. The present lens provides a compact zoom having a relative aperture of $f/2.8$ or faster, yet is of a simple form with as few as two basic groups and as few as six lens elements. The lens consists of a negative group followed by a positive group. This order is the opposite order of usual long focus zoom lenses. Compactness of the lens construction is 35 provided by having an absolute value focal length ratio of the absolute value of the first group to the second group of greater than 1.60 by utilizing only a thin doublet for the first group, and a telephoto objective for the second group. Compactness is aided in that the minimum front vertex distance (FVD) may be less than the maximum focal length. 35

The invention will now be described, by way of example, with reference to the accompanying drawings, in 40 which:- 40

Figures 1 and 2 are diagrammatic side views of lenses embodying the invention, with elements in the widest angle positions;

Figures 1a and 2a are diagrammatic side views of the lenses in the longest focal length position;

Figure 3 is a diagrammatic side view of another lens embodying the invention with the elements thereof in 45 a mid focal range position; and 45

Figure 4 is a diagrammatic side view of another six element lens embodying the invention with the elements thereof in the short focal range position.

In the drawings, lens elements are identified by the reference L followed by an arabic numeral progressively from the object end toward the image end, and lens surfaces are identified by the reference R 50 followed by an arabic numeral from the object end to the image end. Spacings which vary with EFL are indicated by the reference Z, and the film or focal plane is FP. 50

Referring to the drawings, a compact optical system for a zoom lens is shown. The lens is of a simple form having two groups which are relatively movable axially to vary the equivalent focal length (EFL) of the lens. The absolute value of the EFL of the first group F_1 is greater than the lower limit EFL of the lens. The groups 55 are constructed so that the ratio of focal lengths of the respective groups $|F_1|/F_2$ is greater than 1.5. Also, the absolute value of the EFL provides for a degree of compactness unusual for a zoom lens of this focal length range and maximum relative aperture. 55

In a preferred embodiment shown in Figures 1 and 2, a simple construction is provided with only six elements. In Figure 1, the lens is shown in its shorter EFL position and in Figure 2 in its longer EFL position. 60 The front group has negative power and is formed of a negative element L1 and a positive element L2. Although the order of positive to negative can be interchanged, retaining the negative element as the front element is preferred. The second or rear group is a simple four element group with the elements fixed together for movement relative to the front group and the image plane as the focal length of the lens is changed. In this embodiment, the zoom ratio of the lens is 2. Further, the shortest FVD is achieved at the long 65 focal length position and is approximately equal to the focal length. The lens aperture at the shortest focal 65

length is $f/2.8$.

The front group is formed of negative elements L1 and positive elements L2 respectively, which are corrected for optimum balance of distortion and astigmatism. The second group has positive power. The first and second elements L3, L4 of the second group are both positive with convex object side surfaces followed by a relatively thick negative element L5 and a positive meniscus element L6.

In this embodiment, the second group moves toward the object and as the first group moves toward the image as the EFL is increased, the front vertex distance (FVD) decreases with EFL. An aperture defining mechanism is located between elements L5 and L6 and moves with the rear positive group.

An embodiment of the lens as shown in Figures 1 and 2 is constructed as hereinafter described in Table I wherein radii, thickness, and spacing dimensions are set forth in millimeters, and the refractive indices for the helium line at 589.29 nm of the spectrum and the Abbe dispersion numbers for the optical materials are designated as N_d and V_d respectively. The same designations are used in Tables II - V.

A lens embodying the invention as scaled to an image frame of 24×36 mm, a 70 to 145 mm zoom range and subtending semi-field angles of 16.0° to 7.9° is set forth in Table I.

TABLE I

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	R1 = -96.483	3.80	1.815	43.2
L2	R2 = 93.362	1.13		
L3	R3 = 94.885	7.96	1.674	31.9
L4	R4 = -225.454	Z		
L5	R5 = 48.984	6.08	1.700	54.7
L6	R6 = -350.307	.30		
L7	R7 = 36.342	5.31	1.675	48.4
L8	R8 = 277.063	.76		
L9	R9 = -1107.411	12.47	1.754	27.6
L10	R10 = 22.283	8.31		
L11	R11 = 49.921	6.82	1.802	25.6
L12	R12 = 75.151			

EFL	Z	FVD	f/No.
70.0mm	75.92mm	190.6mm	2.8
92.0mm	41.09	165.9	3.2
145.0mm	.50	149.8	4.0

To attain greater compactness and/or extended focal length range or aperture, a more complex lens form can be used. Particularly, the second group may be formed with positive and negative subgroups which move independently for zooming. Also, a secondary motion may be superimposed on the relatively simple motion of the second group to provide a more complex and compound movement resulting in still better optical corrections.

Another embodiment of the lens, as shown in Figures 2 and 2a, is a ten element form capable of the focal length being varied over a zoom range almost as great as 4:1.

The lens of Figures 2 and 2a has two groups. The first group is a doublet formed of a negative biconcave element L1 and a thin positive meniscus element L2, very slightly air spaced. This doublet is air spaced from the second group. In this space is positioned a first diaphragm stop D1.

The second group is formed as two subgroups which move in relation to each other for zooming. The first subgroup comprises a biconcave element L3 followed by a positive doublet formed of a thicker biconvex element L4 and a negative element L5. Thereafter, another thick doublet L6, L7, convex to the object, follows.

The doublet L6, L7 is followed by a positive meniscus L7, convex to the object. This first subgroup is air spaced widely from the second subgroup which follows a second diaphragm stop located in the intermediate spacing. The second subgroup is of negative power with a negative meniscus L9, concave to the object, and a positive element L10.

5 In the embodiment shown in Figures 2-2a, the front group L1, L2 moves first toward the image end and then towards the object end as the EFL is varied from minimum to maximum. The second subgroup L9, L10 of the second group initially moves toward the image end but reverses motion toward the object end. In this embodiment, two aperture defining mechanisms are utilized. Mechanism D1 is located just before L3 and mechanism D2 is located between L8 and L9. At the longer EFL's, mechanism D2 determines the relative
10 aperture.

Another lens as shown in Figures 2 and 2a scaled to an image frame of 24×36 mm, having EFL's of 50.0mm to 192.0mm, is substantially defined in Table II.

TABLE II

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	R1 = -81.235	2.50	1.729	53.4
	R2 = 64.727	.19		
L2	R3 = 64.688	4.50	1.813	25.3
	R4 = 230.458	Z1		
L3	R5 = 116.205	6.50	1.560	61.4
	R6 = -118.230	.15		
L4	R7 = 59.886	12.50	1.489	70.2
	R8 = -96.191	2.00	1.813	25.3
L5	R9 = 557.537	.15		
	R10 = 28.530	15.40	1.489	70.2
L6	R11 = 410.187	3.20	1.633	48.6
L7	R12 = 25.976	2.95		
	R13 = 37.520	5.74	1.489	70.2
L8	R14 = 105.944	Z2		
	R15 = 19.584	2.33	1.614	59.5
L9	R16 = -40.587	.20		
	R17 = 103.944	3.76	1.792	25.5
L10	R18 = -781.970			
Group spacing				
EFL	Z1	Z2	FVD	f/No.
50.0mm	67.831	22.834	172.1	4.0
75.0mm	39.358	21.846	158.8	4.0
135.0mm	12.593	22.208	167.0	4.0
192.0mm	2.696	22.925	190.0	4.0

Another embodiment of the invention substantially as shown in Figures 2 and 2a scaled to an image frame of 24×36 mm, and EFL's of 76.5mm to 192.1mm is substantially defined in Table III.

TABLE III

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5					5
L1	R1 = -88.100	2.50	1.642	59.9	
	R2 = 67.104	.19			
10	R3 = 64.014	4.50	1.812	25.2	10
L2	R4 = 136.313	Z			
	R5 = 134.983	6.50	1.609	56.4	
15	R6 = -159.956	.15			15
	R7 = 58.708	12.50	1.489	70.2	
L4	R8 = -98.315	2.0	1.812	25.2	20
20	R9 = 573.019	.15			
	R10 = 28.413	15.40	1.489	70.2	
25	R11 = 335.947	3.20	1.646	47.6	25
L6	R12 = 25.535	2.95			
	R13 = 35.799	5.74	1.489	70.2	30
30	R14 = 110.481	6.02			
	Aperture	15.80			35
35	R15 = -20.282	2.33	1.605	60.4	
L9	R16 = -40.780	.20			
40	R17 = 142.976	3.76	1.791	25.4	40
L10	R18 = -296.675	105.69			
45	Group spacing				45
EFL	Z	FVD	f/No.		
76.5mm	44.107mm	166.5m	4.0		
50 129.2mm	15.649	168.6	4.0		50
192.0mm	2.100	191.7	4.0		

Here the front group L1, L2 moves toward the object end with increasing EFL as does the second group L3-L10. An aperture defining mechanism is located between element L8 and L9 and moves with the second group.

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Another embodiment of a lens embodying the invention substantially as shown in Figures 2 and 2a is set forth in Table IV. This lens differs in that element L8 is biconvex, as scaled to an image frame of 24×36 mm and EFL's of substantially 50mm to 120mm.

TABLE IV

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d	
5					5
L1	R1 = -65.1214	2.5000	1.633	53.5	
	R2 = 49.9779	.2000			
10	R3 = 49.7071	4.4988	1.803	26.0	10
L2	R4 = 123.0426	30.02 to 1.0			
	R5 = 95.5044	5.6086	1.720	50.4	
15	R6 = -89.8393	.2000			15
L3	R7 = 51.9336	10.1667	1.487	70.4	
	R8 = -56.2006	2.0000	1.805	25.5	
20	R9 = 242.1799	.2000			20
L4	R10 = 35.4902	9.9112	1.505	60.6	
	R11 = 63.9444	2.0000	1.720	50.4	
25	R12 = 67.8449	9.7716			25
L5	R13 = 89.2652	3.6997	1.531	51.3	
	R14 = -75.4657	2.000			
30	Aperture	24.2395			30
L6	R15 = -19.5383	1.5811	1.720	50.4	
	R16 = 211.1908	.2000			
35	R17 = 72.5994	8.000	1.805	25.5	35
L7	R18 = -198.3869				
40		BFL = 40.0mm			40
L8					
L9					
L10					

45 Still another embodiment is a seven element form in which a five element rear group is used, as shown in 45
 Figure 3 in the mid-focal length position. This lens is scaled to an image frame of 24 × 36mm, has EFL's of 70
 to 145mm, and is substantially described in Table V.

TABLE V

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5					5
L1	R1 = -96.5620	2.2900	1.847	23.8	
	R2 = -67.5590	3.7200			
10	R3 = -64.8290	2.1500	1.697	55.5	10
L2	R4 = 2317.6220	-65.56 to .50			
	R5 = 70.8430	4.2600	1.518	59.0	
15	R6 = -258.1480	.5000			15
L3	R7 = 48.0200	3.9000	1.517	64.2	
20	R8 = 204.8770	3.3500			20
	Aperture	.5000			
25	R9 = 37.4330	9.2300	1.583	46.4	25
L5	R10 = 200.0540	1.0900			
	R11 = 639.6840	12.0000	1.847	23.8	
30	R12 = 23.1000	21.7800			30
L6	R13 = 56.0900	2.2300	1.847	23.8	
35	R14 = 138.5020				35

Another six element embodiment of the lens is shown in Figure 4 with the elements in the shortest focal length position. This lens, as scaled to an image frame of 24×36 mm, and having EFL's of 77mm to 145mm, is substantially defined in Table VI.

TABLE VI

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5					5
L1	R1 = -246.583	3.000	1.806	40.7	
	R2 = 47.217	2.199			
10	R3 = 49.870	4.110	1.728	28.3	10
L2	R4 = 295.575	Z			
	R5 = 46.962	6.376	1.658	50.9	
15	R6 = -299.223	0.200			15
L3	R7 = 32.687	6.539	1.720	50.3	
	R8 = 98.647	4.738			
20	R9 = plano	2.500	1.805	25.5	20
L4	R10 = 23.887	4.000			
	Aperture	26.177			
25	R11 = 91.566	3.000	1.603	38.0	25
L5	R12 = -276.325				
30					30

Group spacing

EFL	Z	FVD	f/No.	
35				35
77.25mm	62.39mm	199.0	3.4	
105.0	28.17	181.4	3.9	
145.0	1.88	179.0	4.6	

40 In the foregoing tables, N_d is the index of refraction and V_d (Abbe number) is the dispersion of the lens elements.

The powers of the first and second groups of the disclosed lens are set forth in Table VII.

TABLE VII

Table	F_1	F_2	$ F_1/F_2 $	
45				45
I	-148.70mm	68.79mm	2.16	
II	-88.63	50.07	1.77	
50 III	-97.99	54.51	1.80	50
IV	-77.55	32.05	2.42	
V	-140.25	70.13	2.00	
VI	-129.48	77.26	1.66	

55 The absolute value of the EFL of the first group is always greater than the lower limit EFL of the lens, and the absolute value of the ratio F_1/F_2 is greater than 1.5 and less than 3.0.

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CLAIMS

1. A zoom lens comprising from the object end, a first negative group followed by a second positive group, said groups being movable axially of each other to vary the equivalent focal length of the lens, the absolute value of the equivalent focal length of said first group $|F_1|$ being greater than the lower limit equivalent focal length of said lens, and

$$3 > |F_1| / F_2 \geq 1.6$$

where F_2 is the equivalent focal length of said second group, the lower limit equivalent focal length being greater than the diagonal of the image frame of said lens, said first group consisting of two elements, one of which is biconcave.

2. A zoom lens according to claim 1 where said first group consists of said biconcave element and a biconvex element.

3. A zoom lens according to claim 1 where said first group from the object end consists of said biconcave element and a positive meniscus concave to the object.

4. A zoom lens according to claim 1 where said first group from the object end consists of said biconcave element and a positive meniscus.

5. A zoom lens according to any of the preceding claims wherein said second group comprises from the object end four elements, the first two of said elements being of positive power, followed by a negative element and finally a widely spaced positive element.

6. A zoom lens according to any of claims 1-5 wherein said second group comprises from the object end a singlet, a positive doublet, a thick long focal length meniscus doublet concave to the film plane, a meniscus singlet concave to the film plane, and a negative group widely separated from said meniscus singlet.

7. A zoom lens according to any of claims 1-5 where said second group comprises from the object end a bi-concave element, a bi-convex doublet, a positive doublet in the form of a meniscus convex to the object, a negative meniscus concave to the object, and a bi-convex element.

8. A zoom lens according to any of claims 1-5 where said second group consists from the object end of a bi-concave element, a positive meniscus convex to the object, a negative meniscus concave to the image, and a positive element convex to the object.

9. A lens according to claim 1 scaled to an image frame of $24 \times 36\text{mm}$ and an EFL of 70-145mm substantially as follows:

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	R1 = -96.483	3.80	1.815	43.2
	R2 = 93.362			
L2	R3 = 94.885	1.13	1.674	31.9
	R4 = -225.454	7.96		
L3	R5 = 48.984	6.08	1.700	54.7
	R6 = -350.307			
L4	R7 = 36.342	.30	1.675	48.4
	R8 = 277.063	5.31		
L5	R9 = -1107.411	.76	1.754	27.6
	R10 = 22.283	12.47		
L6	R11 = 49.921	8.31	1.802	25.6
	R12 = 75.151	6.82		



Group spacing

EFL	Z	FVD	f/No.	
5 70.0mm	75.92mm	190.6mm	2.8	5
92.0mm	41.09	165.9	3.2	
145.0mm	.50	149.8	4.0	

where L1-L6 are the lens elements from the object end to the image end, R1-R12 are the surfaces of elements
 10 L1-L6, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements as
 measured by the Abbe number, Z is a variable lens spacing, EFL is the equivalent focal length of the lens,
 FVD is the front vertex distance of the lens, and f/No. is the relative aperture of the lens. 10

10. A lens according to claim 1 scaled to an image frame of 24×36 mm and an EFL of 50-192mm
 substantially as follows:

Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
20 L1	R1 = -81.235	2.50	1.729	53.4	20
	R2 = 64.727	.19			
L2	R3 = 64.688	4.50	1.813	25.3	
25	R4 = 230.458	Z1			25
	R5 = 116.205	6.50	1.560	61.4	
L3	R6 = -118.230	.15			
30	R7 = 59.886	12.50	1.489	70.2	30
	R8 = -96.191	2.00	1.813	25.3	
L5	R9 = 557.537	.15			
35	R10 = 28.530	15.40	1.489	70.2	35
	R11 = 410.187	3.20	1.633	48.6	
L7	R12 = 25.976	2.95			
	R13 = 37.520	5.74	1.489	70.2	
45	R14 = 105.914	Z2			45
	R15 = -19.584	2.33	1.614	59.5	
L9	R16 = -40.587	.20			
50	R17 = 103.944	3.76	1.792	25.5	50
L10	R18 = -781.970				

Group spacing

EFL	Z1	Z2	FVD	f/No.	
50.0mm	67.831	22.834	172.1	4.0	
60 75.0mm	39.358	21.846	158.8	4.0	60
135.0mm	12.593	22.208	167.0	4.0	
192.0mm	2.696	22.925	190.0	4.0	

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where L1-L10 are the lens elements from the object end to the image end, R1-R18 are the surfaces of elements L1-L10, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements, as measured by the Abbe number, Z1 and Z2 are the variable lens spacings, EFL is the equivalent focal length of the lens, FVD is the front vertex distance of the lens, and f/No. is the relative aperture of the lens.

5 11. A lens according to claim 1 scaled to an image frame of $24 \times 36\text{mm}$ and an EFL of 76.5-192.1mm substantially as follows:

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Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
10					10
L1	R1 = -88.100	2.50	1.642	59.9	
	R2 = 67.104	.19			
15	R3 = 64.014	4.50	1.812	25.2	15
L2	R4 = 136.313	Z			
	R5 = 134.983	6.50	1.609	56.4	
20	R6 = -159.956	.15			20
L3	R7 = 58.708	12.50	1.489	70.2	
25	R8 = -98.315	2.0	1.812	25.2	25
L4	R9 = 573.019	.15			
	R10 = 28.413	15.40	1.489	70.2	
30	R11 = 335.947	3.20	1.646	47.6	30
L5	R12 = 25.535	2.95			
	R13 = 35.799	5.74	1.489	70.2	
35	R14 = 110.481	6.02			35
L6	Aperture	15.80			
40	R15 = -20.282	2.33	1.605	60.4	40
L7	R16 = -40.780	.20			
45	R17 = 142.976	3.76	1.791	25.4	45
L8	R18 = -296.675	105.69			

50 Group spacing

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EFL	Z	FVD	f/No.	
76.5mm	44.107mm	166.5m	4.0	
55 129.2mm	15.649	168.6	4.0	55
192.0mm	2.100	191.7	4.0	

where L1-L10 are the lens elements from the object end to the image end, R1-R18 are the surfaces of elements L1-L10, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements as measured by the Abbe number, Z1 is a variable lens spacing, EFL is the equivalent focal length of the lens, FVD is the front vertex distance of the lens, and f/No. is the relative aperture of the lens.

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12. A lens according to claim 1 scaled to an image frame of $24 \times 36\text{mm}$ and an EFL of 50-120mm substantially as follows:



Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5 L1	R1 = -65.1214	2.5000	1.633	53.5	5
	R2 = 49.9779	.2000			
L2	R3 = 49.7071	4.4988	1.803	26.0	
10	R4 = 123.0426	30.02 to 1.0			10
	R5 = 95.5044	5.6086	1.720	50.4	
I3	R6 = -89.8393	.2000			
15	R7 = 51.9336	10.1667	1.487	70.4	15
L4	R8 = -56.2006	2.0000	1.805	25.5	
L5	R9 = 242.1799	.2000			
20	R10 = 35.4902	9.9112	1.505	60.6	20
	R11 = -63.9444	2.0000	1.720	50.4	
L6	R12 = 67.8449	9.7716			
25 L7	R13 = 89.2652	3.6997	1.531	51.3	25
	R14 = -75.4657	2.000			
L8	Aperture	24.2395			30
30	R15 = -19.5383	1.5811	1.720	50.4	30
	R16 = 211.1908	.2000			
L9	R17 = 72.5994	8.000	1.805	25.5	
40	R18 = -198.3869	BFL = 40.0mm			40

where L1-L10 are lens elements from the object end to the image end, R1-R18 are the surfaces of elements L1-L10, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements as measured by the Abbe number, and Z denotes a space which varies with change in equivalent focal length. 45

13. A lens according to claim 1 scaled to an image frame of 24 × 36mm and an EFL of 70 to 145mm substantially as follows:

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Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5 L1	R1 = -96.5620	2.2900	1.847	23.8	5
	R2 = -67.5590	3.7200			
10 L2	R3 = -64.8290	2.1500	1.697	55.5	10
	R4 = 2317.6220	-65.56 to .50			
L3	R5 = 70.8430	4.2600	1.518	59.0	
15	R6 = -258.1480	.5000			15
L4	R7 = 48.0200	3.9000	1.517	64.2	
	R8 = 204.8770	3.3500			
20	Aperture	.5000			20
L5	R9 = 37.4330	9.2300	1.583	46.4	
25	R10 = 200.0540	1.0900			25
L6	R11 = 639.6840	12.0000	1.847	23.8	
	R12 = 23.1000	21.7800			
30 L7	R13 = 56.0900	2.2300	1.847	23.8	30
	r14 = 138.5020				

35 where L1-L7 are lens elements from the object end to the image end, R1-R14 are the surfaces of elements L1-L10, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements as measured by the Abbe number, and Z denotes a space which varies with change in equivalent focal length. 35

14. A lens according to claim 1 scaled to an image frame of 24 × 36mm and an EFL of 77 - 145mm substantially as follows:



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Element	Radius of Curvature (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d	
5 L1	R1 = -246.583	3.000	1.806	40.7	5
	R2 = 47.217	2.199			
10 L2	R3 = 49.870	4.110	1.728	28.3	10
	R4 = 295.575	Z			
15 L3	R5 = 46.962	6.376	1.658	50.9	15
	R6 = -299.223	0.200			
20 L4	R7 = 32.687	6.539	1.720	50.3	20
	R8 = 98.647	4.738			
25 L5	R9 = plano	2.500	1.805	25.5	25
	R10 = 23.887	4.000			
	Aperture	26.177			
30 L6	R11 = 91.566	3.000	1.603	38.0	30
	R12 = -276.325				
Group spacing					30
EFL	Z	FVD	f/No.		
77.25mm	62.39mm	199.0	3.4		
35 105.0	28.17	181.4	3.9		35
145.0	1.88	179.0	4.6		

where L1-L7 are lens elements from the object end to the image end, R1-R14 are the surfaces of elements L1-L7, N_d is the index of refraction of the lens elements, V_d is the dispersion of the lens elements as measured by the Abbe number, and Z denotes a space which varies with change in equivalent focal length. 15. A zoom lens constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.