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PATENT SPECIFICATION

(11) 1 441 119

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(54) ZOOM LENS

(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 present invention relates to a zoom lens.

According to the present invention, there is provided a zoom lens having a supplementary lens of variable magnification and a prime lens of fixed focal length, the supplementary lens having a positive element or combination followed by a negative element or combination which are axially displaceable so as to vary the magnification without varying the position of the image plane, and the prime lens comprising a biconvex lens followed by, in order, a cemented lens element, a biconcave lens and two further biconvex lenses, no radius in the prime lens being shorter than 0.6 times the focal length of the prime lens and the refractive indices of all the biconvex lenses in the prime lens being less than 1.72.

As will be appreciated by those skilled in the art, in designing a lens one must bear in mind the dimensions of the image it is desired to produce in the image plane. For a cine-camera or a film projector, the diagonal of the cine format is an important factor in the design of the lens system. This diagonal is commonly termed the image field diagonal. It is a preferred feature of the present invention that the difference between the minimum focal length of the zoom lens and the focal length of the negative element or combination in the supplementary lens should be less than three times the length of the image field diagonal.

Preferably, in the zoom lens the following conditions are satisfied:

$$0.7r_{16} < r_{12} < 2.1r_{16}$$

$$0.03f_{III} < d_{neg} < 0.55f_{III}$$

where r_{12} is the radius of curvature of the face of the first biconvex lens in the prime lens which lies nearer the supplementary lens, r_{16} is the radius of curvature of the face of the cemented element remote from the supplementary lens, d_{neg} is the mean thickness of the biconcave lens of the cemented element or of the biconcave lens positioned behind such element, and f_{III} is the focal length of the prime lens.

Whereas the ratio of the maximum to the minimum focal length of a zoom lens is important to the usefulness of a zoom lens this ratio is not all important since an increase in the maximum focal length is not as valuable as a decrease in the minimum focal length since, especially in cine cameras, one is often more concerned with photographing in a confined space than with being able to resolve distant objects. For this reason, a lens offering focal lengths from 6 to 16 mm is considered more useful than a lens ranging from 8 to 21 mm even though the ratio of the maximum to the minimum focal length is substantially the same in both cases. In order to enable a comparison of the usefulness of different zoom lenses a parameter Z is defined as follows:—

$$Z = 2_y \times \frac{f_{max}}{f_{min}}$$

where 2_y = field diagonal

Thus, the parameter Z is not only affected by the ratio of the maximum and minimum focal lengths but is also affected by the ratio of the image field diagonal to the minimum focal length.

The parameter Z is defined in British Patent No. 1,397,711.

In accordance with a further preferred feature of the present invention, the parameter Z of the zoom lens is not less than 1.9.

Use of the present invention enables certain dimensions, particularly the maximum diameter of the lens elements in the positive lens or lens combination in the supplementary

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lens, to be reduced, thus enabling a simpler and more efficient manufacturing process to be used. The product of minimum focal length and maximum structural length of the entire objective should preferably be less than 100 times the image field diagonal.

The zoom lens may additionally benefit from having a very fast prime lens, the relative aperture of the entire zoom lens at all focal length settings being suitable 1 to 1.2.

The minimum focal length of the entire lens preferably does not exceed the image field diagonal by more than 10% in order to achieve a distinct wide angle effect.

The invention will now be described further, by way of example, with reference to the accompanying drawing which shows diagrammatically a zoom lens of the invention.

The zoom lens is illustrated in the position for minimum focal length. The prime lens comprises the lens groups III and IV. A diaphragm plane, shown but not referenced, is positioned in front of the lens group III.

On the side nearest to the lens group III the group IV is provided with a cemented element comprising the lenses L_9 and L_{10} and behind which is a biconcave lens L_{11} and two further biconvex lenses L_{12} .

Three numerical examples for a zoom lens and for the prime lens associated therewith are disclosed hereinbelow where r refers to lens surface radius d to the lens thickness, l to air gap length, n_d to the refractive index and v_d to the Abbé number.

In the following examples it is to be understood that small variations in the dimensions are acceptable. More specifically there may be deviations of the curvature of individual surfaces of up to $\pm 10\%$ of the refractive power of the corresponding elements, of up to $\pm 10\%$ of the thicknesses of the corresponding elements, of up to ± 0.03 of the refractive indices, and of up to ± 5 of the Abbé numbers. The units of length are arbitrary and the dimensions are expressed in terms of their ratio to the focal length F_x which thus has the value 1.

EXAMPLE I

				n_d	v_d
L_1	r_1	+8.706	$d_1 = 0.15$	/ 1.805	/ 25.4
	r_2	+2.628	$l_1 = 0.21$		
L_2	r_3	+3.408	$d_2 = 0.43$	/ 1.603	/ 60.6
	r_4	-18.304	$l_2 = 0.01$		
L_3	r_5	+2.278	$d_3 = 0.52$	/ 1.658	/ 50.9
	r_6	-130.310	l_3	$\left\{ \begin{array}{l} 0.05 \dots f_{\min} \\ 0.78 \dots f_M \\ 1.21 \dots f_{\max} \end{array} \right.$	
L_4	r_7	+40.501	$d_4 = 0.08$	/ 1.713	/ 53.8
	r_8	+0.999	$l_4 = 0.24$		
L_5	r_9	-3.780	$d_5 = 0.08$	/ 1.641	/ 60.1
	r_{10}	+1.170	$d_6 = 0.21$	/ 1.847	/ 23.8
L_6	r_{11}	+4.173	l_5	$\left\{ \begin{array}{l} 2.06 \dots f_{\min} \\ 1.63 \dots f_M \\ 0.90 \dots f_{\max} \end{array} \right.$	
L_7	r_{12}	+2.794	$d_7 = 0.21$	/ 1.717	/ 48.0
	r_{13}	-3.655	$l_6 = 0.01$		
L_8	r_{14}	+0.955	$d_8 = 0.42$	/ 1.657	/ 36.7
	r_{15}	-1.513	$d_9 = 0.17$	/ 1.805	/ 25.4
L_9	r_{16}	+2.066	$l_7 = 0.08$		
	r_{17}	-2.166	$d_{10} = 0.19$	/ 1.847	/ 23.8
L_{10}	r_{18}	+1.030	$l_8 = 0.15$		
	r_{19}	+5.136	$d_{11} = 0.23$	/ 1.713	/ 53.8
L_{11}	r_{20}	-1.036	$l_9 = 0.01$		
	r_{21}	+0.946	$d_{12} = 0.23$	/ 1.641	/ 60.1
L_{12}	r_{22}	-380.504			

 $f_{III} = 1.23$
 Group III + IV

$$f_{\min} = 0.594$$

$$f_M = 1$$

$$f_{\max} = 1.683$$

Relative aperture = 1:1.2

 Image field diagonal $2y = 0.54$

This example and the succeeding examples show that all the initially mentioned conditions are satisfied for the prime lens. This results not only in a high speed of operation of the zoom lens but also in a small structural length without curvature radii of excessive shortness and without the need for using special kinds of glass, and with relatively low reflection losses.

The following examples refer solely to the prime lens of a zoom lens as described in Example I.

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EXAMPLE II

			n_d	v_d	
L_7	r_{12}	+2.794	$d_7 = 0.21$	/ 1.717	/ 48.0
	r_{13}	-3.655	$l_6 = 0.01$		
L_8	r_{14}	+0.955	$d_8 = 0.42$	/ 1.657	/ 36.7
	r_{15}	-1.513	$d_9 = 0.04$	/ 1.805	/ 25.4
L_9	r_{16}	+3.800	$l_7 = 0.08$		
	r_{17}	-2.166			Group III+IV
L_{10}			$d_{10} = 0.19$	/ 1.847	/ 23.8
	r_{18}	+1.030	$l_8 = 0.15$		$f_{III} = 1.17$
L_{11}	r_{19}	+5.136	$d_{11} = 0.23$	/ 1.713	/ 53.8
	r_{20}	-1.036	$l_9 = 0.01$		
L_{12}	r_{21}	+1.153	$d_{12} = 0.23$	/ 1.641	/ 60.1
	r_{22}	+42.916			

EXAMPLE III

			n_d	v_d	
L_7	r_{12}	+4.180	$d_7 = 0.21$	/ 1.717	/ 48.0
	r_{13}	-3.655	$l_6 = 0.01$		
L_8	r_{14}	+0.955	$d_8 = 0.42$	/ 1.657	/ 36.7
	r_{15}	-1.513	$d_9 = 0.17$	/ 1.805	/ 25.4
L_9	r_{16}	+2.066	$l_7 = 0.08$		
	r_{17}	-2.166			Group III+IV
L_{10}			$d_{10} = 0.76$	/ 1.847	/ 23.8
	r_{18}	+1.064	$l_8 = 0.15$		$f_{III} = 1.48$
L_{11}	r_{19}	+5.136	$d_{11} = 0.23$	/ 1.713	/ 53.8
	r_{20}	-1.036	$l_9 = 0.01$		
L_{12}	r_{21}	+0.922	$d_{12} = 0.23$	/ 1.658	/ 57.3
	r_{22}	-12.883			

WHAT WE CLAIM IS:—

1. A zoom lens having a supplementary lens of variable magnification and a prime lens of fixed focal length, the supplementary lens having a positive element or combination followed by a negative element or combination which are axially displaceable so as to vary the magnification without varying the

position of the image plane, and the prime lens comprising a biconvex lens followed by, in order, a cemented lens element, a biconcave lens and two further biconvex lenses, no radius in the prime lens being shorter than 0.6 times the focal length of the prime lens and the refractive indices of all biconvex lenses in the prime lens being less than 1.72.

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This example and the succeeding examples show that all the initially mentioned conditions are satisfied for the prime lens. This results not only in a high speed of operation of the zoom lens but also in a small structural length without curvature radii of ex-

cessive shortness and without the need for using special kinds of glass, and with relatively low reflection losses.

The following examples refer solely to the prime lens of a zoom lens as described in Example I.

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EXAMPLE II

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L_7	r_{12}	+2.794	$d_7 = 0.21$	/ 1.717	/ 48.0	
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L_8	r_{14}	+0.955	$d_8 = 0.42$	/ 1.657	/ 36.7	
	r_{15}	-1.513	$d_9 = 0.04$	/ 1.805	/ 25.4	
L_9	r_{16}	+3.800	$l_7 = 0.08$			Group III+IV
	r_{17}	-2.166				$f_{III} = 1.17$
L_{10}			$d_{10} = 0.19$	/ 1.847	/ 23.8	
	r_{18}	+1.030	$l_8 = 0.15$			
L_{11}	r_{19}	+5.136	$d_{11} = 0.23$	/ 1.713	/ 53.8	
	r_{20}	-1.036	$l_9 = 0.01$			
L_{12}	r_{21}	+1.153	$d_{12} = 0.23$	/ 1.641	/ 60.1	
	r_{22}	+42.916				

EXAMPLE III

				n_d	v_d	
L_7	r_{12}	+4.180	$d_7 = 0.21$	/ 1.717	/ 48.0	
	r_{13}	-3.655	$l_8 = 0.01$			
L_8	r_{14}	+0.955	$d_8 = 0.42$	/ 1.657	/ 36.7	
	r_{15}	-1.513	$d_9 = 0.17$	/ 1.805	/ 25.4	
L_9	r_{16}	+2.066	$l_7 = 0.08$			Group III+IV
	r_{17}	-2.166				$f_{III} = 1.48$
L_{10}			$d_{10} = 0.76$	/ 1.847	/ 23.8	
	r_{18}	+1.064	$l_8 = 0.15$			
L_{11}	r_{19}	+5.136	$d_{11} = 0.23$	/ 1.713	/ 53.8	
	r_{20}	-1.036	$l_9 = 0.01$			
L_{12}	r_{21}	+0.922	$d_{12} = 0.23$	/ 1.658	/ 57.3	
	r_{22}	-12.883				

WHAT WE CLAIM IS:—

- 15 1. A zoom lens having a supplementary lens of variable magnification and a prime lens of fixed focal length, the supplementary lens having a positive element or combination followed by a negative element or combination which are axially displaceable so as to vary the magnification without varying the

position of the image plane, and the prime lens comprising a biconvex lens followed by, in order, a cemented lens element, a biconcave lens and two further biconvex lenses, no radius in the prime lens being shorter than 0.6 times the focal length of the prime lens and the refractive indices of all biconvex lenses in the prime lens being less than 1.72.

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2. A zoom lens as claimed in Claim 1 in which the following conditions are satisfied:

$$0.7r_{16} < r_{12} < 2.1r_{16}$$

$$0.03f_{III} < d_{neg} < 0.55f_{III}$$

5 where r_{12} is the radius of curvature of the face of the first biconvex lens in the prime lens which lies nearer the supplementary lens, r_{16} is the radius of curvature of the face of the cemented element remote from the supplementary lens, d_{neg} is the mean thickness of the biconcave lens of the cemented element or of the biconcave lens positioned behind such element, and f_{III} is the focal length of the prime lens.

15 3. A zoom lens as claimed in claim 1, in which the difference between the minimum

focal length of the zoom lens and the focal length of the negative element or combination in the supplementary lens is less than three times the length of the image field diagonal.

4. A zoom lens as claimed in claim 1, in which the parameter Z of the zoom lens is not less than 1.9.

5. A zoom lens as claimed in any preceding claim and substantially as hereinbefore described in any of the accompanying examples as explained with reference to the accompanying drawing.

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