

PATENT SPECIFICATION

(11) 1 537 588

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- (21) Application No. 28212/76 (22) Filed 7 July 1976
(31) Convention Application No. 6078/75
(32) Filed 6 Aug. 1975 in
(33) Austria (AT)
(44) Complete Specification published 10 Jan. 1979
(51) INT CL² G02B 15/16
(52) Index at acceptance G2J 23C



(54) ZOOM LENS

(71) We, KARL VOCKENHUBER, of 118 Pötzleinsdorferstrasse, Vienna 1180, Austria, and RAIMUND HAUSER, of 2 Goldeggasse, Vienna 1040, 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:—

This invention relates to a zoom lens for inter alia a portable camera, such as a cine camera.

United States Patent Specification No. 3,655,271 and West German laid-open patent specification Nos. 2,222,411, 1,101,793, 1,272,580 and 2,029,254 disclose various ways of controlling lenses of a camera to achieve different effects with different arrangements of lenses. However none of them results in a zoom lens capable of being produced on a mass-production basis and able to be fitted to a hand-held cine camera to provide it with the desirable facility of being able to zoom in both the normal and macro ranges of operation while keeping in sharp focus in a film plane in the camera, an image of an object whose magnification is to be changed by the zooming operation.

A zoom lens, in accordance with the present invention, comprises an objective lens provided with a front lens element and a stationary back lens element, and at least two movable intermediate lens elements relatively displaceable along a common optical axis between the front and back lens elements; a first mechanical control means operable to move the intermediate elements with respect to one another and the front and back lens elements in accordance with a first law enabling the magnification of an image of an object, lying in the normal range of the objective, to be varied progressively while the image itself remains in focus in an image plane where a film of the camera is normally located; a second mechanical control means selectively usable in place of the first control means and operable to move the intermediate

elements with respect to one another and the front and back lens elements in accordance with a second law enabling the magnification of an image of an object, lying in the macro range of the objective, to be varied progressively while the image itself remains in focus in the image plane; and, a selector operable by the user of the camera to make one or other of the two control means effective so that zooming without loss of focus is possible in both the normal and macro ranges of the objective.

The two mechanical control means may take any of a large number of different forms. The preferred form, from the point of view of simplicity and accuracy of controlled movement of the lenses, however is one where the lens elements are equipped with cam followers which are guided in slots formed in the walls of tubes encircling and rotatable about the optical axis of the objective.

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

Figures 1 to 4 show two possible embodiments of lenses to which the invention can be advantageously applied.

Figure 5 shows a basic embodiment for a sliding device.

Figures 6, 7A and 7B show possible arrangements of focal length adjustment cams on cam supports.

Figures 8A and 8B show details of a focal length adjusting device for the two slidable elements of a zoom lens.

Figures 9A and 9B show an arrangement for transmitting motion by non-positive means,

Figures 10A to 10C show an arrangement for transmitting motion by positive means, allowing for focal length adjustment over several planes in the macro range,

Figure 11 also shows an arrangement offering this facility but with a different locking device or cam system,

Figures 12A, 12B show positive guiding means for the cam follower with cam supports situated in different planes,

Figures 13A and 13B show an embodiment

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with several cam followers for the second focal length adjusting cam or for different macro zoom ranges, and

5 Figures 14 and 15 show a camera with a supplementary unit, for example a transparency holder or wide-angle attachment, fitted to the lens, the focal length adjustment being controlled in dependence of the said supplementary device.

10 Figure 1 shows a varifocal objective zoom

lens designed particularly for the Super 8 film format. The Table below describes an embodiment of the lens where r refers to the radii, d to the vertex distances, n_d to the refractive indices and v_d to the Abbe numbers. 15 The value of d_1 is numerically equal to

$$\frac{n_d}{v_d}$$

		n_d	v_d
$r_1 + 6.308$	$d_1 = 0.07$	1.805	25.4
$r_2 + 1.976$	$d_2 = 0.06$		
$r_3 + 2.082$	$d_3 = 0.26$	1.620	60.3
$r_4 \text{ plan}$	$d_4 = 0.01$		
$r_5 + 2.341$	$d_5 = 0.15$	1.623	58.1
$r_6 + 4.961$	$d_6 = 0.01$		
$r_7 + 1.805$	$d_7 = 0.22$	1.623	58.1
$r_8 + 12.664$	$d_8 = \begin{cases} 0.04 \dots f_{\min} \\ 0.69 \dots f_M \\ 1.03 \dots f_{\max} \end{cases}$		
$r_9 + 5.981$	$d_9 = 0.05$	1.658	50.9
$r_{10} + 0.567$	$d_{10} = 0.16$		
$r_{11} - 1.086$	$d_{11} = 0.05$	1.669	57.4
$r_{12} + 0.652$	$d_{12} = 0.15$	1.805	25.4
$r_{13} + 7.039$	$d_{13} = \begin{cases} 1.09 \dots f_{\min} \\ 0.32 \dots f_M \\ 0.14 \dots f_{\max} \end{cases}$		
$r_{14} - 0.639$	$d_{14} = 0.05$	1.624	47.0
$r_{15} - 1.288$	$d_{15} = \begin{cases} 0.10 \dots f_{\min} \\ 0.22 \dots f_M \\ 0.06 \dots f_{\max} \end{cases}$		
$r_{16} + 1.097$	$d_{16} = 0.10$	1.691	54.7
$r_{17} - 3.661$	$d_{17} = 0.46$		
$r_{18} + 2.052$	$d_{18} = 0.10$	1.620	60.3
$r_{19} - 2.052$	$d_{19} = 0.01$		
$r_{20} + 0.686$	$d_{20} = 0.13$	1.717	48.0
$r_{21} + 26.527$	$d_{21} = 0.04$		
$r_{22} - 0.848$	$d_{22} = 0.16$	1.785	26.1
$r_{23} + 0.535$	$d_{23} = 0.18$		
$r_{24} + 1.614$	$d_{24} = 0.19$	1.720	50.4
$r_{25} - 0.639$			

 $f_{\min} = 0.43$ $f_M = 1.00$ $f_{\max} = 2.03$ $2y = -0.37$

Relative aperture ratio 1:1.9

The objective lens comprises a stationary positive lens element 1 nearest to the object, a negative lens element 2 situated behind the element 1 and being slidable along the optical axis for the purpose of altering the overall focal length, a negative lens element 3 which is slidable along the optical axis to maintain a constant image position and a stationary positive lens element 4 which converges the pencil of rays diverging behind the element 3 so that they proceed axially parallel in the diaphragm space between the above-mentioned element 4 and a positive base lens 5 which is also stationary.

Figure 2A shows the wide-angle position of the objective lens, Figures 2D and 2E showing middle focal length settings, Figure 2F showing the maximum focal length setting, the individual elements being shown as lenses which are infinitely thin. Focussing of an object situated in the extreme macro range is not only made possible in the setting for minimum overall focal length, but also in every other focal length setting, by sliding the element 3 into the position 3' while the other elements remain in the same position. The construction of the lens therefore complies with the prior art and is disclosed, for example in Patent Specification 1,397,711.

As already mentioned, the focal length is to be additionally adjustable in the said macro range while the image position is to remain constant. This is made possible by initially setting the element 3 towards the element 2, for example in position 3a. In this position the objective lens is focussed on an object plane 6 which is situated in the macro range and the lens will have a focal length of $f=0.28$. To increase the aspect ratio, i.e. the magnification of the image, for the object situated in the plane 6, the elements 2 and 3 are moved into the positions marked with the index b, c in Figures 2B and 2C, the element 2 traversing through part of the distance which it would traverse in normal adjustment of the focal length. The focal length adjustment range for macro exposures is terminated in position c because the movement of the element 3, which increases steeply towards the front, would cause the said element to move

into the path of the element 2. Overlapping of the movements of elements 2 and 3 would occur even earlier if the objects were set at the extreme macro distance (position 3' of the element 3). The pitch of a cam controlling movement of the element 3 however depends merely on the individual focal lengths of the lens elements and can yield an optimum focal length range if suitably selected. A lens of proven practical performance was deliberately selected in the present case to indicate that the invention can be advantageously employed with any desired lens and not one that is a special embodiment.

The focal length of the objective lens in position c is 0.43 and thus adjoins directly on the minimum total focal length of the objective lens with a normal distance setting. However, as will be described subsequently by reference to Fig. 4, it is possible to increase the zoom ratio for macro exposures despite the rapid rise in the adjustment for the element 3.

In the embodiment shown in Fig. 2A a supplementary negative element 7' is diagrammatically illustrated in broken lines. The element 7' can be arranged in front of the complete objective lens 1-5, to achieve an extreme wide-angle effect for the normal distance range in the macro setting of the lens to the plane 6. To achieve this the element 7' is specially constructed as described in copending application No. 32783/76 (now Serial No. 1,537,588) to provide an intermediate image plane coinciding with the plane 6. In the example illustrated in Fig. 2A, the focal length of the element 7 is -3.48 referred to a mean total focal length of the lens 1-5 of 1.0.

Fig. 3 also shows a zoom lens but of a different kind to that of Fig. 1. This lens incorporates a positive front element 10 (see also Fig. 4), a slidable negative element 11 in second place, a third slidable positive element 12 and a fourth negative element 13. The element 13 is followed by a positive base lens 14. Data for such a lens may be obtained from the Table below in which r again refers to the radii, d to the vertex distances and n_d to the refractive indices and v_d to the Abbe numbers.

r_i	d_i	n_d	v_d
$r_1 - 67.2$	$d_1 = 1.9$	1.805	25.4
$r_2 +105$	$d_2 = 1.9$		
$r_3 +116$	$d_3 = 8.3$	1.574	56.4
$r_4 - 60.8$	$d_4 = 4.9$		
$r_5 +187$	$d_5 = 4.4$	1.643	48.0
$r_6 -187$	$d_6 = 0.1$		
$r_7 + 45.4$	$d_7 = 5.7$	1.656	50.9
$r_8 +166$	$d_8 = 0.8$	29.3	
$r_9 + 93.2$	$d_9 = 3.8$	1.805	25.4
$r_{10} - 52.2$	$d_{10} = 1.0$	1.620	60.3
$r_{11} + 16.6$	$d_{11} = 4.9$		
$r_{12} - 37.9$	$d_{12} = 1.0$	1.744	44.8
$r_{13} + 41.2$	$d_{13} = 41.8$	2.0	
$r_{14} + 77.7$	$d_{14} = 0.8$	1.741	27.6
$r_{15} + 30.0$	$d_{15} = 3.8$	1.652	44.9
$r_{16} - 30.0$	$d_{16} = 0.1$		
$r_{17} + 19.9$	$d_{17} = 2.7$	1.720	50.4
$r_{18} + 78.2$	$d_{18} = 2.8$	14.1	
$r_{19} - 41.1$	$d_{19} = 0.9$	1.620	60.3
$r_{20} + 17.4$	$d_{20} = 1.9$		
$r_{21} \infty$	$d_{21} = 8.2$	1.569	56.1
$r_{22} \infty$	$d_{22} = 5.05$		
$r_{23} + 17.8$	$d_{23} = 4.2$	1.570	49.5
$r_{24} - 49.7$	$d_{24} = 3.5$		
$r_{25} - 16.5$	$d_{25} = 2.4$	1.847	23.8
$r_{26} + 16.5$	$d_{26} = 1.35$		
$r_{27} -585$	$d_{27} = 3.8$	1.569	63.1
$r_{28} - 12.4$	$d_{28} = 0.2$		
$r_{29} + 18.9$	$d_{29} = 3.1$	1.620	60.3
$r_{30} - 23.3$			

This lens, which is disclosed in the United States Patent Specification 3,773,402, is diagrammatically illustrated in Fig. 4 by lenses which are infinitely thin, Fig. 4A representing the wide-angle position, Fig. 4G

the teleposition of the lens and Figs. 4D and 4F showing medium focal settings for the normal distance range.

By adjusting the element 12 into the position 12a the objective lens is focused to the plane

6' in the macro range. To achieve zooming in the macro range, the focal length must also be adjusted with a constant image position. Proceeding from the setting which is focused to the plane 6' the element 11 takes up the positions 11b, 11c with progressive adjustment, and simultaneously the element 12 is adjusted to respective positions 12b and 12c.

In Fig. 4C, the image ratio is 1:1 due to the re-positioning of the element 12. The direction of motion of the element 11 then reverses and the element 12 is moved to the front more steeply (see Fig. 4E) to obtain a further increase of the zoom ratio without encountering mechanical difficulties in socketing and guiding the moving lens elements 11 and 12. In this position the focal length is 12.07 and therefore already extends far into the normal focal length adjusting range from 7.28 to 55.46. The focal length of 12.07 can be increased still further by a distributed construction of the control cams for the elements 11 and 12, for example on two different supports, the elements 11 and 12 then moving towards the front element 10.

Zooming with this lens is possible not only in the macro range, but the wide-angle range can be increased to an extreme degree by the addition of a negative supplementary lens 15 as is mentioned in the above numbered patent application. The element 15 has an assumed focal length of -28.38 . In the present exemplified embodiment the zooming ratio which can be achieved by the invention extends down to 3.48 to produce an image angle of approximately 90° by attaching the supplementary lens element 15 in front of the front element 10.

Fig. 5 shows a lens mount for the movable intermediate lens elements 2 and 3 the motions of which are determined by a cam support tube 33 having its wall formed with a control cam 25' of the shape shown in Fig. 7A to be described subsequently, for example for the element 2, and a double cam slot 23 having the shape shown in Figure 6 and for the element 3. A tubular operating handle, formed in two parts 34, 34', is rotated for adjusting the focal length. Cam followers 22, 24 are supported in the tubular handle 34, 34' and are entrained in the course of rotation, the elements 2, 3 sliding along the optical axis O of the lens in accordance with the shape of control cam surfaces of the slots 25', 23 borne on by the respective cam followers 22, 24.

When the cam follower 24 is positionally controlled by a first of the camming sides or edges of the slot 23, the element 3 performs the focusing motion for the object plane 6 in the macro range associated with the second focal length adjusting cam while the element 2 remains stationary. In this way focal length adjustment in the macro range is achieved. In mechanical terms this result is obtained by

the operating tube 34 being constructed in two parts, the part 34' which supports the follower 22 for the element 2 remaining stationary by virtue of the pin-slot guide 35 when the handle is slid axially. The pin of this guide 35 entrains the part 34' only when the handle 34 is rotated. The follower 24 can be driven between its two positions by a changeover spring which causes the follower to selectively engage one of the two cams provided by the two flank edges of the control slot 23.

Embodiments showing the arrangement of the control cams on a cam support are diagrammatically illustrated in Figs. 6, 7A and 7B. The embodiment illustrated in Fig. 6 shows a cam support 20 with control cams, for example for the lens illustrated in Figs. 1 and 2. The cam support 20 can be constructed as a tube shown in developed form in Fig. 6. One cam slot 21 is associated with a cam follower 22, connected to the element 2, and one cam slot 23 is associated with a cam follower 24 of the element 3.

When the focal length is adjusted in the normal distance range the cam follower 22 bears non-positively upon the cam slot boundary 25 and the follower 24 bears non-positively upon the cam 26. The facilities for controlling the cam follower when this engages with the cams will be described subsequently.

The construction or shape of the cams 25 and 26 is known and it is therefore not necessary to describe in detail the relative positions of cams and cam followers.

On the side of the lens corresponding to the wide-angle position the slots 21 and 23 have extensions 27, 28 of a length x for focusing the lens in the macro range. The cam follower 22 does not alter its relative position in the extension 27 along the optical axis of the lens but the element 3 is displaced by the amount "y" parallel to the optical axis by means of the follower 24. The amount "y" corresponds to the distance through which the element 3 slides into the position 3' (see also Fig. 2A). If zooming is to be performed in the macro range the cam followers 22, 24 are applied to the left-hand flank of the control slot 21 or 23, with reference to Fig. 6. These flanks are constructed as the focal length adjusting cams 29, 30 for an object situated at a macro distance defined by the traversing distance "z" of the follower 24. In the course of adjusting the focal length the element 3 which is driven by the cam follower 24 moves progressively towards the element 2 while the cam 29 for the element 2 has a point of reversal at a magnification $\beta=1$ through the lens 3 in the direction of motion in order to increase the zooming ratio (in a manner similar to that described by reference to Fig. 4).

It should be noted that the positions of the cam followers 22 and 24 illustrated in Fig. 6 do

not correspond to the axial positions of the mounts for the lens elements which are to be controlled. In practice, the cam followers 22 and 24 will occupy axially-spaced positions as is clear from Figure 5.

Fig. 7A shows a cam support 31 in which the cam followers 22 and 24 trace their respective cam slots in a positive manner. The cams 25', 26' extend over a first range of the support. The ends of the cams are provided with parallel cam sections 32 which guide the transfer of the cam followers 22, 24 from the focal length adjusting cams 25', 26' associated with the normal distance range to the focal length adjusting cams 29', 30', for a specific object plane in the macro range.

Fig. 7B shows another method of constructing a cam support 31A. In this case the cams 25'', 29'' or the cams 26'', 30'' are separate, each of the lens elements 2 and 3 being associated with two cam followers 22a, 22b or 24a and 24b respectively. In this embodiment the cam followers 22a, 24a or 22b, 24b must be capable of being alternately switched to the lenses 2, 3.

Fig. 8A shows a cam support 44 constructed in flat form. The elements 2, 3 are supported in mounts 45 or 46 which can slide along a column 43. Each of the mounts or their cam followers 49, 50 are biased to the appropriate focal length adjusting cams by a torsion spring 47 or 48 whose direction of force is reversible. The focal length adjusting cams are constructed as the boundary surfaces of control slots 51, 52. The support 44 with the control slots can slide transversely to the optical axis O along pin-slot guides 53, the shape of the control cams in the slots converting the said sliding motion into a motion along the optical axis towards the mounts 45, 46. The focal length adjustment for the normal range is limited by a ratchet 54 on the support 44.

If focussing is desired in the macro range of this system, adjustment of the carrier merely requires overcoming the spring force of the ball catch 55 to enable the cam follower to bear upon the cam sections 56 or 57 while the direction of the spring force 47, 48 remains the same.

The cam followers must bear upon the cam sections 58, 59 if the focal length is to be adjusted at a specific macro distance. This is achieved by changing the control levers 60 into the illustrated arrow direction. The changeover can be effected after the ball catch 55 has engaged the recess 54.

Locking means illustrated in Figure 8B for the operation of the changeover lever 60 is provided to prevent any changeover of the cam followers to the macro focussing cam in the macro zooming range. Only one of the levers is shown in the interest of simplicity. The lever 60a has two recesses 61, 62 which co-operate with a pawl 64 that can pivot

about an axis 63. Pivoting about the axis 63 drives an axial cam 65 on a carrier 44.

The method of operation of the locking means is as follows. In the position illustrated in Figure 8B, the spring 48a biases the mount 46 or its cam follower 50 upon the cam 59 of the control slot 52. The axial cam 65, which is raised with respect to the carrier 44, incorporates a ramp. The ball 55 drops into the recess 54, when the cam followers 49, 50 enter into the expanded control regions formed in the upper ends of the slots. The pawl 64 which is driven by the cam 65 pivots about the axis 63 and drops into the recess 62. The lever 60a is therefore locked against any changeover of the spring 48a for the entire tracing range of the cam 59.

Changeover of the direction of spring force is not possible in the expanded region of the control slot 52 since the pawl 64, driven by a cam which corresponds to the cam 65, could also drop into a recess 61 in which position of the lever the follower 50 bears upon the cam 57 (macro focussing). Obviously it is essential that both lenses are moving in accordance with the profiles of the cam flanks which produce either focussing in the macro range or zooming, i.e. focal length adjustment.

One embodiment of the invention in which the focal length setting can be controlled in several macro distances is shown in Figures 9A and 9B. The lens 3 is accommodated in a mount 66. The mount is provided with a cam follower 67. In the course of the tracing motion of the cam follower 67 with respect to various control cams in a control slot 68 of a support 69 the lens 3 is moved along the optical axis O in accordance with laws which are specific to the control cams. The control slot 68 has at least one cam section 70 which drives the lens 3 for zooming over the normal distance range. Another cam section 71 is allocated to focussing in the macro region. A spring 72', whose direction of force is reversible, switches the cam follower 67 to the cams 70 or 71 respectively in a manner similar to that of the device illustrated in Figure 8. In the position illustrated in Figure 9A the cam follower 67 is biased towards a control cam 72 which is disposed on another carrier 73. The carrier 73 by itself can be adjusted parallel to the optical axis O for pre-selecting focal length control cams, by a changeover device (not shown), and can be adjusted in the direction of the arrow 74 together with the carrier 69 by a focal length adjusting device which is also not shown. The control cam 72 directly adjoins one end of the macro focussing cam 71 and is thus allocated to focal length adjustments at the macro distance which corresponds to focussing at this end of the macro cam 71. If the support 73 is moved to the left—with reference to Fig. 9A—the spring 72' will urge the cam

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 follower 67 to another focal length adjusting cam 75 in the control slot 68 for another specific macro distance. Focal length adjustment for the normal distance range, focusing in the macro range and focal length adjustment for objects situated in two different planes in the macro range is thus possible with relatively simple means of construction.

One embodiment of the invention in which any desired number of focal length adjustment curves associated with specific planes in the macro range can be used for control purposes and is shown in Fig. 10A to C.

Two mount parts 78, 79 for the lenses 2, 3 are guided parallel to the optical axis O on stationary guide columns 76, 77. To control the adjusting motion along the optical axis the mount 78 supports a cam follower 80 and the mount 79 supports a cam follower 81. The cam followers 80, 81 are guided in respective control slots 83, 84 of a disc cam 82. The cam provided by the slot 83 associated with the cam follower 80 and the cam 84 associated with the cam follower 81 have each a gently curved section α which is associated with focal length adjustment in the normal distance range. In the course of adjusting the focal length in the macro range, the cam followers 80, 81 traverse through the section β of both cams. A focal length adjusting device 85, comprising an operating handle 86 and an operating handle 87 (Figure 10B) is provided for transmitting the shape of the control cams to the cam followers. The handle 86 supports the disc cam 82, a further disc cam 88 being mounted on the operating handle 87. Both disc cams together with their handles can be independently rotated about a stationary axis 89. As can be seen by reference to Figure 10C, the disc cam 88 is provided with several spline grooves or slots so that one of three pairs of cams for the macro adjustment of the lenses 2 and 3 can engage in a specific angular position with the cam follower 80, 81 which are mounted on the spindle 89.

The disc cam 88 assumes the position shown in broken lines in Figure 10B for adjusting the focal length in the normal distance range, neither of the two cam followers being able to engage with the cams of the disc cam 88. The lenses 2 and 3 are therefore driven merely by the cams 83, 84 through the range α . The transition angle to the section β is so acute that rotation of the handle 86 or of the disc cam 82 beyond the α region results in self-locking action.

If the operating handle 87 together with the disc 88 is then moved into the position shown in solid lines in Fig. 10B, one of the cam pairs 90, 91 or 92 will engage with the associated cam follower 80 or 81. All cams of the disc 88 have cut-outs to permit free motion of the cam followers 80, 81 for focal length adjustments over the normal distance range α . This can be effected solely by clock-

wise rotation of the handle 87 or of the disc cam 88 associated therewith with reference to Figs. 10A and C—the cam followers bearing on the appropriate underside of the cam and being deflected laterally in dependence on the shape of the cams 83, 84 which are situated beneath. To effect the adjustment, it is necessary that the cam followers are situated in the transition of the regions α and β —with reference to cams 83 and 84—at the beginning of the adjusting motion.

If the disc cam 88 is rotated in the clockwise direction proceeding from this position, it results in a focal length adjusting motion of the lenses 2 and 3 in terms of forming an image of an object in the macro region with a constant image position. In this case the cam followers 80, 81 will move in accordance with laws defined by the cam regions β of the cams 91 or 92.

The circular middle line 93 illustrated in Fig. 10C discloses that with the exception of the cam 90 the cams associated with the cam follower 80 for the element 2 have an inwardly extending characteristic. This means that the cams 91, 92 control focal length adjustment in the macro region while the circular cam 90 does not result in any axial adjustment of the element 3 and therefore controls macro focusing accompanied by simultaneous adjustment of the element 3. The cams 91 and 92 are focal length adjustment cams for different macro distances. The effect of fading out in the form of dissolving the image sharpness can also be achieved by the above-described facility of changing directly from the focal length adjustment for the macro range or macro focusing cam into the normal focal length adjustment cam. This device also permits zooming in other macro distances, in which case the disc 88 must be exchanged for another disc with further cams 91, 92 which correspond to the focal length adjustment cams.

Fig. 11 shows another possible embodiment of a cam support with focal length adjustment cams which are positively traced for several macro distances. All cams of this embodiment are disposed on a single support 94. One cam follower 95 is associated with the element 2 and is guided in a slot 96. One follower 97 is associated with the element 3 and is guided in a slot 98 for adjusting the focal length over the normal distance range. Altering the focal length results in the support 94 being adjusted in the direction of the arrow 99.

The changeover of the focal length range for normal distances to macro distances is obtained by adjustment of the cam follower 97 to the left, with reference to Fig. 11. To this end, a locking device 100 for a focal length adjusting cam 101 or the said locking device 100 and a further locking device 102 for the focal length adjusting cam 103 must first be released. The

method of controlling the locking device will be described subsequently.

The cams 101 and 103 for the element 3 are associated to different planes in the macro range, the element 3 moving towards the element 2 due to being driven by the cam follower 95 and the cam section 104. The support 94 also has a cam section 105 for controlling focusing in the macro range.

A support illustrated in Figs. 12A and B has a cam slot 107 in which a cam follower 108 is positively guided. The cam slot is defined by three cam sections which control different settings of the lens which is not shown in the interests of simplicity. The cam section 109 controls the motion of the cam follower 108 for normal focal length adjustment, the cam section 110 provides this control for macro focusing and the cam section 111 provides this control for focal length adjustment in the macro range.

A further cam support 112, which is adjustable with the support 106 in the control direction for the cam follower 108 but can be adjusted in the direction of the arrow 113' when changing over the adjusting facilities of the lens, is also provided since, as already mentioned, the cam follower 108 is to be positively guided. The support 112 incorporates cams 109a to 111a which are parallel to the cams 109 to 111. A specific path for the cam follower is thus released in dependence on the lateral position of the support 112 in relation to the support 106. According to Fig. 12A it is possible to adjust the focal length over the normal distance range and to obtain focusing in the macro range. The focal length adjusting cam for the macro range is disclosed in Fig. 12B. Stop abutments, which limit the lateral adjusting travel of the support 106 so that the cam slot generated thereby corresponds to the diameter of the cam follower 108, are designated with the numerals 113 and 114.

One embodiment in which several cam followers are provided for controlling adjustable optical elements is shown in Figs. 13A and 13B. Controlling the element 2 by means of cam supports 115 has already been described in similar exemplified embodiments but the lens element 3 is associated with a cam support 116 which supports four cams 117 to 120 each of which can be brought into engagement with a cam follower 121 to 124. A mount 125 for the lens element 3 is guided along the optical axis O by means of a column 126 and supports a pin 127 which is inserted into the support 116 and is guided in a guide slot 128 (Fig. 13B).

The cam followers 121 to 124 support operating buttons 129 to 132 each of which is associated with a known ratchet device 133 so that only one of the cam followers can be engaged with the cam associated therewith.

The cam followers 121 to 124 are station-

arily supported while the support 116 can be adjusted relative to the cam followers in the direction of the arrow 134 (Fig. 13B). In the illustrated example, the cam follower 123 is in engagement with the cam 119 associated therewith. The cams 117 to 119 control the adjustment of focal length in the macro range.

In the course of the adjusting motion of the support 116 the support 115 is entrained in the same direction by means of the guide rod 135 but the rails 136 prevent adjustment of the support 115 in the direction of the optical axis O while the support 116 can be adjusted along the rods 135 in the direction of the optical axis, namely in dependence on the shape of the cam 117 to 120 which is being traced. In the course of the adjusting motion the pin 127 of the mount 125 slides in the slot 128. Advantageously, the operating handle for adjustment in the direction of the arrow 134 acts on the guided support 115.

Figs. 14 and 15 show a particularly advantageous embodiment of the apparatus for cine cameras. A wide-angle supplementary unit 141 can be fitted in front of the front element 1 of a cine camera 140 part of which is shown in Fig. 14. The wide-angle supplementary lens comprises the negative lens element 6 (see Fig. 2) which is supported in a mount 143 that can be fitted upon a camera lens mount.

Fitting the supplementary wide-angle lens unit 141 displaces a tracer rod 144 which thus releases a locking tube 146 which extends over the actual focal length cam tube 147, which can be constructed, for example in the same way as the tube 31 of Fig. 7A. Displacement of the locking tube 146 in relation to the cam tube 147 releases the cam sections 29" and 30" for adjusting the focal length in the macro range, the intermediate image situated in the macro range being sharply focused by means of the negative lens 6. The strongly divergent action of the lens 6 will then provide the extreme wide-angle effect. The locking devices 100, 102 of Fig. 11 can be controlled by the tracer rod 144 in place of the locking tube 147.

Fig. 15 shows a similar embodiment for use with a cine camera 150. Operation of a macro button 151 causes a similarly constructed locking tube 152 to be moved into the illustrated position so that the cam sections 29" and 30" are released for adjusting the focal length in the macro range. At the same time, a locking nose 153 is adjusted by a rod 154, associated with the tube 152, from an obstructing position in front of the zoom lens so that a transparency holder 155 can be placed in front of the front lens element 1 of the zoom lens. A transparency 156 which is inserted into the transparency holder 155 is situated accurately in a plane at the distance from the front lens 1 with which the macro focal length adjusting cams 29", 30" are also

associated. If several such zoom cams are provided, it is possible to switch the locking nose 153 in the position which will only permit the holder 155 to be fitted which is associated with the selected focal length adjusting cam.

The device according to the invention is not confined to its application in cine cameras, but can be used generally for all zoom lenses, for example for photographic cameras, microscopes or copying apparatus.

WHAT WE CLAIM IS:—

1. A zoom lens having an objective lens provided with a front lens element which may be movable for the purpose of focal length adjustment but which remains stationary during zooming and a stationary back lens element, and at least two movable intermediate lens elements relatively displaceable along a common optical axis between the front and back lens elements to produce zooming; a first mechanical control means operable to move the intermediate elements with respect to one another and the front and back lens elements in accordance with a first law enabling the magnification of an image of an object, lying in the normal range of the objective, to be varied progressively while the image itself remains in focus in an image plane; a second mechanical control means selectively useable in place of the first control means and operable to move the intermediate elements with respect to one another and the front and back lens elements in accordance with a second law enabling the magnification of an image of an object, lying in the macro range of the objective, to be varied progressively while the image itself remains in focus in the image plane; and, a selector operable by the user of the zoom lens to make one or other of the two control means effective so that zooming without loss of focus is possible in both the normal and macro ranges of the objective.

2. A lens as claimed in claim 1, in which the positions on the optical axis of the intermediate lens elements are controlled by cams provided by the profiles of the edges of slots through which pass cam follower pins provided on the intermediate lens elements, the slot edges being provided on adjustment means which are movable to alter the positions of the intermediate lens elements.

3. A lens as claimed in claim 2, in which the adjustment means comprise cam plates manually rotatable about the same axis and one of which is movable along the axis to engage a slot edge with or disengage it from the or each cam follower pin.

4. A lens as claimed in claim 2, in which the slots are enlarged at one end portion and have each enlarged end portion flanked by dissimilar slot edge profiles, the cam followers being resiliently urged against one or other

slot edge in dependence on which of the two laws in governing the movement of the intermediate lens elements.

5. A lens as claimed in claim 4, in which the adjustment means includes a flat plate formed with two slots each enlarged at one end, the plate being displaceable in its own plane to alter the positions of the intermediate lens elements.

6. A lens as claimed in claim 2, in which one slot branches into more than one slot portion each corresponding to a different object plane in the macro range, and the slot portions are individually selectable to control the position of an associated cam follower during zooming of an object in the selected plane.

7. A lens as claimed in claim 2, in which one slot edge includes a cam surface which is displaceable transversely to broaden or narrow the slot and thus adjust the focal length of the lens to suit different preselected planes in the macro range at which an object to be zoomed may be located.

8. A lens as claimed in claim 2, in which at least one of the slots is formed in a rotatable tube encircling the common optical axis.

9. A lens as claimed in claim 8, in which the slots are formed in respective rotatable tubes encircling the common optical axis and providing the adjustment means, the tubes being so connected that their axial positions can vary as they are rotated and a resilient bias being provided which is switchable to urge the tubes together or apart, one of the tubes having a wider slot than the cam follower which co-operates with it the wider slot being defined between two dissimilar camming edges one of which is effective when the movement of the intermediate lens elements is to be controlled by the first law and the other of which is effective when the intermediate element is to be controlled by the second law.

10. A lens as claimed in claim 8, in which the tube has two slots each having parallel sides between which a cam follower fits, each slot having circumferentially spaced end-portions and one pair of end-portions of the two slots are effective to govern movement of the intermediate lens elements in accordance with the first law and the other pair of slot end-portions being effective to govern movement of the intermediate lens elements in accordance with the second law.

11. A lens as claimed in claim 10, in which the two slots include parallel intermediate slot sections which extend in planes normal to the common optical axis and which engage the cam follower pins simultaneously to bridge the opposite end-portions of the two slots.

12. A lens as claimed in claim 8, in which each intermediate lens element is provided with two selectably effective cam followers

associated. If several such zoom cams are provided, it is possible to switch the locking nose 153 in the position which will only permit the holder 155 to be fitted which is associated with the selected focal length adjusting cam.

The device according to the invention is not confined to its application in cine cameras, but can be used generally for all zoom lenses, for example for photographic cameras, microscopes or copying apparatus.

WHAT WE CLAIM IS:—

1. A zoom lens having an objective lens provided with a front lens element which may be movable for the purpose of focal length adjustment but which remains stationary during zooming and a stationary back lens element, and at least two movable intermediate lens elements relatively displaceable along a common optical axis between the front and back lens elements to produce zooming; a first mechanical control means operable to move the intermediate elements with respect to one another and the front and back lens elements in accordance with a first law enabling the magnification of an image of an object, lying in the normal range of the objective, to be varied progressively while the image itself remains in focus in an image plane; a second mechanical control means selectively useable in place of the first control means and operable to move the intermediate elements with respect to one another and the front and back lens elements in accordance with a second law enabling the magnification of an image of an object, lying in the macro range of the objective, to be varied progressively while the image itself remains in focus in the image plane; and, a selector operable by the user of the zoom lens to make one or other of the two control means effective so that zooming without loss of focus is possible in both the normal and macro ranges of the objective.

2. A lens as claimed in claim 1, in which the positions on the optical axis of the intermediate lens elements are controlled by cams provided by the profiles of the edges of slots through which pass cam follower pins provided on the intermediate lens elements, the slot edges being provided on adjustment means which are movable to alter the positions of the intermediate lens elements.

3. A lens as claimed in claim 2, in which the adjustment means comprise cam plates manually rotatable about the same axis and one of which is movable along the axis to engage a slot edge with or disengage it from the or each cam follower pin.

4. A lens as claimed in claim 2, in which the slots are enlarged at one end portion and have each enlarged end portion flanked by dissimilar slot edge profiles, the cam followers being resiliently urged against one or other

slot edge in dependence on which of the two laws in governing the movement of the intermediate lens elements.

5. A lens as claimed in claim 4, in which the adjustment means includes a flat plate formed with two slots each enlarged at one end, the plate being displaceable in its own plane to alter the positions of the intermediate lens elements.

6. A lens as claimed in claim 2, in which one slot branches into more than one slot portion each corresponding to a different object plane in the macro range, and the slot portions are individually selectable to control the position of an associated cam follower during zooming of an object in the selected plane.

7. A lens as claimed in claim 2, in which one slot edge includes a cam surface which is displaceable transversely to broaden or narrow the slot and thus adjust the focal length of the lens to suit different preselected planes in the macro range at which an object to be zoomed may be located.

8. A lens as claimed in claim 2, in which at least one of the slots is formed in a rotatable tube encircling the common optical axis.

9. A lens as claimed in claim 8, in which the slots are formed in respective rotatable tubes encircling the common optical axis and providing the adjustment means, the tubes being so connected that their axial positions can vary as they are rotated and a resilient bias being provided which is switchable to urge the tubes together or apart, one of the tubes having a wider slot than the cam follower which co-operates with it the wider slot being defined between two dissimilar camming edges one of which is effective when the movement of the intermediate lens elements is to be controlled by the first law and the other of which is effective when the intermediate element is to be controlled by the second law.

10. A lens as claimed in claim 8, in which the tube has two slots each having parallel sides between which a cam follower fits, each slot having circumferentially spaced end-portions and one pair of end-portions of the two slots are effective to govern movement of the intermediate lens elements in accordance with the first law and the other pair of slot end-portions being effective to govern movement of the intermediate lens elements in accordance with the second law.

11. A lens as claimed in claim 10, in which the two slots include parallel intermediate slot sections which extend in planes normal to the common optical axis and which engage the cam follower pins simultaneously to bridge the opposite end-portions of the two slots.

12. A lens as claimed in claim 8, in which each intermediate lens element is provided with two selectably effective cam followers





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each engageable in its own slot in the tube, the selective engagement of one cam follower with its slot controlling movement of the associated lens element when it is to be governed by the first law, and the selective engagement of the second cam follower with its slot controlling movement of the associated intermediate lens element when it is to be governed by a second law.

13. A lens as claimed in any one of the preceding claims, in which the selection of the second control means moves a locking nose in front of the front lens to a position at which a holder for a transparency which is to be zoomed in the macro range can be temporarily mounted in front of the front lens in the correct plane for such zooming to be carried out.

14. A lens as claimed in any one of the preceding claims, in which one of the intermediate lens elements is negative.

15. A lens as claimed in claim 14, in which both of the intermediate lens elements are negative.

16. A lens as claimed in any one of the preceding claims, in which the focal length

of the front lens element is less than k -times the maximum total focal length of the zoom lens, where k is the ratio of the maximum total focal length of the zoom lens to the minimum total focal length of the zoom lens.

17. A lens as claimed in claim 8, in which each cam follower pin passes through slots provided, respectively, in two relatively movable, concentrically, arranged tubes.

18. A lens as claimed in any one of claims 1 to 12, including a device which responds to the positioning of a readily-removable supplementary unit on a mount in front of the lens, by making the second control means effective to produce at said image plane a focussed image of an object in a predetermined plane in the macro range.

19. A lens as claimed in claim 1, arranged and adapted to operate substantially as described with reference to any one of the embodiments of the invention, or modifications thereof, or improvements thereto, illustrated in the accompanying drawings.

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Agents for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1979.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.