

Oct. 14, 1958

B. E. LUBOSHEZ
COMPOSITE PRISMS AND PRISMATIC MAGNIFICATION
SYSTEMS COMPRISING SAME

2,855,819

Filed Sept. 1, 1955

3 Sheets-Sheet 1

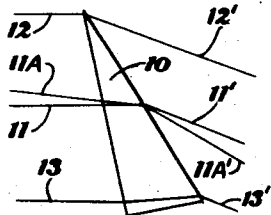
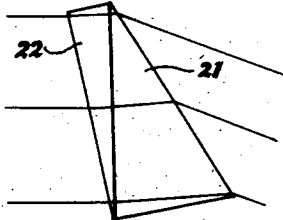
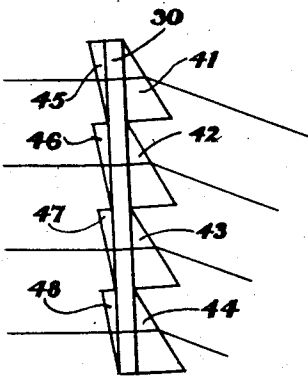
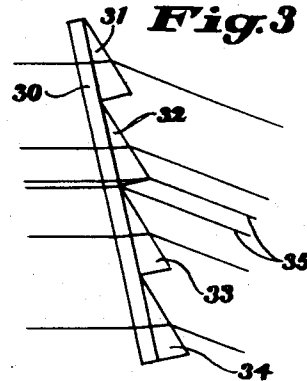
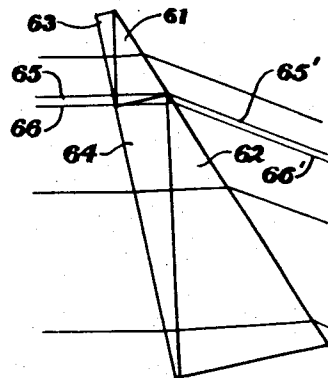
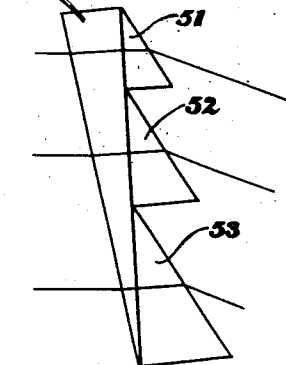
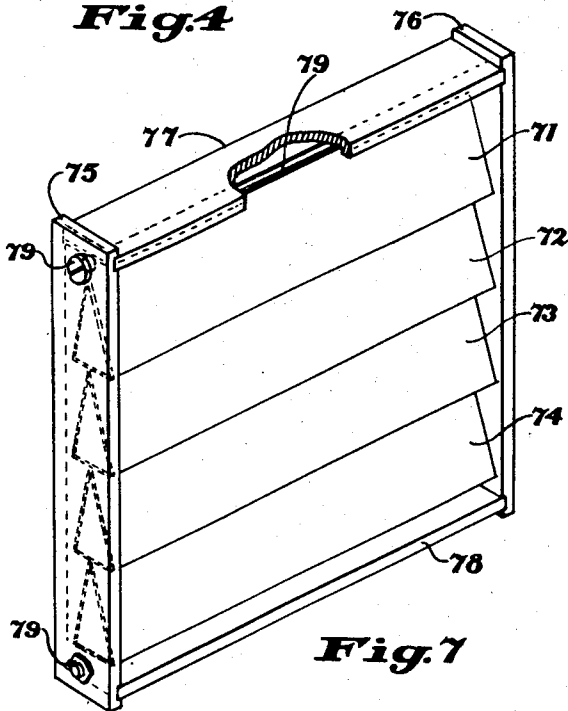
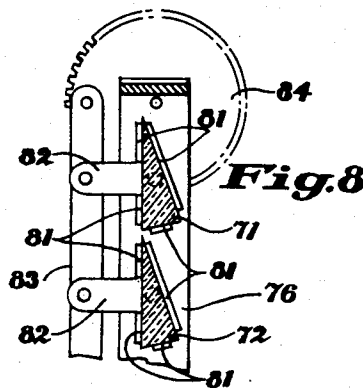
Fig. 1
PRIOR ART**Fig. 2**
PRIOR ART

Fig. 3 T2033
X2007
X2036
X2264

**Fig. 5****Fig. 4****Fig. 6****Fig. 7****Fig. 8**

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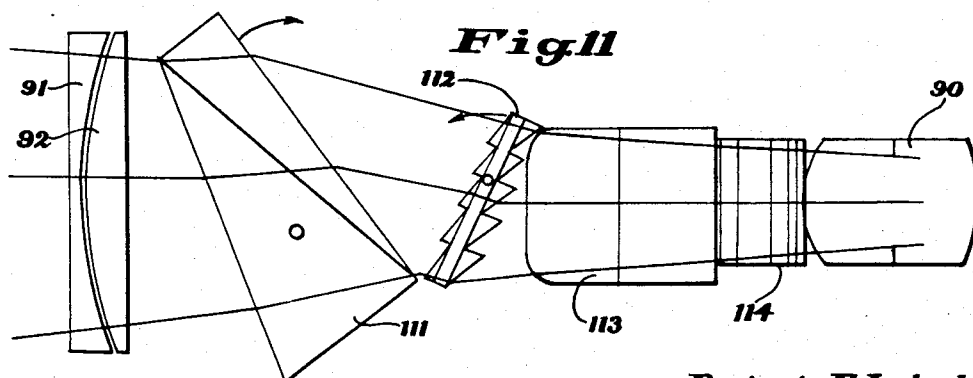
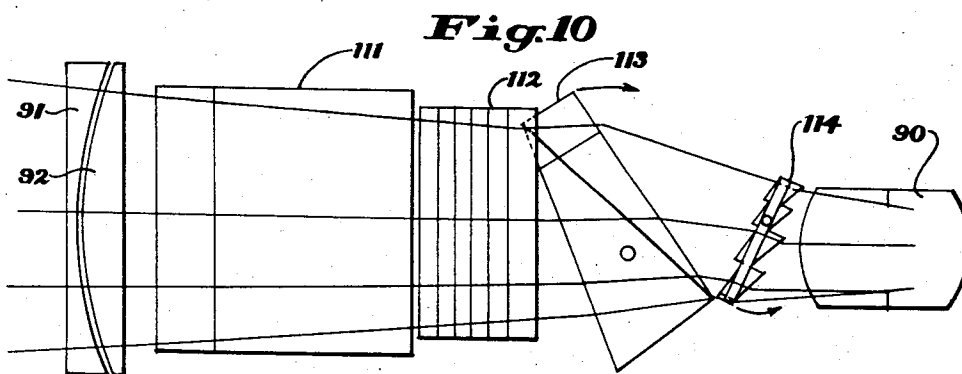
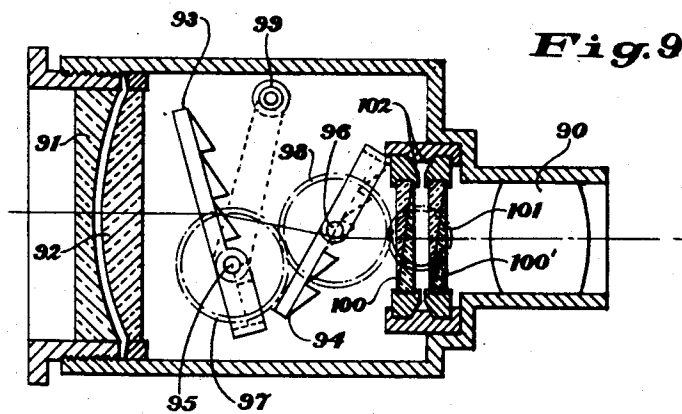
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Fig.12

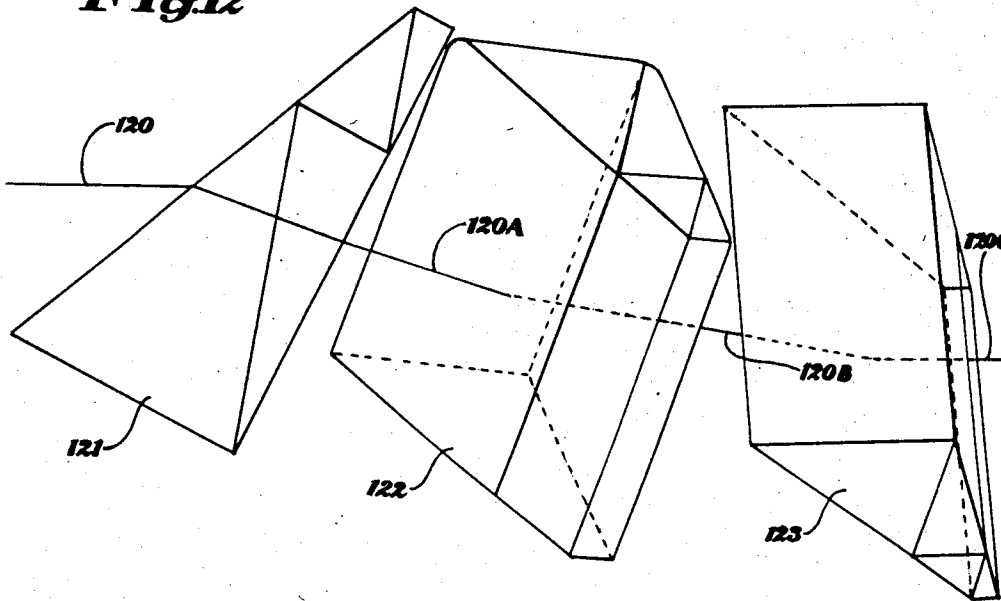


Fig.13

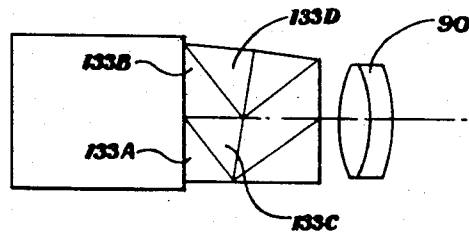
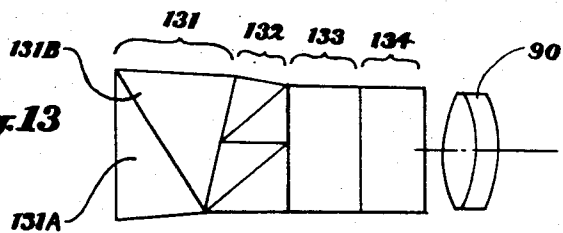


Fig.14

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2,855,819

COMPOSITE PRISMS AND PRISMATIC MAGNIFICATION SYSTEMS COMPRISING SAME

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Application September 1, 1955, Serial No. 531,991

3 Claims. (Cl. 88—1)

This invention relates to prism magnification systems including the type which magnifies an image anamorphotically, i. e. in one direction more than in the transverse direction, and also the type which magnifies the image equally in all directions. The word "magnification" as here used refers either to an increase or a decrease in the image size, magnification producing an increase being greater than unity and that producing a decrease being less than unity.

An object of the invention is to provide a prism magnification system which is lighter in weight and smaller in size than heretofore known and which can be constructed so as to vignette the image less at the edges of the field.

Another object of the invention is to provide prisms for prism magnification systems which are larger in aperture area than is practicable with known prisms.

It has been known for many years that when light from a distant object traverses a refracting prism in a direction other than that of minimum deviation, then the object viewed through the prism is magnified in the direction perpendicular to the refracting edge of the prism but is not magnified in the direction parallel thereto. There are aberrations however, in a single prism, for example, the degree of magnification changes progressively across the field and unless the prism is achromatized there is a serious unilateral color or breaking up of each ray of white light into a spectral fan of rays, and so customarily a second prism is provided which deviates the light in the opposite direction to the first prism, in which case the aberrations are, to a large extent, cancelled out while the magnifications of the two prisms are cumulative. This arrangement may be called a simple two-prism anamorphoser. Forms are also known using three or four prisms which are carefully calculated so as to eliminate the aberrations more completely.

It has been known for many years also that two anamorphosers crossed will magnify an image in all directions substantially equally, and in my copending application, Serial No. 453,092, filed August 30, 1954, certain novel and useful arrangements are described which involve two anamorphosers so arranged. In some of these arrangements the magnification is fixed (but can be changed by reversing the whole prism system) while in others the magnification is variable from 2 to 2.5 to about $\frac{1}{2}$ or $\frac{2}{3}$ by rotating the individual prisms about axes of rotation parallel to their refracting edges. Two further copending applications No. 498,167 and 498,168 filed March 31, 1955, now Patents 2,780,140 and 2,780,141 issued February 5, 1957, describe systems made up of simple unachromatized refracting prisms with the addition of correcting wedges for correcting the unilateral color and the deviation of the axis which occurs in some of these systems when, by adjusting the angles of refraction and the angles of tilt of the individual prisms, the other aberrations are eliminated. A third application, Serial No. 531,884 filed concurrently herewith, describes prism magnification systems which comprise X prisms

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(where X is an integer between 3 and 8 inclusive) which are axially aligned with each other and positioned at angles of

$$\frac{360^\circ}{X}$$

with each other around the axis. Or, in another form, these magnification systems comprise three simple two-prism anamorphosers arranged at 120° from each other around the axis. These systems magnify equally in all directions as closely as can be detected by observation and can be made more compact than other prior systems.

In Serial No. 498,168, the correction of unilateral chromatic aberration is discussed at considerable length and it is pointed out that this color aberration is improved by tilting each individual prism farther from its position of minimum deviation during design and making the refracting angles smaller to maintain the magnification constant, but that on the other hand, this tilting of the prisms makes the system longer and since systems are usually used in an expanding cone of light, it makes it necessary to make the prisms larger until a limiting case is reached in which the prism face is parallel to the boundary of the expanding cone and thus no matter how large the prism is made, it will not pass the cone of light. Of course, practical forms of this invention stop considerably before this theoretical limit is reached.

When used in an expanding cone of light, it is important to make the system as short as possible because the longer it is, the larger the prisms have to be. Accordingly, it is one of the principal objects of this invention to make the prisms thinner so as to bring them more closely to the apex of the cone of light and thus make it possible to make them smaller in aperture area while still passing the whole cone of light. This benefit is compounded since if the prisms are smaller in aperture area, they can be made still smaller in thickness and thus can be brought together still more compactly and so on.

According to the present invention, at least one of the prisms of a magnifying prism system is made up in a Fresnel type of construction and comprises a plurality of prism elements having mutually equal refractive indices and refracting angles and means for supporting said prism elements with their refracting faces respectively codirectional, that is, either in a common plane or at least mutually parallel to each other while still permitting light to pass freely through a considerable aperture area.

In structure, this Fresnel type of construction differs greatly from the molded or pressed Fresnel type lenses used in lighthouses and searchlights and for similar purposes which are molded or pressed of a single piece of glass. It has never been found possible to provide sufficiently accurate optical surfaces by those processes and the present invention is confined to a novel type of structure in which a plurality of prism elements are made up and optically polished with accurate optical surfaces and with mutually equal refracting angles and are accurately mounted in or on a support so that they are supported with their respective refracting faces codirectional. That is, each prism has two refracting faces and the front faces are all mutually parallel or else they lie in the same plane and the rear faces are all mutually parallel or lie in the same plane. Obviously, the front and back faces cannot both be coplanar.

Several constructional forms are contemplated and other variations will doubtless occur to those skilled in the art. One simple form for making up an unachromatized prism according to the invention consists of a

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flat plane-parallel sheet of glass with the prismatic elements cemented onto one face thereof with the edge of one prism element against the base of the next. In this way prisms with rather large aperture areas can be made up. According to a slightly different constructional form of unachromatized prisms, the elemental prisms are mounted in a frame in which the ends of the prisms fit into pockets in the sides of the frame, the frame extending around the refracting edge of the top prism and the base of the bottom prism to form a complete square frame. This second form permits a little more freedom in choosing the relative positions of the prisms, that is, choosing how close to being coplanar the front surfaces, for example, should be so as to minimize the shadowing of the optical beam by the step between the refracting edge of one prism and the base of the next.

Still other variations are useful in constructing achromatic prisms. Achromatic prisms are those which comprise two refracting prism elements cemented together, one deviating the light downward and the other upward, the deviations and dispersions being chosen so that there is a net deviation but zero net dispersion. A prism element which deviates the light in the same direction as the whole achromatic prism is designated as positive in accordance with a known convention, and elements deviating it in the opposite direction are called negative. According to one form of construction, achromatic prisms are made up by cementing a set of prismatic elements on one side of a plate of glass with the bases down and a second set on the opposite side of the plate of glass with the bases up, the angles of the prisms and the types of glasses used being chosen to give chromatic correction. According to another form of construction, the thinner of the two prisms according to the prior art is made up as a whole prism analogous to the plano parallel plate of glass in the constructional form described above and the prismatic elements corresponding to the thicker prism of the prior art are cemented to this large prism giving a saw-tooth effect.

According to a preferred constructional form of the invention, an achromatic prism is made up in which the two prism elements of the prior art are both replaced by a series of smaller prism elements, the two series of elements being paired off and cemented together in pairs, the thicker edge or base of one pair being cemented onto the thinner edge of another pair so that the saw-tooth line of union is in the interior of the composite prism body and the exterior faces of the composite prism body are plane. This form of the invention is particularly preferable when the refractive indices of the two types of glass used are equal for at least one wavelength of light so that light of at least that one wavelength is not deviated by the internal faces where the edges of two prism pairs are cemented together.

In the prior art the magnification of the prism systems is varied by changing the tilt of the individual prisms. This is also done with my Fresnel-type prisms either by rotating the whole composite prism about an axis or by mounting the individual elements on separate axes and rotating them in unison. Prisms according to the present invention are useful in any prior art system known to applicant and in the systems described in my copending applications, and optionally only one of the prisms of a system is made according to the present invention or any number or all of them. There is a slight shadow banding across the aperture area due to the shadows cast by the bases of the individual prism element which appears to be unavoidable. However, this is more than counterbalanced in most cases by the greater area which is practicable with this improved form of prism and by the resulting decrease in vignetting at the edge of the image field. It appears that the largest prism of any given prism system is the most advanta-

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geous to make up according to this improved form, but on the other hand, the smaller prisms are ordinarily closer to the aperture stop of the optical system and thus would be less likely to cause the shadow bands just mentioned to be visible in the image plane. As previously mentioned, when even the smallest prism of the system is made according to the present invention, the larger prisms can be brought in closer to the apex of the cone of rays which is to be passed by the system and thus the larger prisms are made smaller and the advantages gained are commensurate with those gained by making the largest prism composite. The invention will be better understood in connection with the accompanying drawings in which:

Figs. 1 and 2 show prisms according to the prior art,

Figs. 3 and 4 show prisms in which the prism elements are cemented onto a large piece of transparent material,

Fig. 5 shows a similar prism in which a thin prism wedge is used instead of a plane-parallel sheet,

Fig. 6 shows a composite prism according to a preferred form of the invention having smooth exterior faces,

Fig. 7 shows a composite prism in which the prism elements are supported at their ends,

Fig. 8 shows a cross-sectional view of a prism system in which the prism elements are mounted at their ends for individual rotation,

Fig. 9 shows a two-prism variable anamorphoser in which both prisms are composite in accordance with the present invention,

Figs. 10 and 11 show a four-prism zoom system in which two of the four prisms are composite in accordance with the present invention,

Fig. 12 shows a three-prism magnifying system such as that shown in my concurrently filed application in which all three prisms are composite,

Figs. 13 and 14 show a fixed magnification telescopic system in which all four prisms are made up as a solid block of material and three of them are composite in accordance with the present invention.

In Fig. 1 a prism 10 is traversed by a pencil of parallel rays including the axis 11 and boundary rays 12 and 13, all of which are refracted and emerge as rays 11', 12' and 13' which are also parallel to each other but are closer together and hence, according to a fundamental law of optics, the angle between this bundle of rays and another bundle of rays represented by ray 11A' is magnified by this prism.

Fig. 2 is similar but shows a prism which is achromatized by cementing together a positive prism of crown glass 21 and a negative prism of flint glass 22 having a smaller refracting angle. This corrects the chromatic aberration and leaves the magnification and deviation substantially the same as in Fig. 1 so long as the total prism angle is the same.

Fig. 3 shows a simple form of composite prism according to the invention. This prism comprises a flat plano parallel plate of glass 30 onto one side of which are cemented a series of prism elements 31, 32, 33 and 34 in parallel relationship. Assuming that these prism elements have the same refractive index and vertex angle as prism 10 of Fig. 1, the deviation and magnification will both be the same and the prism gains a great deal in compactness as is obvious from the drawing. There is one slight disadvantage, however, and that is the shadow banding, that is, the base of each of the prism elements cuts off a part of the emerging beam. For example, prism 32 cuts off the space between rays 35. In many applications, however, this shadowing is more than compensated for by the greater prism area made possible by the invention.

Fig. 4 shows an achromatized prism, the construction of which is similar to the prism of Fig. 3. In Fig. 4 the plane-parallel plate 30 has the same function as that in Fig. 3 and the prisms 41, 42, 43 and 44 are arranged

the same as prisms 31 to 34 in Fig. 3 with this difference that the angle of these prisms in Fig. 4 corresponds to the angle of prism 21 in Fig. 2 rather than to the prism 10 in Fig. 1. On the other side of the plate 30 is another set of prisms 45, 46, 47 and 48, which correspond to prism 22 of Fig. 2 and are cemented onto the plate 30 with the bases upward. This prism is achromatized as the prism in Fig. 2, assuming the same types of glass and the same prism angles, and gives the same magnification at the same angle of tilt. Here again, however, there are shadow bands as in Fig. 3. The saving in thickness and weight of the prism, however, is even greater in the achromatized prisms than it is in the simple prisms.

Fig. 5 shows another form of the composite prism according to the invention in which the negative prism 22 is large enough to fill the whole aperture area and takes the place of the flat plate 30 in Figs. 3 and 4, while the positive prism 21 of Fig. 2 is replaced by a set of smaller prism elements having the same refractive index and prism refracting angle 51, 52 and 53. These prism elements may all be of uniform size as in Figs. 3 and 4 or they may be progressively larger across the area as shown in Fig. 5, the prism element cemented to the base of prism 22 being smaller than the prism element 53 cemented to the apex of prism 22 to give a uniform thickness of the whole prism as measured to the tips of the saw teeth. Still other variations are possible which are designed relative to the whole prism system of which the prism is a part so as to attain the maximum compactness, and some of these will be described with reference to Figs. 9 to 14.

Fig. 6 shows a composite achromatized prism according to a preferred form of the invention in which there is no shadow band effect in light of a selected wavelength. This prism is made up of two sets of prismatic elements, a set of positive prisms 61 and 62 and a set of negative prisms 63 and 64, cemented together in pairs, that is, prism 61 is cemented to prism 63 and prism 62 is cemented to prism 64, and in addition, the base of one cemented pair of prisms is cemented to the truncated apex of another pair, this apex being for the most part the base of the negative prism of the latter pair and being preferably the same width as the base of the prism pair cemented thereto. The positive prisms 61 and 62 are made of a low dispersion glass, that is, a high dispersive index V, and the negative set of prisms 63 and 64 are made of a high-dispersion glass having exactly the same refractive index for a selected wavelength of light. Rays of light lying between ray 65 and ray 66 then traverse the cemented surface joining the base of one pair of prisms and the apex of the other and emerge between rays 65' and 66'. In the selected wavelength of light these rays will not be deviated differently from all the other rays, of which rays 65 and 66 are samples. However, there will be some scattering of light of other wavelengths which will cause a little over-all haze in the image plane. Preferably the wavelength selected for zero deviation at the cemented surface is the wavelength of maximum effect in the optical receptor, and thus the over-all haze will generally be negligible.

There are many pairs of glasses available commercially which differ considerably in dispersion and are identical in refractive index for one wavelength, and by selection of melts the matching wavelength is as close as necessary to the selected value for most applications. For more exact matching, known methods of fine annealing are used.

By way of example, in the Schott catalog, SK-16 matches with F-9, F-2, and F-12, SK-21 with SF-9 and SK-14 with F-14 at different wavelengths between the D line and the F line, and if one of glasses EK-96 and EK-99 made by the Eastman Kodak Co. is substituted for SK-16 the wavelength of coincidence is shifted about two or four hundred angstroms toward the

shorter wavelengths. Another pair perhaps more resistant to atmospheric action is PSK-3 and KzF-1.

Fig. 7 shows a different form of structure in which the prism elements 71, 72, 73 and 74 are supported at their ends by a square frame of any known structure which preferably extends all around the aperture area without obscuring it. In the form shown, it consists of two end plates 75, 76, which optionally and preferably are recessed to receive the ends of the prism elements and the ends of two side plates 77, 78 at the top and bottom. The frame is conveniently held together by two long rods 79 which are threaded at one end and either threaded or provided with a screw head or the like at the other end.

This form of structure has some advantages over that shown in Fig. 3 in that it eliminates the thickness of the plate 30 and permits the designer a wider choice in positioning the prisms 71, 72, 73 and 74 relative to one another. Since in most systems an adjoining prism is larger or smaller in aperture area frame members 75, 76 usually will not interfere with the corresponding frames of the next prism to the detriment of the over-all compactness of the system.

Fig. 8 shows a modification of Fig. 7 in which the prisms are mounted for individual rotation, the view being a section across the prisms and only two prisms 71, 72 being shown. The prisms are mounted on individual end plates with edges 81 turned up to clamp the prism. Each individual plate is pivoted in the end plate 76 and is provided with an arm 82, all the arms being connected by a bar 83 pivoted at their ends, and this bar in turn is pushed and pulled by the pinion wheel 84 for rotating the prisms to change the magnification. The pinion 84 is turned in a manner known in the prior art and is for connecting this composite prism with another for movement in unison.

A similar pivoted end plate is at the other end of each prism, but it is optional whether the lever arms and sliding bar are provided at both ends or at only one end. This form of construction is particularly useful in situations in which an extremely large aperture area is required.

Fig. 9 shows a 2-prism anamorphoser corresponding to Fig. 6 of my Serial No. 498,168 except that the prisms are made in composite form according to the present invention. Light from a distant object is collimated by the collimating or focusing lenses 91, 92 in known manner and the collimated light then passes through the prism system by which it is magnified in the plane of the diagram but not perpendicular thereto. The prism system comprises two composite prisms 93 and 94 which are mounted to rotate on axes 95 and 96, the prisms being rotated in unison by means of gear wheels 97 and 98 turned by a crank 99. The angles, refractive indices and tilt angles of the prisms are in accordance with the prior art or optionally are as described in my earlier application in which case the axial ray is transmitted without noticeable deviation but with a varying degree of unilateral color which is corrected by a pair of dispersion wedges 100, 100' which are rotated around the optical axis by gear wheel 101 and beveled gears 102 so that the vectorially added effect of the two dispersions is to substantially correct the unilateral color of the prism system. The dispersion wedges are each made up of two wedge elements of different kinds of glass so as to spread out the spectrum without deviating the ray of a selected median color. This correction of unilateral color is the subject of my Serial No. 498,168 and is not an integral part of the present invention. Finally the light passes through the objective lens 90, shown schematically, which focuses it at the focal plane (not shown). All the optical elements are mounted in a suitable barrel or box shown more or less schematically with focusing threads for element 91.

Figs. 10 and 11 show the top and side view respectively of a four-prism zoom system located in collimated light

in an optical system represented by an objective lens 90 shown schematically and variable collimating lens 91, 92. This system corresponds generally to Figs. 21 and 22 of my Serial No. 453,092 and comprises four achromatic prisms 111, 112, 113, and 114 in order from front to rear. As shown, the second and fourth prisms 112 and 114 are made in the composite form of the type shown in Fig. 4. All four of the prisms could be made in this form, but for some applications it is preferable to have only two so as to reduce the shadow banding effect of the bases of the small prism elements. It will be noted that prisms 92 and 94 cross each other whereas if two prisms which act in the same plane were made composite it would, in some cases, result in the shadows of the prism bases having a different effect in different parts of the image plane because in some parts of the image plane the two sets of shadow bands would coincide and have no more effect than one set of shadow bands whereas in other parts of the image plane one set of shadow bands would fall in the interstices of the other set and would double the shadowing effect, and this would result in uneven illumination in different parts of the field. This is kept to a minimum, however, by having only one prism made composite in each plane. It will be noted that prism 113 is rounded on the corners so that prism 112 can be brought in closer thereto than would otherwise be possible. This is an advantage in prism systems of this kind but is not considered a feature of the present invention.

The prism angles and indices of refraction are or may be the same as in prior art anamorphoser systems, two such anamorphoser systems and the lenses 90, 91 and 92 making up a zoom system in accordance with my Serial No. 453,092.

It may be noted that the light rays shown in Figs. 10 and 11 are not all intended to be from the same object point, but generally to delineate the cone of rays to be passed by the prism system.

Fig. 12 shows a three-prism magnifying system which may be mounted in front of an objective lens, not shown, or in collimated light in any optical system where there is sufficient room for it and is similar to the systems described in my concurrently filed application with the difference that the individual prisms are made up in accordance with the preferred form of the invention shown in Fig. 6. There is this additional difference that the prisms shown in Fig. 12 are achromatized or at least partially achromatized whereas the prisms shown in my coiled application are individually unachromatized. It may be noted that systems of this type can also be made up using composite prisms of any of the kinds shown in Figs. 3, 4, 5 and 7.

The system shown in Fig. 12 briefly consists of a front prism 121 with base downward which receives a ray of light 120 and bends it downward in the plane of the diagram to become ray 120A, a second prism 122 which is or may be positioned so that the refracted ray 120A strikes its front face at the same angle as ray 120 strikes the front face of prism 121, but prism 122 is rotated around this ray 120A by approximately 120° so that it bends the light ray upward half as much as prism 121 bends it downward and also bends it behind the plane of the diagram into the direction 120B. A third prism 123 receives ray 120B likewise at the same angle of incidence and is rotated around this ray 120B approximately another 120° so that it bends the ray up again into the horizontal and forward into parallelism with the plane of the diagram along path 120C which is the axis of the associated lens system. This type of system has been found to give uniform and distortion-free magnification and can be made more compact and lighter in weight by incorporating the present invention.

Figs. 13 and 14 are top and side views of a solid block magnifying system corresponding to Figs. 7 and 8 of my Serial No. 453,092. In this system four pairs of prisms

131, 132, 133 and 134 make up the magnifying attachment for lens 90 and three of the four prism pairs incorporate the composite structure according to the present invention leaving the front pair of prisms 131 in the original form consisting of a prism of high refractive index 131A and one of low refractive index 131B. The other prisms are made up in sections, prism 133, for example, comprising two high-index prisms 133A and 133B which correspond to prism 131A and two low-index prisms 133C and 133D which correspond to 131B. Of course, all four prism pairs can be made composite but in some systems an internal shadow surface as far from lens 90 as is prism 131, would be focused near enough to the focal plane to show up in the image.

The examples shown herein are illustrative of the great variety of prism systems which can be made in accordance with the present invention, and the invention is not limited thereto but is of the scope of the appended claims.

I claim:

1. A composite achromatic light-deviating prism having two outer faces opposite each other and a cemented interface therebetween, one of said three faces having a sawtooth-like profile, said composite prism having a base defined as that side of the prism toward which light rays entering the prism through one face and leaving through the opposite face are deviated and having an apex defined as the side of the prism opposite the base, in which the said composite prism comprises a plurality of prismatic elements of positive light-deviating power made of glass of relatively low chromatic dispersion and prismatic means of negative light-deviating power made of glass of relatively higher chromatic dispersion, in which said plurality of positive prismatic elements are arranged with a corresponding face of each in mutually coplanar relationship and with the respective opposite faces in mutually parallel relationship forming said sawtooth-like profile, said plurality of positive prism elements being arranged from the base to the apex of said composite prism with the apex of one element adjacent to the base of the next and collectively covering an area coextensive with one of said two outer faces of said composite prism and the other of said outer faces being coextensive with said negative prismatic means, and in which all said positive prismatic elements and negative prismatic means are cemented together for mutual support whereby substantially all of a bundle of parallel rays traversing said composite prism except for those rays passing obliquely through the bases of said prism elements are equally deviated away from said base of said composite prism by said negative prismatic means and are deviated toward said base by said positive prism elements to emerge as a parallel bundle with a net deviation toward said base.

2. A composite achromatic light-deviating prism which comprises a plurality of prismatic elements of positive light deviating power made of glass of relatively low chromatic dispersion and an equal number of prismatic elements of negative light-deviating power made of glass of relatively higher chromatic dispersion in one-to-one correspondence therewith, in which said plurality of positive prismatic elements are arranged with a corresponding face of each in mutually coplanar relationship and with the respective opposite faces in mutually parallel relationship forming a sawtooth-like profile, said plurality of positive prism elements being arranged from the base to the apex of said composite prism with the apex of one element adjacent to the base of the next, said plurality of negative prismatic elements likewise being arranged with a corresponding face of each in mutually coplanar relationship and with the respective opposite faces in mutually parallel relationship also forming a sawtooth-like profile, and the base of each negative prismatic element being adjacent to the apex of the corresponding positive prismatic element and the apex of each negative prismatic element being adjacent to the base of the corre-

sponding positive prismatic element, and which comprises means for supporting all said prismatic elements cemented into a transparent body capable of imparting equal deviation to substantially all of a bundle of parallel rays of light traversing said prism.

3. A composite prism according to claim 2 in which said two sawtooth profiles are complementary in form and are cemented directly to each other.

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