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Margolis

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(54) **COMPLEX MODULAR AFOCAL VARIATOR WITH SPHERICAL AND CHROMATIC ABERRATION CORRECTION**

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G02B 15/173 (2006.01)
G02B 15/02 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 15/15*** (2013.01); ***G02B 15/173*** (2013.01); *G02B 15/02* (2013.01)

(58) **Field of Classification Search**
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USPC 359/672–675
See application file for complete search history.

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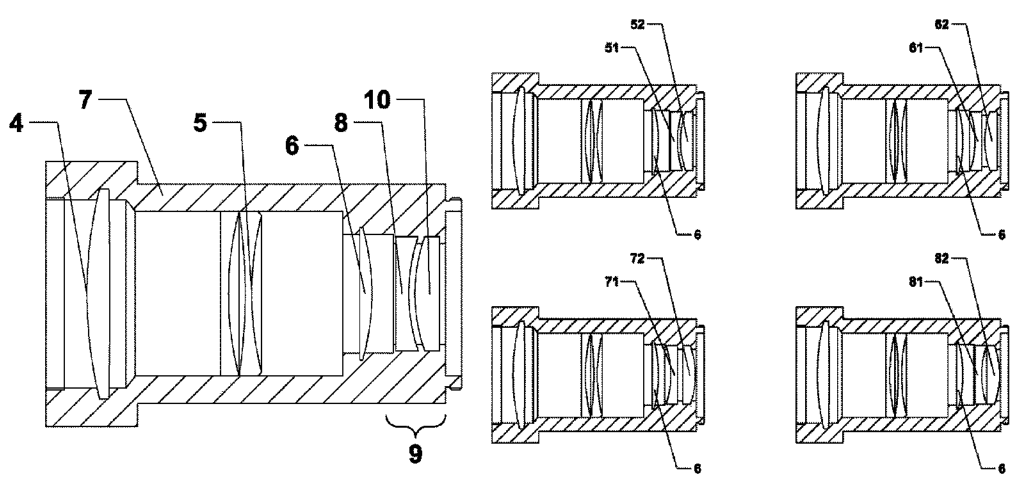
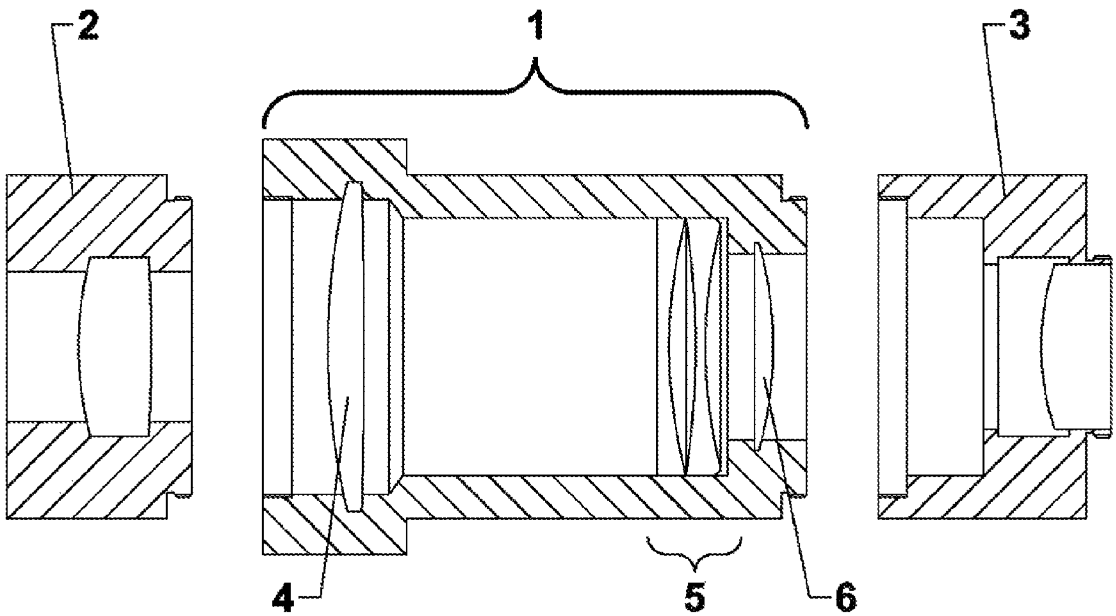
(57) **ABSTRACT**

The present invention provides a complex modular afocal variator in which a modular afocal variator is supplemented with additional optics to form a more complex, but still modular afocal variator system, that can impart internal focusing as well as active spherical and chromatic aberration corrective improvement.

15 Claims, 7 Drawing Sheets





PRIOR ART

FIGURE 1

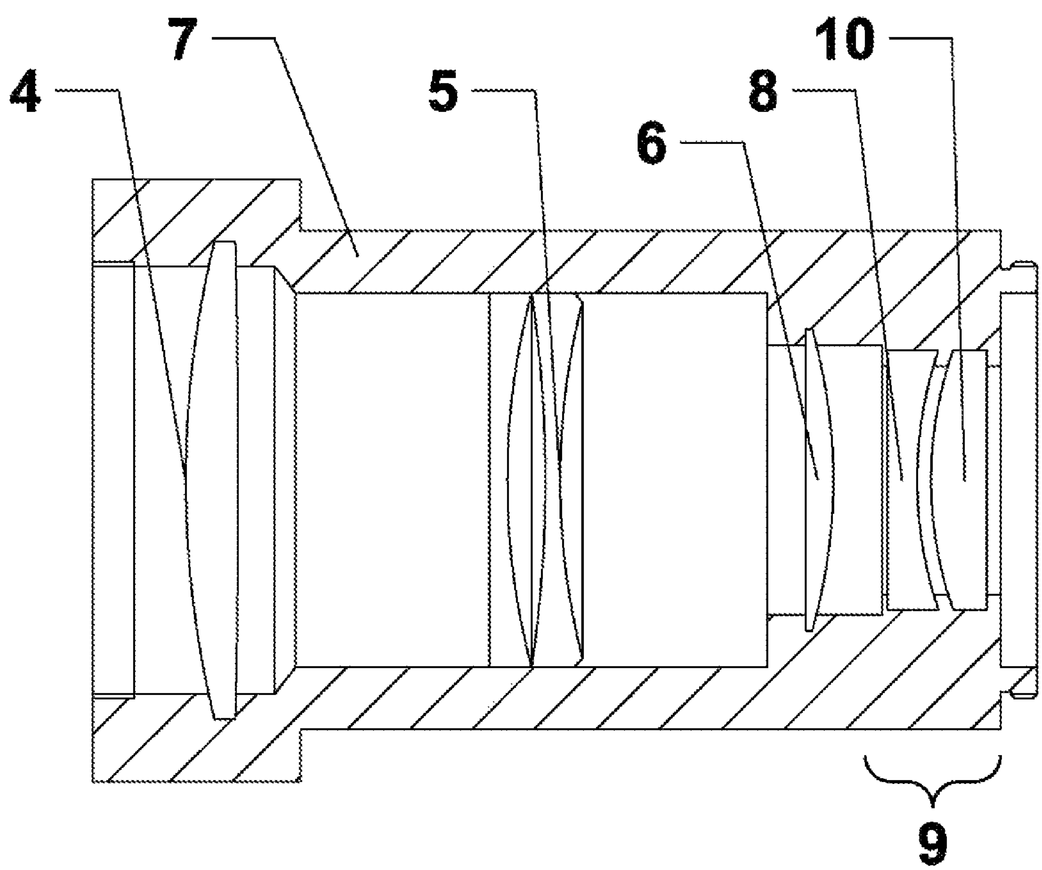


FIGURE 2

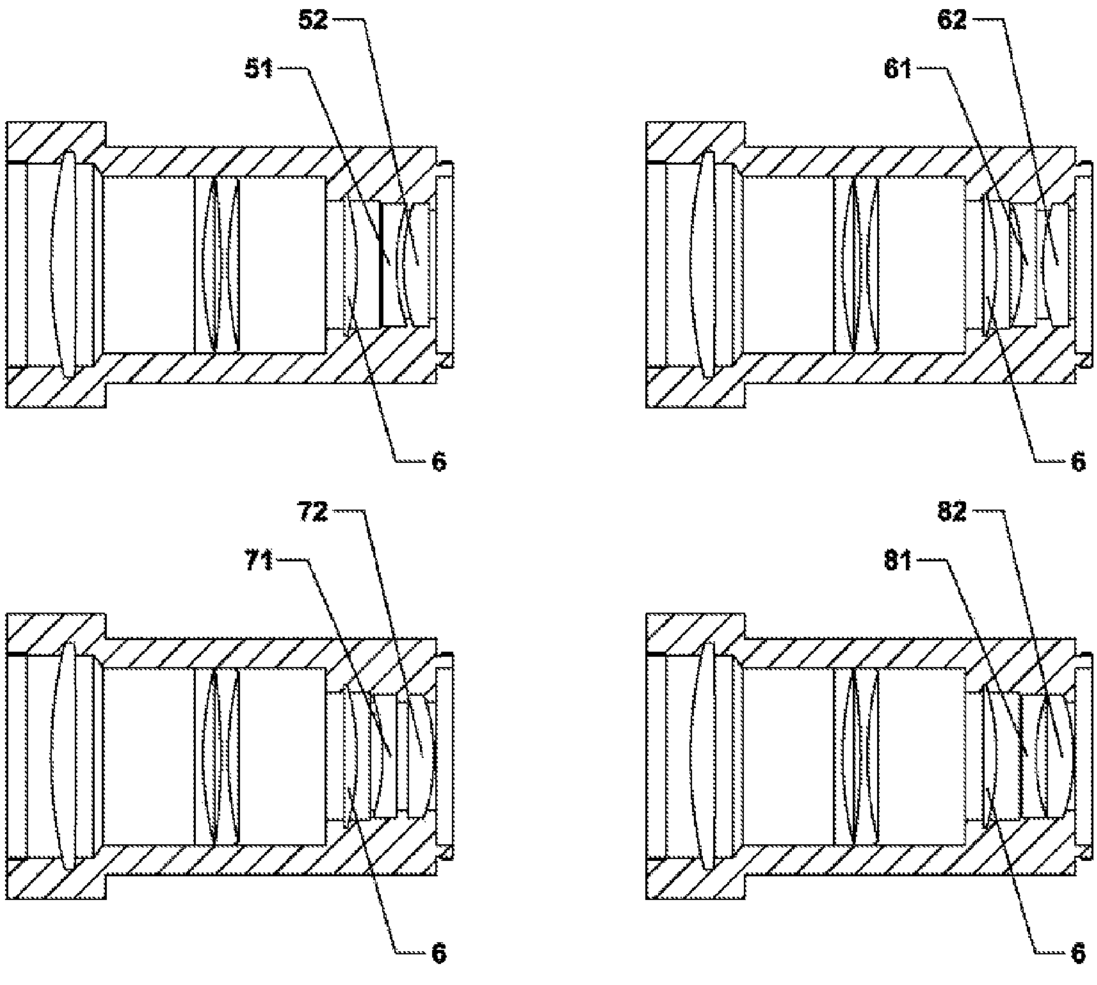


FIGURE 3

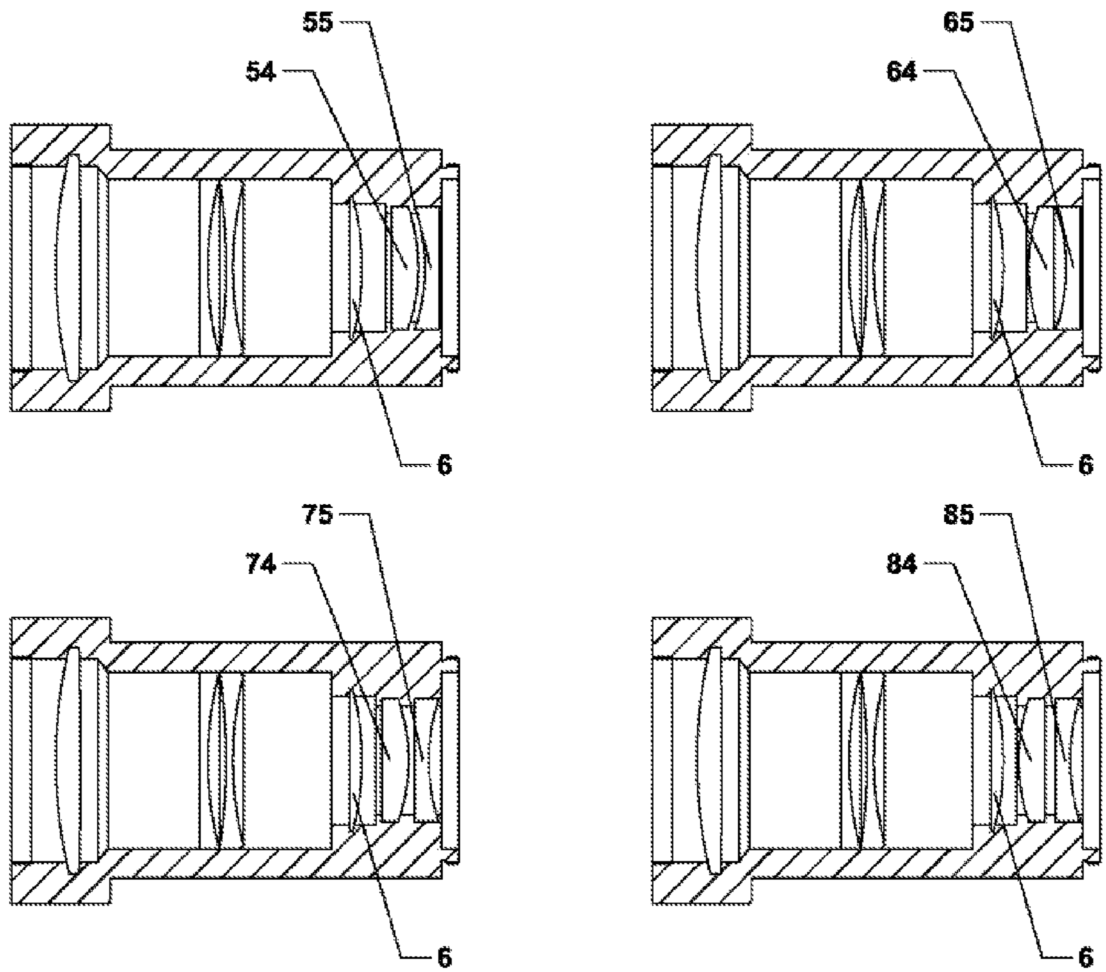


FIGURE 4

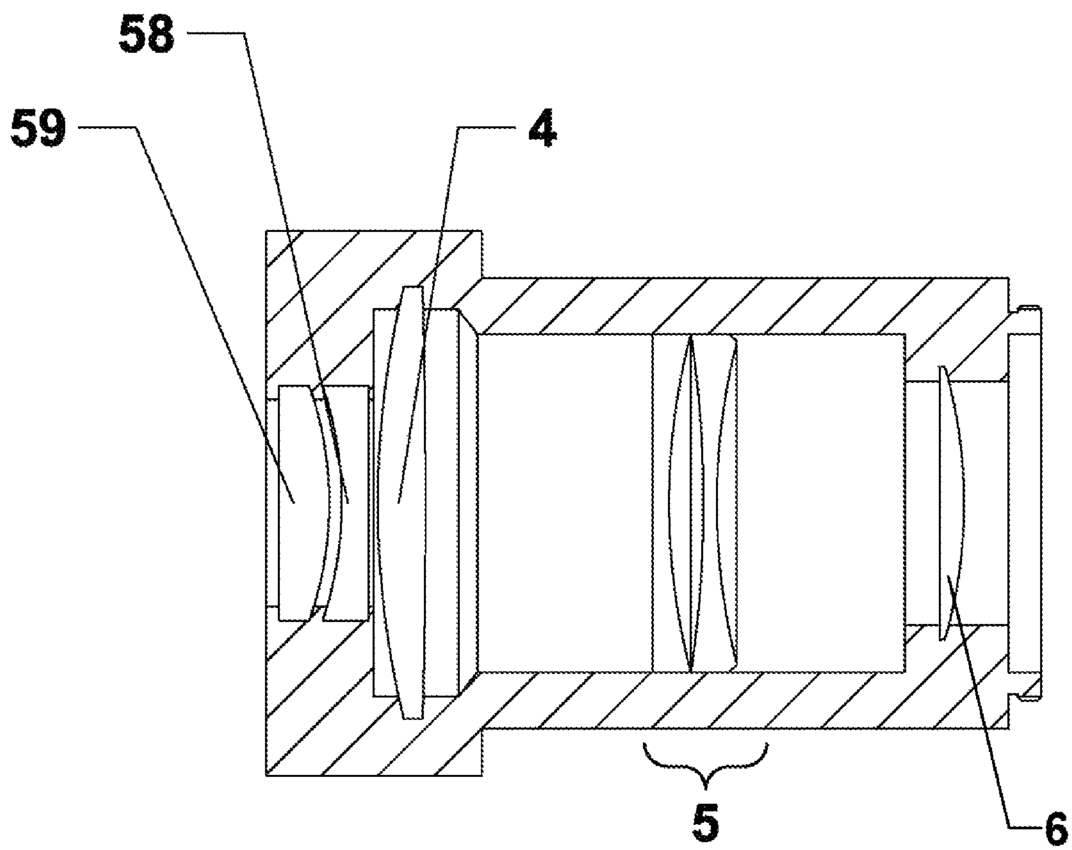


FIGURE 5

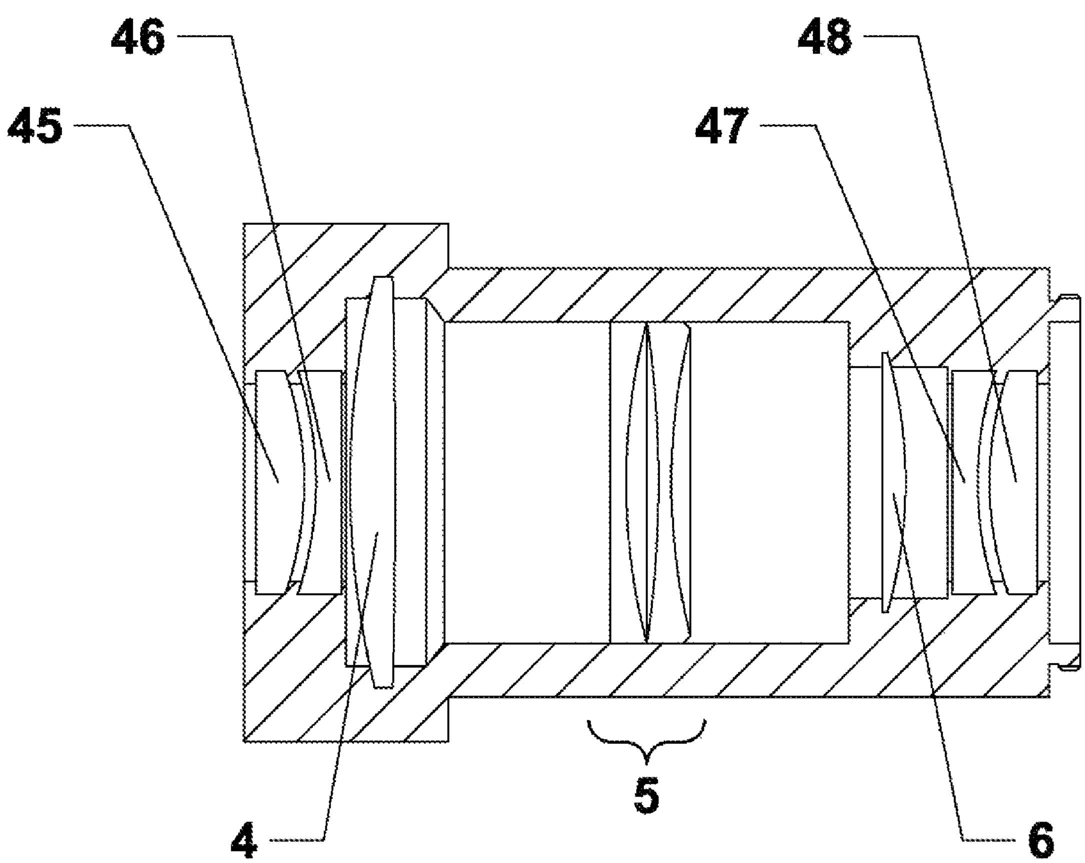


FIGURE 6

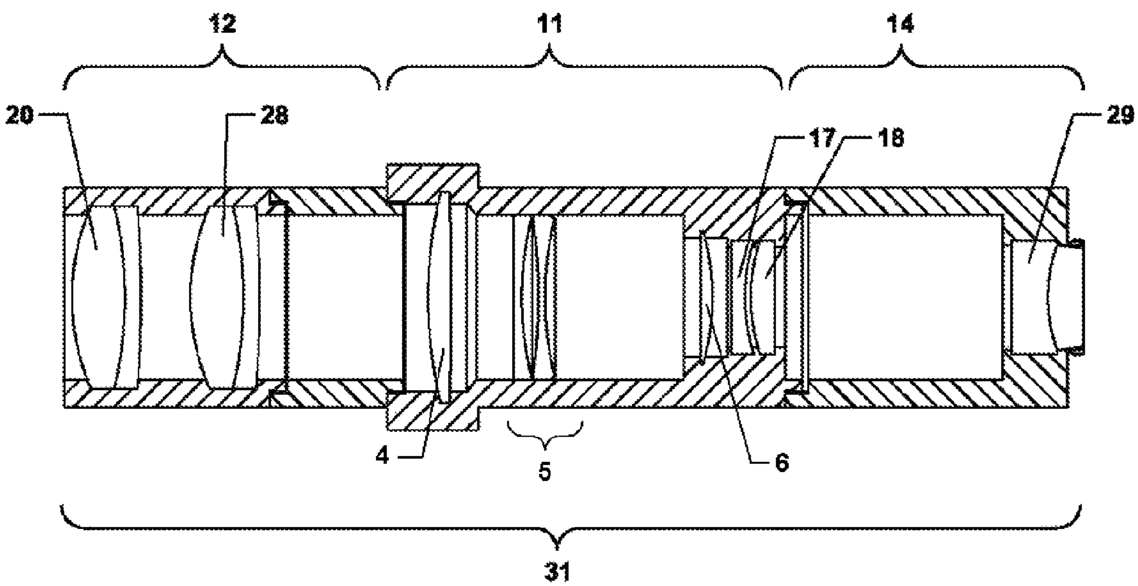


FIGURE 7

COMPLEX MODULAR AFOCAL VARIATOR WITH SPHERICAL AND CHROMATIC ABERRATION CORRECTION

CROSS REFERENCE TO RELATED APPLICATIONS

This application is the U.S. National Stage of International Application No. PCT/US2010/024446, filed Feb. 17, 2010 and published in English on Aug. 26, 2010 as WO 2010/096461, which claims the benefit of U.S. Provisional Application 61/153,896, filed Feb. 19, 2009; all of which are hereby incorporated by reference in their entirety to the extent not inconsistent with the disclosure herein.

BACKGROUND OF THE INVENTION

The present invention relates to an optical system in which a non-formula-specific modular afocal variator in combination with a supplemental lens system provides the optical system with both focusing means and active spherical and chromatic aberration corrective improvement for distant and near-focus. The combination of the modular afocal variator with the supplemental lens system produces a new type of integrated focusing device for optical systems that is itself a modular system.

Optical variators are typically used in optical systems to change the magnification of an image. For example, afocal variators have been used in projector lenses to alter the size of a projected image on a screen. In many instances, optical variator devices are used in combination with a front optical system or a rear optical system. In some instances they have even been used in combination with both a front objective system and a rear optical system. However, traditional optical systems which incorporate variator optical systems to alter the size of an image are not able to focus the image, and are usually only functional at relatively short back focal distances.

While the use of variators, either alone or in combination with either a front optical system or a rear optical system, are known, they largely are not known to have been used to alter active focal length so as to act as a focusing system as opposed to a system for altering image size at a fixed focal plane, such as a zoom lens. In the past where it has been desired to alter focal length, this has usually been accomplished by continuously or discretely changing the length of the optical system, or by changing the location or type of imaging lenses in the front, rear, or both front and rear optical systems. Generally the prior art has altered focal length by manipulating the imaging lens system, changing the length of the optical system, or changing the location or type of lenses in either the front or rear optical systems.

For example, Hillman (U.S. Pat. No. 2,937,570) discloses a telescope system in which the image forming lenses are moved in order to focus the system. Focusing is accomplished by moving the objective lens relative to the focusing lens, both of which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a central, modular position of an afocal variator, nor by determining the optical effect of an afocal variator and incorporating its front and rear elements into the image-forming optics, but still retaining a central modular element which is non-image-forming and essentially non-formula specific.

Matsumura (U.S. Pat. No. 4,318,585) discloses an optical system with an afocal focusing group, but in which the afocal focusing group is a Galilean telescope rather than an afocal variator. Furthermore, the system as taught by Matsumura does not incorporate the front, rear or front and rear elements of an afocal variator into the calculation and formulation of the image forming optics.

Quenderff (French Patent No. 2,572,545) teaches the use of a zoom lens to make enlarged pictures, and also teaches the use of various known mechanical devices for connecting together optical modules. However, it does not disclose the use of a central afocal variator module as a focusing element.

Margolis (U.S. Pat. No. 4,988,173), in contrast, teaches the use of a modular afocal variator optical system which can be used in optical instruments, such as long-distance microscopes, as the mechanism for providing focus. However, in this reference the modular afocal variator does not impart active spherical or chromatic aberration corrective improvement within the characteristics of the modular afocal variator itself. This modular afocal variator may in fact cause additional spherical and chromatic aberration.

While U.S. Pat. No. 4,988,173 teaches the use of a modular afocal variator as the focusing means of optical devices, it does not teach that under specific conditions the modular afocal variator can be supplemented with a lens system which can be positioned to impart active transitional spherical and chromatic aberration corrective improvement when incorporated in optical devices so as to provide focus and improved image quality over a range of far and near focal points. Additionally, the modular afocal variator of U.S. Pat. No. 4,988,173 has additional limitations, such as the functional size of the aperture of the optical system. What is needed is an improved modular afocal variator system that provides active correction of spherical and chromatic aberration and greater operational parameters.

SUMMARY OF THE INVENTION

In view of the foregoing, the present invention provides an optical system in which a modular afocal variator (MAV) is supplemented with additional optics to form a more complex, but still modular afocal variator system. Provided that the supplemental optics are added to a MAV, such as a MAV taught in Margolis (U.S. Pat. No. 4,988,173), the resulting complex modular afocal variator system (CMAV) no longer acts simply as a focusing means, but also acts in conjunction with the specific supplemental optics as a transitionally active spherical and chromatic corrective improvement system. Thus, the CMAV of the present invention serves at least three primary functions simultaneously: 1) changing the magnification of an image, 2) variable internal focusing, and 3) active spherical and chromatic corrective improvement. The use of a CMAV, which not only serves as a focusing means but also acts as a transitionally active spherical and chromatic improvement system which can be incorporated within any optical device into which it can be physically interfaced, is believed to be novel, unique and previously not taught in the art.

The complex modular afocal variator (CMAV) of the present invention comprises: a) a fixed length housing; b) a first positive lens system, a central negative lens system, and a second positive lens system in optical series disposed within the fixed length housing, where the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system; and c) a supplemental lens system disposed within the fixed length housing, wherein the supplemental lens system comprises a supplementary positive lens system and a supplementary negative lens system that are of equal power or near equal power to each other, and wherein the supplemental lens system is positioned in front of the first positive lens system or positioned behind the second positive lens system. In a further embodiment, the CMAV comprises a second supplemental lens system disposed within the fixed length housing, wherein one of either the supplemental lens system or second supplemental lens system is positioned in front of the first positive lens system and the other is positioned behind the second positive lens system. Preferably, the supplemental lens system or second supplemental lens system should be positioned as near to the MAV as practicality will permit regardless of whether the supplemental lens system is in front of or behind the MAV.

The supplemental lens systems and second supplemental lens systems comprise a positive lens system in contact with or positioned in close proximity with a negative lens system of equal power or near equal power. Preferably the optical power of the supplementary positive lens system and negative lens system are within 10% of each other, within 5% of each other, within 1% of each other, or more preferably the same as each other. Because the supplementary positive and negative lens systems are of equal or close to equal power, the addition of the supplemental lens system will minimally affect the focusing function of the device compared to a similar MAV which does not have the supplemental lens system. In one embodiment, the supplemental lens systems used herein have neutral optical power or near neutral optical power. In one embodiment, the negative and positive lenses are achromatic lenses. Preferably, the supplementary negative and positive systems are chosen to have the same or similar focal lengths to that of the second positive lens system of the MAV.

In a further embodiment, the supplementary positive and negative lens systems can be moved slightly closer together or further apart, if desired. This can be accomplished by moving the supplementary positive lens system, the negative lens system, or both. In one embodiment, the distance between the MAV and at least one of the supplementary positive lens system or negative lens systems remains constant. The distance between the supplementary positive lens system and supplementary negative lens system can range from zero (they contact each to other) to any distance within reasonable limits so as not to depart markedly from the afocal condition of the supplemental lens system. It can be expected that a reasonable separation between the supplementary positive lens system and supplementary negative lens system can be made to accommodate a more efficient acceptance of an incoming or exiting beam of light or other electromagnetic source.

The fixed length housing is any tube or structure used in optics able to house lenses and other optical devices. Preferably, the fixed length housing is an elongated approximately cylinder-shaped tube, but can be any shape suitable for optical devices as known in the art. The fixed length housing may also comprise means for adjusting or manipulating optical components disposed within the housing. For example, the fixed length housing may comprise known means in the art for moving the central negative lens system between the first and second positive lens systems.

Optionally, the fixed length housing includes a front end connecting means for substantially permanently connecting with a front optical system and a rear end connecting means for substantially permanently connecting with a rear optical system. In this way, the CMAV may be inserted into various optical systems and devices. The CMAV of the present invention may be put into substantially any optical system into which it can physically fit with substantial disregard for formula specificity. If the CMAV were to be removed from the modular optical systems of the present invention, it would not substantially change the characteristics of the optical system in which it had formerly been placed. For example, where the CMAV is positioned in a telescope between a front objective lens system and a rear optical lens system it can be used to focus the telescope. However, if the CMAV of the present invention were to be removed from the telescope the remaining system would still function as a normal telescope.

In one embodiment, the present invention teaches the construction of optical systems and devices which can incorporate a MAV with supplemental optics which then becomes, in effect, an entirely new type of modular focusing system which not only focuses optical systems, but also actively improves their correction for spherical and chromatic aberrations from distant to near focus to function reasonably over a wide range of possible working distances.

In a further embodiment, the present invention provides active spherical and chromatic corrective improvement by means of a MAV supplemented with additional optics that then becomes a total modular focusing/aberrationally-improving system to telescopes, microscopes or other lens systems of all types and focal lengths as are suited for use with it, so that numerous variants of the active spherical and chromatic aberration improving system may be provided.

In another embodiment, the present invention teaches an active spherical and chromatic aberration correctively-improving modular system which is predicated upon a set of rules for such incorporation into optical systems of various types. Additionally, the modular variation system incorporates removable and system-separable rear supplements so that the original non-active system is essentially restored in function.

The complex modular afocal variation systems of the present invention can be additionally supplemented with compressor or expander lens systems. For example, positive or negative lens systems positioned in back of said modular afocal variator that may or may not be subsumed into the rear lens system of the modular afocal variator itself, depending on need or design criteria. The systems and devices of the present invention may also be designed for easy integration into robotically-controlled or motor-controlled optical devices, whether controlled manually or by computer control or by equivalent devices. Optionally, the systems and devices of the present invention further allow out-gassing of devices in which the modular system is used in vacuum environments such as laser focusing chambers or in outer space.

In a further embodiment, the present invention provides CMAV modules providing active spherical and chromatic corrective improvement which are produced with rear supplemental optical systems able to be oriented in multiple ways so that multiple modules have varying desired spherical and chromatic characteristics, one of which will be more or less best-suited to almost any optical device in which it is incorporated. Multiple CMAV modules may be structurally similar allowing the modules to be physically interchangeable and easily inserted and replaced in standard optical systems and devices. It is believed having multiple structurally similar CMAV modules able to be incorporated "off the shelf" into optical systems and devices will ease optimization and construction and make such optical systems and devices more economical to manufacture. Optionally, optical systems contain multiple devices having CMAV modules of the present invention which can be used either ganged or elsewhere, such as in a multi-port optical device.

In one embodiment, the present invention provides optical systems that are able to image, with suitable accessories if necessary, directly onto sensors which have fields typical of those in common microscopical, telescopical or photographical practice, such as fields generally equal to or even greater than, those of typical microscope or telescope eyepieces, or of typical photographical formats or video formats. In one embodiment, the image is projected onto sensors having fields typical of those used in common microscopical practice. In another embodiment, the image is projected onto virtually any screen or sensor of large size, such as, but not limited to, those used in cinema projection, video projection or micro projection.

The foregoing embodiments of the present invention are obtained by providing optical systems with an incorporated spherical and chromatic aberration correctively-improving modular system composed of the combination of a MAV with supplemental optical systems (forming a CMAV) which have the ability to vary the actual focal length of the system without the need to physically change the length dimension of the body of the optical system or other optical systems, or without the need to change the lens system of the lens position of the front of the optical system or the rear optical system, if any.

These and other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination, and elements as herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an optical system as taught in the prior art containing a modular afocal variator (MAV) positioned between a front and rear optical system.

FIG. **2** shows a complex modular afocal variator (CMAV) module of the present invention, in which a supplemental lens system is positioned behind the second positive lens system.

FIG. **3** shows four CMAV modules of the present invention in which the supplemental lens system is positioned behind the second positive lens system. In each of these modules, the negative lens of the supplemental lens system is closest to the second positive lens system, however the orientation of the negative and positive lens in the supplemental lens system differ in each module.

FIG. **4** shows four CMAV modules of the present invention in which the supplemental lens system is also positioned behind the second positive lens system. In each of these modules, however, the positive lens of the supplemental lens system is closest to the second positive lens system. Similar to the modules shown in FIG. **3**, the orientation of the negative and positive lens in the supplemental lens system differ in each of these modules.

FIG. **5** shows a CMAV module of the present invention in which the supplemental lens system of the present invention is positioned in front of the first positive lens system.

FIG. **6** shows a CMAV module of the present invention in which a first supplemental lens system is positioned in front of the first positive lens system and a second supplemental lens system is positioned behind the second positive lens system.

FIG. **7** illustrates a CMAV module as depicted in FIG. **2** placed within a conventional optical device.

DETAILED DESCRIPTION OF THE INVENTION

As henceforth used throughout this application, "modular afocal variator system (MAV)" shall mean an optical system which includes in optical series a positive lens system, called the "front positive lens system" or "first positive lens system"; a moveable central negative lens system, called the "central negative lens system"; and another positive lens system, called the "rear positive lens system" or "second positive lens system", as described and set forth in U.S. Pat. No. 4,988,173, including all permutations disclosed in said patent dealing with focusing means. As used herein, a "lens system" can comprise a single lens or more than one lens as is known in the art.

As used herein, "neutral optical power" means the particular lens system is an afocal optical system which provides no net convergence or divergence of light as it passes through the lens system. "Near neutral optical power" means the particular lens systems may provide a small amount of convergence or divergence of light, preferably less than 5% convergence or divergence, more preferably less than 1% convergence or divergence.

The complex modular afocal variator systems (CMAVs) of the present invention are obtained by providing a MAV combined with supplemental lens systems in front of the first positive lens system or behind the second positive lens system, or both. A CMAV of the present invention is integrated into optical devices to vary the actual focal length of the optical systems without the need to physically change the length dimension of the body of the optical device or other optical systems, or without the need to change the lens system or the lens position of an additional lens system to the front or rear.

"Spherical aberration" is the basic aberration which leads to the failure of a lens to form a perfect image of a monochromatic, on-axis point source object. Aspheric surfaces may be applied to reduce this defect. When rays from a point on the axis passing through the outer lens zones are focused closer to the lens than rays passing the central zones, the lens is said to have negative spherical aberration; if the outer zones have a longer focal length than the inner zones, the lens is said to have positive spherical aberration. In the first instance, the lens is said to be uncorrected or undercorrected; in the second it is overcorrected.

"Chromatic aberration" is the lens aberration resulting from the normal increase in refractive index of all common materials toward the blue end of the spectrum. The change in image size from one color to another is known at lateral chromatic difference of magnification

MAVs, as previously known in the art, are themselves incapable of correcting spherical and chromatic aberrations. In fact, a typical MAV introduces very small but noticeable spherical and chromatic errors on its own. Usually, these can be overcome to a large extent by reducing the aperture of the system so that only the central part of the MAV is actually used, but this also limits the aperture possible from the entire optical device in which it is interfaced unless other optics are used to compensate, if possible.

The introduction of the MAV system in conjunction with a supplemental optical system to form a CMAV, as taught in the present invention, provides spherical and chromatic aberration corrective improvement that is obtained over a wide range of working and/or operational distances. A CMAV of the present invention provides a continuous transition and compensatory corrective improvement for spherical and chromatic aberrations over many working/operational distances. At the same time, this improvement makes it possible for optical devices to operate at greater apertures than a typical MAV would allow by itself.

A CMAV of the present invention is composed of one or more supplemental lens systems positioned in close proximity in front of the first positive lens system of the MAV, behind the second positive lens system of the MAV, or both. The supplemental lens system is a negative and positive lens system held in close proximity to a positive or negative lens of near or equal power of near or equal power. The supplementary negative and positive lens systems are preferably, but are not limited to, achromatic negative and positive lens systems. Preferably, the negative and positive lens systems of the supplemental lens system are chosen to be of near or similar focal length to that of the second positive lens system of the MAV.

Because the supplementary negative and positive lens systems are positioned in close proximity to one another and have the same or nearly the same optical power as one another, the supplemental lens system provides neutral or near neutral optical power.

In and of themselves, these supplemental lens systems are afocal additions to the original MAV. However, by juxtaposing their orientations with respect to each other, as well as whether the negative or positive system is chosen to be front or rear, different types of complex modular afocal variators (CMAV) can be provided. For example, when the supplemental lens system is placed behind the second positive lens system of the MAV, up to eight different types of CMAV modules can be provided (shown in FIGS. **3** and **4**). Each CMAV module is only different with respect to the potential spherical and chromatic characteristics it imparts. Thus, by selecting one of these eight permutational CMAV modules, spherical and chromatic characteristics can be imposed on any optical device into which it can interfaced. This is highly desirable, for example, when a CMAV is selected to be used with infinity-corrected microscope objectives. Many infinity corrected objectives use proprietary but public domain systems which have deliberate spherical and chromatic errors in the objective optics which are corrected in the telescope optics. By choosing the appropriate CMAV permutation, much of this reciprocal error can be corrected by the CMAV itself. Further, the option of selecting among up to eight permutational modules allows lens designers to utilize the CMAV best suited to their demands. Consequently, each CMAV is non-formula specific in that it can be introduced into any optical device, provided there is physical room to do so. Yet, each CMAV will impart to any such optical device a spherical and chromatic characteristic of some kind or another. Further, a compatible CMAV will additionally correct errors arising within its front traditional section to some extent or another.

In addition to all of the foregoing which has emphasized adding supplemental optics to the rear system of a MAV to create a CMAV, the supplemental optics can be positioned in front of the MAV's first positive lens system instead of the second positive lens system. It is also understood that the supplemental optics can be added to be both in front and in back of the first and second positive lens systems. The essential requirement is that in doing so, the CMAV thus produced still and all operates as an afocal variator similar to the original MAV.

In preferred embodiments, the present invention provides the combination, in optical series, of a front objective lens (which in itself, can be composed of any optical construction deemed appropriate, including but not limited to any and all known microscope objective types, all known telescope objective types, any and all known eyepiece types, and, in fact, any and all other known imaging lenses or negative beam introducing types, either refractive or diffractive composed of glass, plastic, multiple elements of optical glass whether cemented or otherwise joined and/or spaced, or of any translucent minerals or any other known refractive materials of spherical or aspherical form, so long as they can eventually or in conjunction, produce a focus at any front or back conjugate), and a CMAV comprising a supplemental lens system which can be composed of any refractive materials or any known lens types known in the art as are required to provide a transitionally focusable spherical and chromatic improvement to an optical device.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination of elements as herein described, and, more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the claims, insofar as they may be precluded by the prior art.

FIG. **1** shows an exploded view of an optical device containing a MAV as taught in U.S. Pat. No. 4,988,173. The optical device, in this case a telescope, comprises a front optical system **2** and a rear optical system **3** with a MAV **1** inserted in between. The MAV **1** contains a first positive lens system **4**, in this case a single lens, in the front of the MAV **1** and a second positive lens system **6**, also a single lens in this case, in the rear. A moveable central negative lens system **5** is positioned between the first positive lens system **4** and the second positive lens system **6**. The exact position of the negative lens system **5** between the first positive lens system **4** and second positive lens system **6** can be adjusted to achieve the desired focus. As is standard in the art, the optical device was designed first and the MAV introduced into the device if physically possible. As discussed in U.S. Pat. No. 4,988,173, a MAV of this type can be introduced into an optical system with virtual disregard to considerations for changing the optical system's characteristics except to impart internal focusing. The MAV's position within the optical device was chosen to provide the greatest amount of internal focusing capability. No active correctional improvement for spherical or chromatic aberration using the MAV was taught or suggested.

FIG. **2** shows one CMAV of the present invention. Preferably, the optical components are mounted and held in a state-of-the-art fixed length housing **7** which permits activation and movement of central negative lens system **5** towards and away from front positive lens system **4** and second positive lens system **6**, all constituting a MAV as shown in FIG. **1**. However, as now taught in the present invention, the CMAV **11** also includes a supplemental lens system **9** positioned in back of the second positive lens system **6** so as to form a spherical and chromatic correctively-improving system. The supplemental lens system **9** comprises a supplementary negative lens system **8** and positive lens system **10** (in this case both single lenses) positioned in close proximity to each other so as to be of neutral or near to neutral power. Preferably, the supplemental lens system **9** is composed of negative and positive lens systems of equal or essentially near equal focal length, ideally equal to the focal length of the second positive lens system **6**.

For permutational reasons, positive lens system **10** can be positioned, alternatively, in front of negative lens system **8** as shown in the configurations of FIG. **4** herein. A multitude of CMAVs are possible by varying the orientation of the supplementary positive lens system **10** and negative lens system **8**, the single requirement being that the supplemental lens system **9** be a neutral or near-neutral addition so that the original MAV is still an afocal variator when it is upgraded to being a CMAV. Spherical and chromatic aberration corrective improvement or deliberate introduction of compensatory error to some extent or another, by means of lens orientation and element selection is thus initially provided. By selecting multiple or combined elements for the negative and positive lens systems **8** and **10**, further control of aberrations is provided. The whole device now constitutes a functional Complex Modular Afocal Variator (CMAV) that can be made, derived, computed according to practice in the art, and/or empirically determined, in numerous permutations, provided that the additional negative and positive lens systems **8** and **10** combine to be of neutral or near neutral optical power.

FIG. **3** shows four permutational CMAV modules in which the supplementary negative lens system (**51**, **61**, **71** and **81** in the different configurations) is positioned closer to the second positive lens system **6** of the MAV than the supplementary positive lens system (**52**, **62**, **72** and **82**), but where each of the lens orientations differ. Lens combinations **51**/**52**, **61**/**62**, **71**/**72** and **81**/**82** are the possible orientations when a negative lens system is positioned closest to the second positive lens system **6** of the MAV.

FIG. **4** shows four permutational CMAV modules in which the supplementary positive lens system (**54**, **64**, **74** and **84** in the different configurations) is positioned closer to the second positive lens system **6** of the MAV than the supplementary negative lens system (**55**, **65**, **75** and **85**), but where each of the lens orientations differ. Lens combinations **54**/**55**, **64**/**65**, **74**/**75** and **84**/**85** are the possible orientations when a positive lens system is positioned closest to the second positive lens system **6** of the MAV.

FIG. **5** shows a CMAV module in which the supplemental lens system **9** of the present invention is positioned in front of the first positive lens system **4**. This supplemental lens system **9** comprises a supplementary positive lens system **59** and supplementary negative lens system **58**.

FIG. **6** shows a CMAV module containing supplemental lens systems positioned both in front of and in back of the original MAV system. The supplemental lens system in front of the first positive lens system **4** comprises a supplementary positive lens **45** and negative lens **46**, and the supplemental lens system **9** in back of the original MAV system comprises a supplementary negative lens **47** and positive lens **48**. In embodiments where the CMAV contains two supplemental lens systems, the negative and positive lens systems of each supplemental lens system may have the same or different configurations. Additionally, the distance between the supplementary positive lens system and supplementary negative lens system can be slightly adjusted, i.e., moved closer together or further apart, if desired. The distance between the supplementary positive lens system and supplementary negative lens systems can be adjusted when the lenses are in any configuration as shown in FIGS. **3**-**6**. When the optical system contains two supplemental lens systems (one positioned in front of the MAV and the other positioned behind the MAV), the distance between the supplementary positive lens system and supplementary negative lens system can be adjusted in either supplemental lens system or both.

FIG. **7** shows a complete optical device **31** in which a CMAV **11** is sandwiched between a front objective lens system **12**, containing lenses **20** and **28**, and a rear optical system **14**, containing an amplifier lens **29**. In this particular device, lenses **20** and **28** are Achromat lenses having a c.400 mm focal length, and the rear negative plano-concave amplifier lens **29** has a focal length of c.−100 mm. The CMAV **11** contains a central negative lens **5** positioned between a front positive lens system **4** and a second positive lens system **6**, as described above. Additionally, the CMAV **11** contains a supplemental lens system **9** comprising a supplementary negative lens **17** and supplementary positive lens **18**. In this example, the supplementary negative lens **17** is a c.−150 mm focal length plano-concave lens positioned in very close proximity to the supplementary positive lens **18**, which is a positive plano-convex lens of c.+150 mm focal length by art known means. The CMAV **11** is mounted to front objective lens system **12** and rear optical system **14** by art known means to constitute a telescope system, as would be the case with a MAV system per U.S. Pat. No. 4,998,173; however, the CMAV **11** is not only interfaced as a focusing means, but as spherical and chromatic correctionally-improving system as well, capable of focus from infinity to as close as c.600 mm from an object to be viewed. All lens systems shown can subsequently be made of cemented or spaced multiple lens elements.

The system above and equivalents which can be derived from it can be made from any suitable combination of optical materials or lens types, be they of whatever refractive, diffractive and dispersive characteristics as known in the art, the only limitation being their suitability for actual use. In addition, the use of single or multiple focal variators in other applications to focus, concentrate or disperse light or other electromagnetic wavelengths is also taught. While not shown in FIGS. **1** through **7**, the addition of art known fixed or variable diaphragms, or other known optical components inside the optical system components may be used to obtain an excellent depth of field or to control other aberrations as well as the speed of the entire system as focus gets progressively closer to an object.

Having now fully described the present invention in some detail by way of illustration and examples for purposes of clarity of understanding, it will be obvious to one of ordinary skill in the art that the same can be performed by modifying or changing the invention within a wide and equivalent range of conditions, formulations and other parameters without resort to undue experimentation without affecting the scope of the invention or any specific embodiment thereof, and that such modifications or changes are intended to be encompassed within the scope of the appended claims. All art-known functional equivalents, of any such materials and methods are intended to be included in this invention. The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention that in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments and optional features, modification and variation of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention as defined by the appended claims.

As used herein, "comprising" is synonymous with "including," "containing," or "characterized by," and is inclusive or open-ended and does not exclude additional, unrecited elements or method steps. As used herein, "consisting of" excludes any element, step, or ingredient not specified in the claim element. As used herein, "consisting essentially of" does not exclude materials or steps that do not materially affect the basic and novel characteristics of the claim. In each instance herein any of the terms "comprising", "consisting essentially of" and "consisting of" may be replaced with either of the other two terms.

When a group of materials, compositions, components or compounds is disclosed herein, it is understood that all individual members of those groups and all subgroups thereof are disclosed separately. When a Markush group or other grouping is used herein, all individual members of the group and all combinations and subcombinations possible of the group are intended to be individually included in the disclosure. Every formulation or combination of components described or exemplified herein can be used to practice the invention, unless otherwise stated. Whenever a range is given in the specification, for example, a temperature range, a time range, or a composition range, all intermediate ranges and subranges, as well as all individual values included in the ranges given are intended to be included in the disclosure. In the disclosure and the claims, "and/or" means additionally or alternatively. Moreover, any use of a term in the singular also encompasses plural forms.

All references cited herein are hereby incorporated by reference in their entirety to the extent that there is no inconsistency with the disclosure of this specification. All headings used herein are for convenience only. All patents and publications mentioned in the specification are indicative of the levels of skill of those skilled in the art to which the invention pertains, and are herein incorporated by reference to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference. References cited herein are incorporated by reference herein in their entirety to indicate the state of the art as of their publication or filing date and it is intended that this information can be employed herein, if needed, to exclude specific embodiments that are in the prior art. For example, when composition of matter are claimed, it should be understood that compounds known and available in the art prior to Applicant's invention, including compounds for which an enabling disclosure is provided in the references cited herein, are not intended to be included in the composition of matter claims herein.

The invention claimed is:

1. A complex modular afocal variator comprising:

a) a fixed length housing;

b) a first positive lens system, a central negative lens system, and a second positive lens system disposed within the fixed length housing, wherein the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system; and

c) a supplemental lens system disposed within the fixed length housing, wherein the supplemental lens system is positioned in front of the first positive lens system or positioned behind the second positive lens system, and wherein said supplemental lens system comprises a supplementary positive lens system and a supplementary negative lens system that are of equal power or near equal power to each other,

wherein the supplementary positive lens system and supplementary negative lens system are positioned in close proximity to one another and wherein the supplementary positive lens system and supplementary negative lens system have the same focal length as the second positive lens system.

2. The complex modular afocal variator of claim **1** wherein said complex modular afocal variator is able to provide magnification and focusing of an image without altering the length of the fixed length housing or the distance between the first and second positive lens systems, and wherein said complex modular afocal variator is able to provide spherical and chromatic aberration correction.

3. The complex modular afocal variator of claim **1** further comprising a second supplemental lens system disposed within the fixed length housing, wherein said second supplemental lens system comprises a second supplementary positive lens system and a second supplementary negative lens system that are of equal power or near equal power to each other, and wherein one of either the supplemental lens system or second supplemental lens system is positioned in front of the first positive lens system and the other is positioned behind the second positive lens system.

4. The complex modular afocal variator of claim **1** wherein the supplemental lens system is an afocal optical system that does not affect the focus of light passed through the complex modular afocal variator.

5. The complex modular afocal variator of claim **1** wherein the supplementary negative lens system is positioned in front of the supplementary positive lens system in the supplemental lens system.

6. The complex modular afocal variator of claim **1** wherein the supplementary positive lens system is positioned in front of the supplementary negative lens system in the supplemental lens system.

7. The complex modular afocal variator of claim **1** wherein the supplementary positive lens system and negative lens system of the supplemental lens system are achromatic lenses.

8. The complex modular afocal variator of claim **1** wherein the fixed length housing comprises a front end connecting means and a rear end connecting means able to attach the fixed length housing to a front optical system and a rear optical system.

9. An optical device comprising a front optical system; a rear optical system; and a complex modular afocal variator in optical series, wherein said complex modular afocal variator comprises:

a) a fixed length housing;

b) a first positive lens system, a central negative lens system, and a second positive lens system disposed within the fixed length housing, wherein the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system;

c) a supplemental lens system disposed within the fixed length housing, wherein the supplemental lens system is positioned in front of the first positive lens system or positioned behind the second positive lens system, and wherein said supplemental lens system comprises a supplementary positive lens system and a supplementary negative lens system that are of equal power or near equal power to one each other; and

d) a second supplemental lens system disposed within the fixed length housing, wherein said second supplemental lens system comprises a second supplementary positive lens system and a second supplementary negative lens system that are of equal power or near equal power to each other, and wherein one of either the supplemental lens system or second supplemental lens system is positioned in front of the first positive lens system and the other is positioned behind the second positive lens system.

10. The optical device of claim **9** wherein said complex modular afocal variator is able to provide magnification and focusing of an image without altering the length of the optical device and wherein said complex modular afocal variator is able to provide spherical and chromatic aberration correction.

11. The optical device of claim **9** wherein the supplemental lens system comprises a positive lens system and a negative lens system positioned in close proximity to one another.

12. The optical device of claim **11** wherein the positive lens system and negative lens system of the supplemental lens system have the same focal length as the second positive lens system.

13. A method of correcting spherical or chromatic aberration in an optical system comprising the steps of inserting a complex modular afocal variator into optical series with said optical system, wherein said complex modular afocal variator comprises:

a) a fixed length housing;

b) a first positive lens system, a central negative lens system, and a second positive lens system disposed within the fixed length housing, wherein the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system; and

c) a supplemental lens system disposed within the fixed length housing, wherein the supplemental lens system is positioned in front of the first positive lens system or positioned behind the second positive lens system, and wherein said supplemental lens system comprises a supplementary positive lens system and a supplementary negative lens system that are of equal power or near equal power to each other; and

d) a second supplemental lens system disposed within the fixed length housing, wherein said second supplemental lens system comprises a second supplementary positive lens system and a second supplementary negative lens system that are of equal power or near equal power to each other, and wherein one of either the supplemental lens system or second supplemental lens system is positioned in front of the first positive lens system and the other is positioned behind the second positive lens system.

14. The method of claim **13** wherein the supplemental lens system comprises a positive lens system and a negative lens system positioned in close proximity to one another.

15. The method of claim **14** wherein the positive lens system and negative lens system of the supplemental lens system have the same or similar focal lengths as the second positive lens system.

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(12) **United States Patent**
Margolis

(10) **Patent No.: US 7,869,139 B2**
(45) **Date of Patent: Jan. 11, 2011**

(54) **MODULAR AFOCAL VARIATOR OPTICAL SYSTEM PROVIDING FOCUS WITH CONSTANT MAGNIFICATION**

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(73) Assignee: **Infinity Photo Optical**, Boulder, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/605,554**

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(51) **Int. Cl.**
G02B 13/00 (2006.01)

(52) **U.S. Cl.** **359/744**; 359/672

(58) **Field of Classification Search** 359/672–675, 359/744

See application file for complete search history.

(56) **References Cited**

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4,318,585	A	3/1982	Matsumura
4,988,173	A	1/1991	Margolis
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5,452,133	A	9/1995	Margolis

FOREIGN PATENT DOCUMENTS

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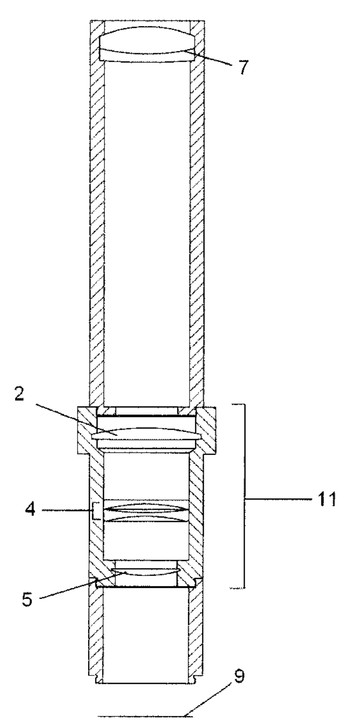
(57) **ABSTRACT**

The present invention provides optical systems containing an afocal variator able to impart focus means to the optical system, as well as essentially constant magnification throughout the focal translation. The present application teaches a specific formula or set of spacing requirements for the positioning of the afocal variator that can be used with any afocal variator optical lens system comprised of various lens combinations. Provided that the formula for spacing the afocal variator within the optical system is utilized, the afocal variator acts not only to focus the optical system but maintains substantially constant magnification during the translation of focus.

5 Claims, 4 Drawing Sheets



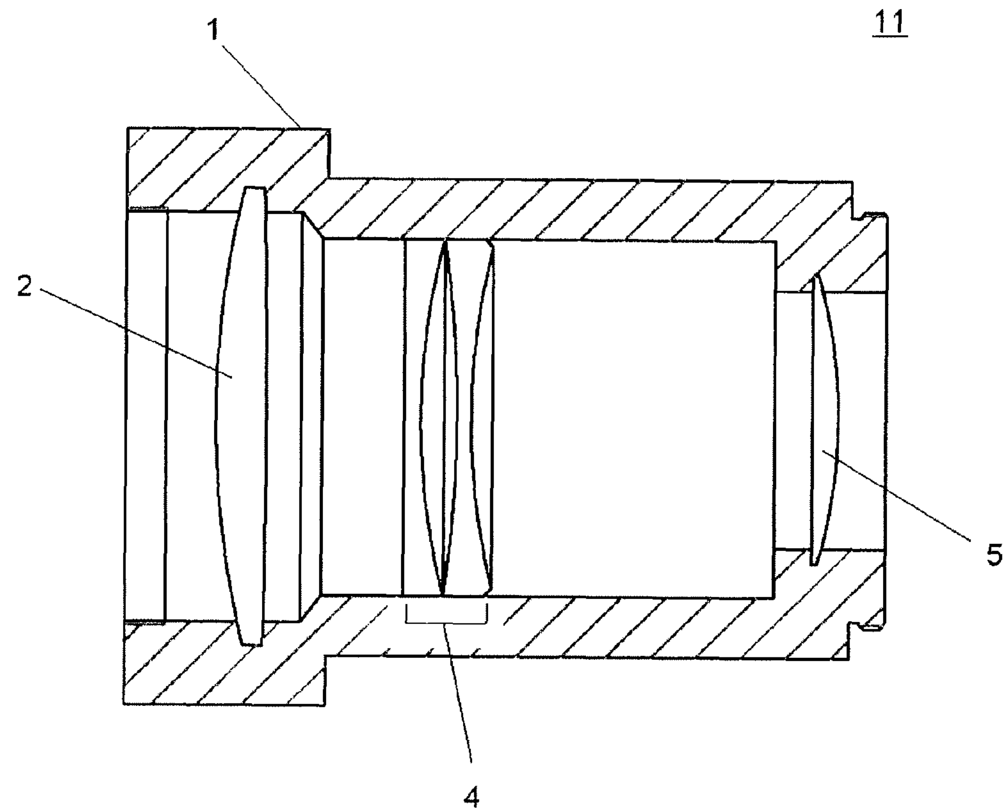


FIGURE 1

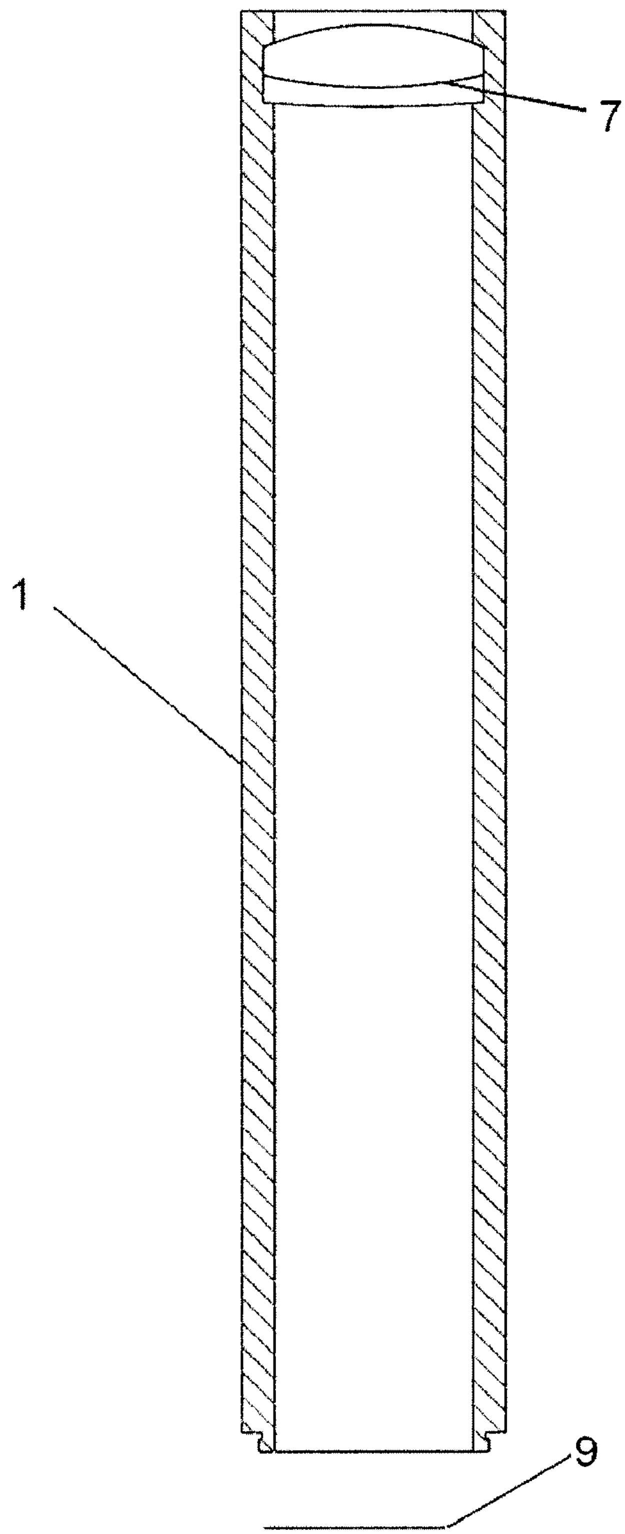


FIGURE 2

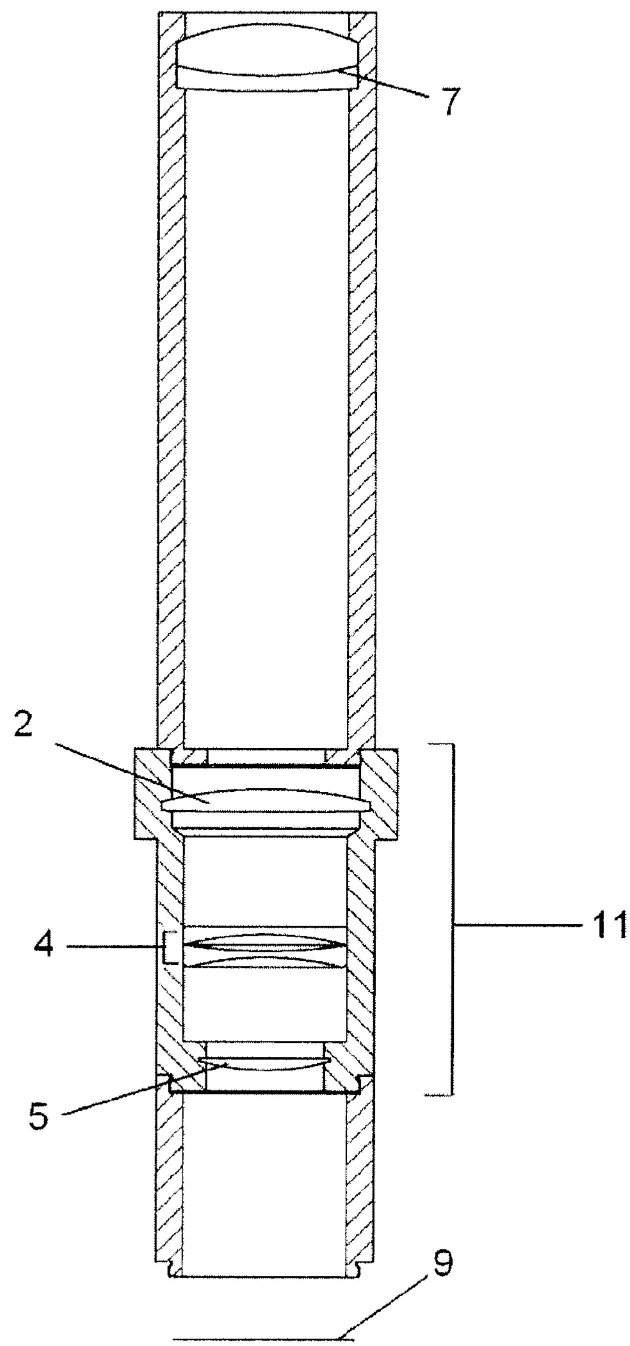


FIGURE 3

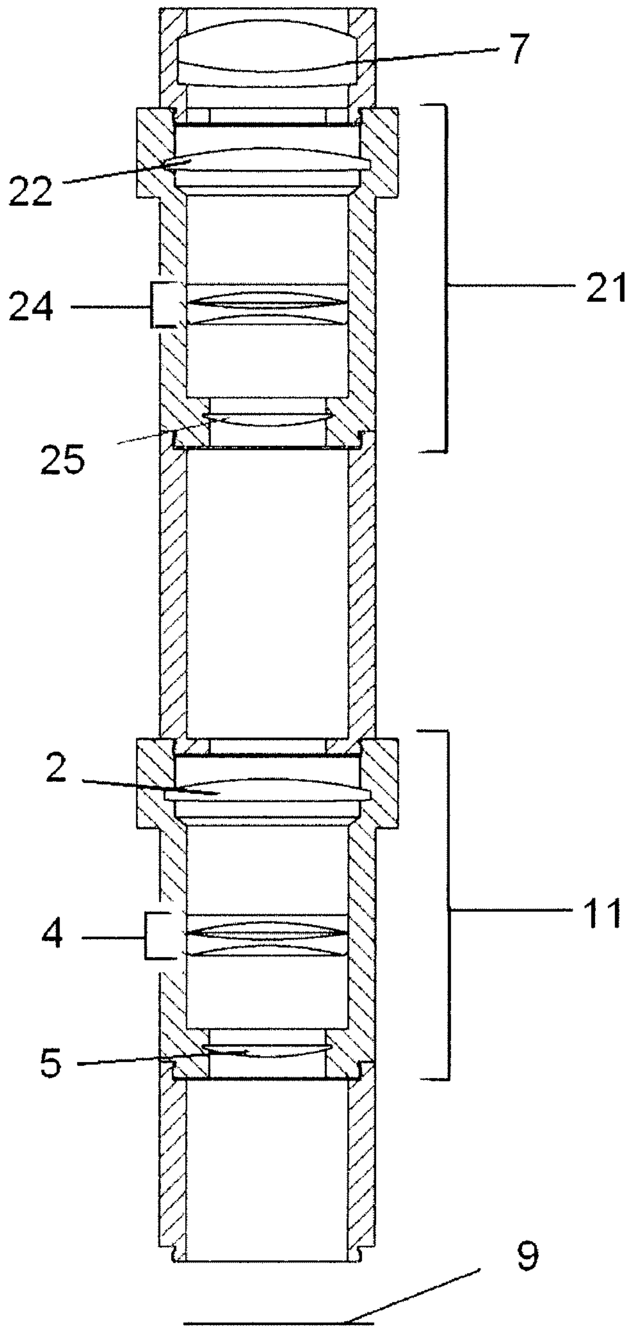


FIGURE 4

MODULAR AFOCAL VARIATOR OPTICAL SYSTEM PROVIDING FOCUS WITH CONSTANT MAGNIFICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application 61/109,612, filed Oct. 30, 2008, which is incorporated herein in its entirety to the extent not inconsistent herewith.

BACKGROUND OF THE INVENTION

The present invention relates to combined optical systems in which an afocal variator optical system is specifically positioned to provide not only focusing means, but virtually constant magnification during focal translation.

Optical variators are typically used in optical systems to change the magnification of an image. For example, afocal variators have been used in projector lenses to alter the size of a projected image on a screen. In many instances, optical variator devices are used in combination with a front optical system or a rear optical system. In some instances they have even been used in combination with both a front objective system and a rear optical system. However, traditional optical systems which incorporate variator optical systems to alter the size of an image are not able to focus the image, and are usually only functional at relatively short back focal distances.

In the past where it has been desired to alter focal length, this has usually been accomplished by continuously or discretely changing the length of the optical system, or by changing the location or type of imaging lenses in the front or rear optical systems of the device, or in both front and rear optical systems. Hillman (U.S. Pat. No. 2,937,570) discloses a telescope system in which the image forming lenses are moved in order to focus the system. That is, focusing is accomplished by moving objective lens and focusing lens, which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a portion of an afocal variator, nor by moving a portion of any other non-image forming modular optical lens system. It does not include a central afocal variator module which does not comprise a portion of the image-forming optics. If any of the movable lenses of any of the systems taught by Hillman were removed, the entire system would be affected, very probably to the point that the system would no longer function for its intended purpose. Quenderff (French Patent No. 2,572,545) uses a zoom lens to make enlarged pictures, and also teaches the use of various art known mechanical devices for connecting together optical modules. However, it neither teaches nor suggests the use of a central afocal variator module as a focusing element.

Margolis (U.S. Pat. No. 4,988,173), in contrast, teaches the use of an afocal variator optical system which can be used in optical instruments, such as long-distance microscopes, as the mechanism for providing focus. However in this reference and all other references known to the applicant, no optical focusing systems have been used with an afocal variator which imparts virtually constant magnification through the range of focal translation. While the noted reference teaches the use of an afocal variator as the focusing means of optical systems, it does not additionally teach that under specific conditions and positions the afocal variator can, in and of itself, be positioned to impart virtually constant magnification through the range of focal translation.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide optical systems in which an afocal variator is positioned to impart focus means to the optical system, as well as essentially constant magnification throughout the focal translation. The present application teaches a specific formula or set of spacing requirements that can be used with any afocal variator optical lens system comprised of various lens combinations. Provided that the formula for spacing the afocal variator within the optical system is utilized, the afocal variator acts not only to focus the optical system but maintains substantially constant magnification during the translation of focus. Therefore, the use of an afocal variator is not only an indiscriminate means of focus but also acts specifically to provide constant or essentially constant magnification during such focus.

The imaging optical system of the present invention comprises an optical housing; an objective lens system disposed at one end of the optical housing and having a first focal plane; and a modular afocal variator disposed within the optical housing in optical series with the objective lens system. The modular afocal variator comprises a first positive lens system, a central negative lens system, and a second positive lens system, where the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system. The modular afocal variator is placed at a position so as to provide focus to the optical system while maintaining essentially constant magnification throughout the focal translation.

As described herein, the modular afocal variator is positioned between the objective lens system and the focal plane so that the first positive lens system is closer to the objective lens than the second positive lens system. In one embodiment, the modular afocal variator is positioned so that the distance between the first positive lens system and the focal plane is 66% (±15%) of the focal length of the first positive lens system, and the distance between the second positive lens system and the focal plane is 100% (±15%) of the absolute value of the focal length of the central negative lens system.

In another embodiment, the modular afocal variator is positioned so that the distance between the first positive lens system and the focal plane of the objective lens system is between 50% to 80% of the absolute value of the focal length of the first or second positive lens system. Preferably the distance between the first positive lens system and the focal plane is between 60% to 70% of the absolute value of the focal length of the first or second positive lens system. The focal length of the second positive lens system should be within 10% of the focal length of the first positive lens system (as expressed in positive terms), preferably within 5% of the focal length of the first positive lens system. More preferably, the focal lengths of the first and second positive lens systems are the same. The modular afocal variator is additionally positioned so that the distance between the second positive lens system and the focal plane is between 85% to 115% of the absolute value of the focal length of the central negative lens system. Preferably, the distance between the second positive lens system and the focal plane is between 95% to 105% of the absolute value of the focal length of the central negative lens system.

The objective lens system can comprise a single lens or multiple lenses. The objective lens system produces the focal plane either alone or in conjunction with other optical components, such as additional lenses, that may be present and positioned within the optical housing. An intermediary image is the image of an object produced at the second focal plane by the objective lens and modular afocal variator along with any additional optical components incorporated into the device. Depending on the application, the intermediary image may be viewed by an observer, such as through an eye piece, or detected using a film or sensor. The intermediary image may also be further manipulated by subsequent optical components.

The optical housing is any tube or structure used in optics able to house lenses and other optical components. Preferably, the optical housing is an elongated approximately cylinder-shaped tube, but can be any shape suitable for optical devices as known in the art. The optical housing may also comprise means for adjusting or manipulating optical components disposed within the housing. For example, the optical housing may comprise known means in the art for moving the central negative lens system between the first and second positive lens systems.

The afocal variator as described herein can be used as the primary means of focus for an optical system or as a secondary or fine focus for an optical system that contains additional means for focus. For example, the optical system may comprise a mechanical focus as is known in the art or a second modular afocal variator which is not positioned according to the formula described herein to provide primary focus. In such a system, the primary focusing means is used to generally focus the image while the afocal variator as defined herein is used as the fine focus while maintaining the magnification of the image. It is another object of the present invention to provide a secondary or fine focus to optical systems which utilize a primary mechanical focus as is known in the art, said secondary or fine focus imparting an essentially constant magnification throughout the focal translation. It is also another object of the present invention to provide a secondary or fine focus to optical systems which incorporate internal optical focusing capabilities, such as taught in U.S. Pat. No. 4,988,173, said secondary or fine focus imparting an essentially constant magnification throughout the focal translation. The focusing means can be activated by any means known in the art either manually, by motorized activation or by remote control.

The light traveling through the optical system can be split as is known in the art to allow the optical device to manipulate or direct the different split beams as desired. Accordingly, the optical system may further comprise different port positions utilizing beamsplitters, mirror diverters, or other optical devices able to split a beam of light traveling through the optical system. Each different port position may comprise a modular afocal variator positioned as taught herein such that one or more of the port positions are able to be positions where an image is focused without essential magnification change beyond the original depth of field of the imaging optical system.

It is another object of the present invention to provide combined optical systems and computational systems which are predicated upon using the essentially constant magnification during focal translation as obtained from the present invention. Similarly, it is another object of the present invention to provide optical systems with essentially constant magnification throughout focal translation that can be reliably used to obtain data and other characteristics for use with computers or other analytical devices known in the art.

The present invention is designed for easy integration into robotically-controlled or motor-controlled optical systems, whether controlled manually or by computer control or by equivalent devices whether known in the art or developed in the future. The structure of the optical systems of the present invention allow out-gassing of the devices so that they may be used in vacuum environments such as laser focusing chambers or in outer space. In addition the present invention provides afocal variator focusing systems with essentially constant magnification which are economical to manufacture. The present invention also produces optical systems which have fields typical of those used in common video, photographical and microscopical practice, say equivalent to those of video sensors, microscope eyepieces and photographical formats used in common practice and, with the addition of suitable accessories, can project the image only virtually any screen or sensor, including large sizes such as are used in cinema projection or micro projection.

The foregoing and other objects of the present invention are obtained by providing an afocal variator to optical systems to vary the focus without the need to physically change the length dimension of the body or of the optical system, and without the need to change the lens system or the lens position of an additional lens system to the front or rear, all the while maintaining essentially constant magnification during focal translation. The system of the present invention is distinguished from other types of optical systems for imparting focus or the like in that, although based on an overall "covering formula" with regard to the positioning of the modular afocal variator, the optics so derived are otherwise non-formula specific. The "covering-formula" now taught by the present application provides the novel and unique arrangement of optical systems disclosed herein, imparting essentially constant magnification during focal translation. To applicant's knowledge, no such combined optical system with such characteristics is known in the art.

One embodiment of the invention provides an optical image system comprising a modular afocal variator system physically placed, interfaced or positioned modularly within the optical system, such that the focus provided by the modular afocal variator system to the entire optical system is of a specific character, namely, that focal translation above, through and below an object is essentially constant and without appreciable magnification change over a distance beyond that of the original depth of field of the optical system in which the modular afocal variator system is incorporated. Another embodiment of the invention provides methods of focusing the optical image system by placing the modular afocal variator within said optical image system. Preferably, the modular afocal variator system is placed 50% to 85%, more preferably 60% to 70%, of either the modular afocal variator's first positive lens system's or second positive lens system's focal length, as expressed in positive physical dimensional measurement, down from the original focal point of said imaging optical system's original focal plane. In one embodiment, the modular afocal variator system is placed 66%, +/−15%, chosen on the basis of either the modular afocal variator's first positive lens system's or second positive lens system's focal length, as expressed in positive physical dimensional measurement, down from the original focal point of said imaging optical system's original focal plane. Additionally, the modular afocal variator system is placed so that the second positive lens system is positioned 85% to 115% of the modular afocal variator's central negative lens system's focal length, as expressed in positive physical dimensional measurement, from the focal plane. Preferably, the second positive lens system is placed 100%, +/−15%, of the modular afocal variator's central negative lens element's focal length, as expressed in positive physical dimensional measurement, from the focal plane.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination, and elements herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of a modular afocal variator as taught in the prior art containing a negative lens system positioned between a first and second positive lens system.

FIG. **2** is a diagram of an optical system containing an objective lens system able to form an image at a focal plane.

FIG. **3** is a diagram of an optical system of the present invention, where the modular afocal variator of FIG. **1** has been positioned within the optical system of FIG. **2** according to the formula described herein. When properly positioned within the optical system in relation to the original focal plane, the modular afocal variator is able to impart not only focus but also essentially constant magnification during focal translation.

FIG. **4** is a diagram of the optical system of FIG. **3** further having a second modular afocal variator as used for establishing primary focus per U.S. Pat. No. 4,988,173 (Margolis).

Additional features and advantages of the present devices and methods may be obtained by reference to the following detailed description and accompanying drawings that set forth illustrative embodiments, in which the principles of the methods, devices and apparatuses are utilized.

DETAILED DESCRIPTION

As used herein, the term "essentially constant magnification" means the magnification of an image remains the same or approximately the same as the original magnification as the image is focused. Preferably the magnification does not vary by more than 10% of the original magnification. More preferably the magnification does not vary by more than 5% of the original magnification. Even more preferably, the magnification does not vary by more than 1% of the original magnification.

As used herein, the term "focal plane" refers to the imaginary line perpendicular to the optical axis which passes through optical system's focal point. It is also the area behind the lens where light is gathered to form a sharply-focused image.

As used throughout this application, "modular afocal variator system" or "afocal variator" shall mean an optical system which includes in optical series a positive lens or lens system, sometimes called the "front positive lens system," a moveable central negative lens or lens system, sometimes called the "central negative lens system" and another positive lens or lens system, sometime called the "rear positive lens system," as described and taught in U.S. Pat. No. 4,988,173 (Margolis), including all permutations and equivalents.

FIG. **1** is a diagram of a modular afocal variator optical system **11**, according to U.S. Pat. No. 4,988,173 (Margolis) which consists of an optical housing **1** in which there is located a first positive lens system **2**, in this instance having a c.160 mm focal length, a central negative lens system **4**, in this case a negative doublet of c.−60 mm focal length, and a second positive lens optical system **5**, in this case having a c.160 mm focal length. As is known in the art and as taught by U.S. Pat. No. 4,988,173, when the modular afocal variator **11** is between imaging element lens systems, focus is imparted to the combined system by the activation of movement of the afocal variator's central negative lens system **4**. The central negative lens system **4** can be moved using any device known in the art, such as a linear slider, a helical slider, or by any other art known means for providing continuous linear motion to the central negative lens system **4** within the optical housing **1**.

The modular afocal variator **11** is joined to an optical system of virtually any type which can physically accommodate the modular afocal variator **11** spaced according to a formula provided herein, whether it incorporates mechanical focus, another afocal variator or internal focusing system or any other focusing system other than that provided by the present invention. FIG. **2** shows an optical system having an objective lens system **7** within an optical housing **1** with a conventional back tube length. The objective lens system **7** produces an image at the focal plane **9** (the original focal plane) at the back distance of the optical housing **1**. The modular afocal variator **11** is attached or positioned within the optical housing **1** of the optical system as illustrated in FIG. **3**. The modular afocal variator **11** can further be attached to a top visual (e.g. eyepiece), photographic material, sensor or any other electromagnetic or electro-optical recording medium know to the art.

The optical system can further comprise additional optical components used in optical devices. In one example, the optical system incorporates a second modular afocal variator **21** as illustrated in FIG. **4**. The second modular afocal variator **21** contains its own first positive lens system **22**, central negative system **24** and second positive lens system. When placed in a position within the optical system outside of the formula disclosed herein, the second modular afocal variator **21** is able to provide focus as disclosed in U.S. Pat. No. 4,988,173 (Margolis). When used in conjunction with the modular afocal variator **11** positioned according to the formula disclosed herein, the second modular afocal variator **21** is able to provide primary focus to the optical system and the modular afocal variator **11** is able to provide secondary or fine focus while maintaining essentially constant magnification during the fine focus. Additional optical components can be used as known in the art depending on the desired design of the optical system.

To impart not only focus but essentially constant magnification throughout focal translation, the position of the modular afocal variator **11** is not indiscriminately positioned within the optical system, but rather occupies a specific position within the optical system according to a formula. The modular afocal variator **11** of the present invention is carefully positioned so that the first positive lens system **2** is 66% (+/−15%) of its focal length down from where the intermediary image would have been formed in the conventional tube length system, i.e. focal plane **9**. In the embodiments described in FIGS. **1**-**3**, where the first and second positive lens systems each have a focal length of c.160 mm and the central negative lens system has a focal length of c.−60 mm, this is equivalent to the first positive lens system **2** being positioned 66% of 160 mm, or c. 106 mm, from focal plane **9**. Likewise, a formula pertains to the spacing required between the second positive lens system **5** of the modular afocal variator **11** to the focal plane **9**. This is determined as 100% (+/−15%) of the central negative lens system's **4** focal length, expressed as positive added spacing. Using the above measurements, this is equivalent to the second positive lens system **5** being positioned 100% of 60 mm, or c.60 mm, from focal plane **9**.

It is therefore seen that the prior art single-purpose focusing afocal variator is now transformed into a system which provides not only indiscriminate magnification altering focus, but the novel characteristic based on a formula-specific position in an optical system that provides near constant magnification throughout focal translation.

The systems taught herein, and current or future equivalents which can be derived from it, can be made from any suitable combination of optical materials or lens types, be they of whatever refractive, diffractive and dispersive characteristics as known in the art, the only limitation being their suitability for actual use. In addition, the use of single or multiple focal variator systems in other applications for focus, to concentrate or to disperse light or other electromagnetic wavelengths is also taught. While not shown in FIGS. **1** through **4**, the addition of art known fixed or variable diaphragms or tapered tubes inside the optical system components may be used to obtain an excellent depth of field or to control other aberrations as well as the speed of the entire system as focus is translated.

It is therefore seen that the present invention teaches and provides optical systems in which an afocal variator is so positioned in optical systems so that essentially constant magnification is maintained throughout focal translation in accordance with the formula taught by the present invention, thereby providing two functions to such systems: variable internal focusing and active maintenance of magnification during such. The present invention also provides this focusing capability to virtually any optical system into which it can be physically introduced, according to the formula provided herein. In addition, the present invention teaches an active maintenance of constant magnification throughout focal translation which can be modular in which case, it could be removed or be supplemental to, any optical systems in which it can be physically interfaced.

The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments, exemplary embodiments and optional features, modification and variation of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention as defined by the appended claims. The specific embodiments provided herein are examples of useful embodiments of the present invention and it will be apparent to one skilled in the art that the present invention may be carried out using a large number of variations of the devices, device components, methods steps set forth in the present description.

All references cited in this application are hereby incorporated in their entireties by reference to the extent that they are not inconsistent with the disclosure in this application. It will be apparent to one of ordinary skill in the art that methods, devices, device elements, materials, procedures and techniques other than those specifically described herein can be applied to the practice of the invention as broadly disclosed herein without resort to undue experimentation. All art-known functional equivalents of methods, devices, device elements, materials, procedures and techniques specifically described herein are intended to be encompassed by this invention.

What is claimed is:

1. An imaging optical system comprising:

a. an optical housing;

b. an objective lens system disposed at one end of the optical housing and having a focal plane; and

c. a modular afocal variator disposed within the optical housing in optical series with the objective lens system, wherein the modular afocal variator comprises a first positive lens system, a central negative lens system, and a second positive lens system, where the central negative lens system is positioned between the first and second positive lens systems and is able to be moved continuously towards and away from the first positive lens system and towards and away from the second positive lens system,

wherein the modular afocal variator is positioned so that the distance between the first positive lens system and the focal plane is 66% (±15%) of the focal length of the first positive lens system, and the distance between the second positive lens system and the focal plane is 100% (±15%) of the absolute value of the focal length of the central negative lens system, and

wherein the modular afocal variator provides focus to the optical system while maintaining essentially constant magnification throughout the focal translation.

2. The optical system of claim **1** further comprising a second afocal variator, wherein the first modular afocal variator is able to provide fine focus with essentially constant magnification throughout the focal translation the second afocal variator is able to provide primary focus to said optical system.

3. The optical system of claim **1** further comprising means for activating focus of the optical system, wherein means for activating focus is motorized activation or remote control activation.

4. The optical system of claim **1** further comprising one or more port positions able to split a beam of light traveling through the optical system, wherein one or more port positions comprise a modular afocal variator positioned to allow an image to be focused without essential magnification change beyond the original depth of field of the imaging optical system.

5. A method of focusing an optical image system having a focal plane comprising the steps of positioning a modular afocal variator having a first positive lens system, a central negative lens system, and a second positive lens system, within said optical image system so that the distance between the first positive lens system and the focal plane is 66% (±15%) of the focal length, as expressed in positive physical dimensional measurement, of the first positive lens system, and the distance between the second positive lens system and the focal plane is 100% (±15%) of the focal length, as expressed in positive physical dimensional measurement, of the central negative lens system,

wherein focal translation above, through and below an object is essentially constant and without appreciable magnification change over a distance beyond that of the original depth of field of the optical image system in which the modular afocal variator system is incorporated.

* * * * *

US005452133A

United States Patent [19]

Margolis

[11] Patent Number: 5,452,133

[45] Date of Patent: Sep. 19, 1995

[54] VARIATOR OPTICAL SYSTEM

[76] Inventor: **H. Jay Margolis**, 704 Mohawk Dr., #15, Boulder, Colo. 80303

[21] Appl. No.: **101,544**

[22] Filed: **Aug. 2, 1993**

[51] **Int. Cl.**[6] **G02B 15/02**

[52] **U.S. Cl.** **359/672**; 359/673; 359/674; 359/675

[58] **Field of Search** 359/672–675

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,853,387	12/1974	Demaine et al.	359/672
4,427,268	1/1984	Ikemori	359/673

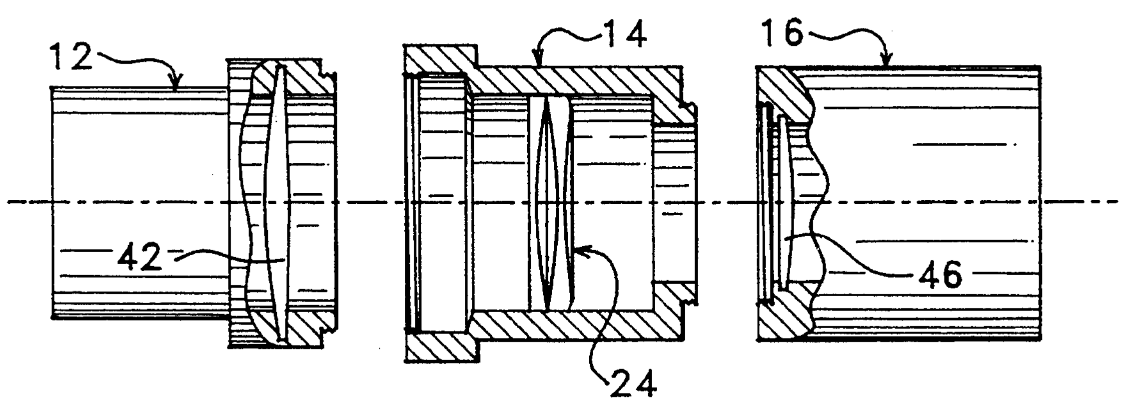
Primary Examiner—Scott J. Sugarman

Attorney, Agent, or Firm—Donald W. Margolis

[57] **ABSTRACT**

An afocal optical module simulator (aoms) for use in conjunction with one or two other optical modules to simulate an afocal variator optical system. The aoms is comprised of an optical module having a front and a rear end, and includes a movable negative lens. The front end of the aoms includes a mechanism for securing a front optical module which may include as its rear most element a positive lens system which will be located juxtaposed to, but spaced from, the movable negative lens within the aoms. Similarly, the rear end of the aoms includes a mechanism for securing a rear optical module, which includes as its front most element a positive lens system which will be located juxtaposed to, but spaced from, the movable negative lens within the aoms. The front optical system provides an optical element adjacent to the front of the movable negative central optical element, and/or a rear optical system provides an optical element adjacent to the rear of the movable negative central optical element, which front and/or a rear optical system can be connected in combination to vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension of any system, and without the need to change the position of any lens other than the central movable negative optical element, and without the need to change the lenses of the front or rear optical systems.

11 Claims, 1 Drawing Sheet



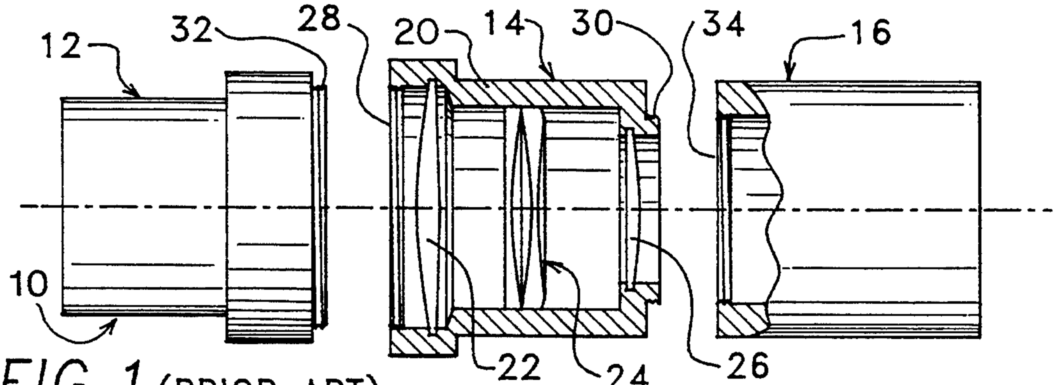


FIG. 1 (PRIOR ART)

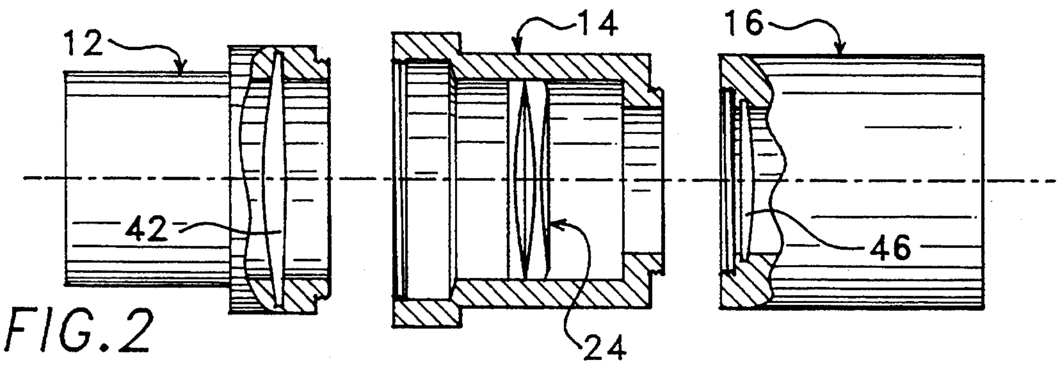


FIG. 2

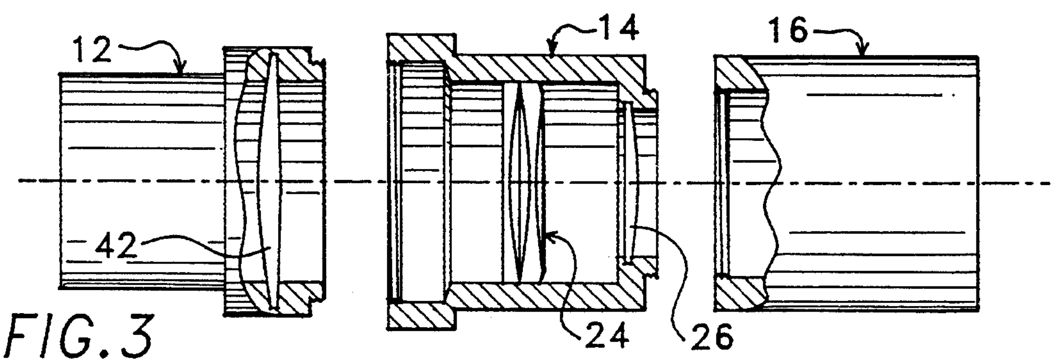


FIG. 3

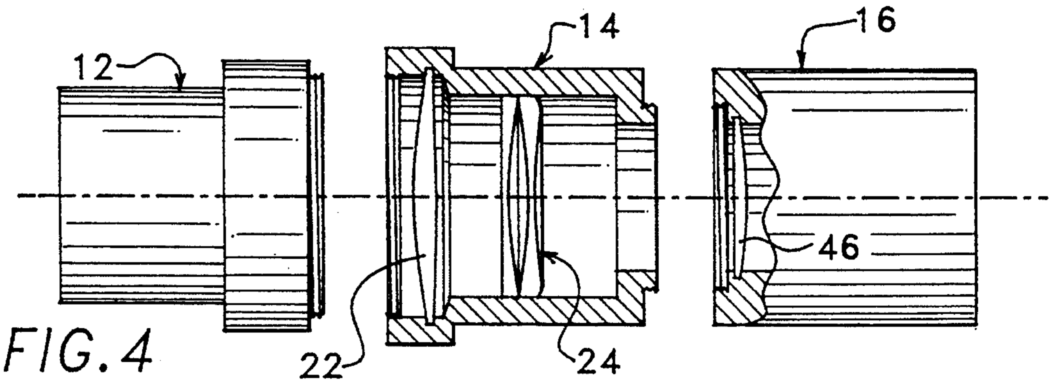


FIG. 4

VARIATOR OPTICAL SYSTEM

BACKGROUND OF THE INVENTION

a) Field of the Invention

This invention relates to an optical imaging system. More specifically it relates to such a system in which a partial variator system is used in conjunction with either or both a front optical systems and a rear optical system, in which either the front optical system, the rear optical system, or both the front and rear optical systems provide one or more optical element in conjunction with the partial variator system to form an afocal variator.

b) Discussion of the Prior Art

"Varios" and "variators" are well known and useful optical systems. Such systems have found use primarily in zoom lens systems and in projectors, for example, to change the size of a projected image on a screen. Afocal variators of the specific type described in the present application have been known and in commercial use and on sale, by themselves, for at least twenty years, for example for use in projector lenses to alter the size of a projected image on a screen. The applicant of the present invention has taught the use of variators as focusing devices in the following listed related applications in conjunction with both refractive and partially obscured reflective optical systems. However, in all such instances, such variator optical systems have been used as complete and separate subsystems, independent of the front and of the rear imaging optical systems with which they are interfaced. That is, that while the front and the rear imaging optical systems are taught to be connected to and integrated with the variator, as modules, neither the front optical system, nor the rear optical system, nor the combined front and rear optical systems, as previously taught by applicant, does any portion of those optical systems provide an element of the afocal variator. That is, in the prior art, no portion of the front optical system, nor of the rear optical system, nor of the combined front and rear optical systems are taught or suggested to be subsumed into nor form a working portion of the afocal variator.

Applicant's related applications include U.S. Pat. No. 5,191,469 entitled AFOCAL VARIATION FOCUSING SYSTEM FOR MIRRORED OPTICAL SYSTEMS, U.S. Pat. No. 5,054,896 entitled CONTINUOUSLY FOCUSABLE MICROSCOPE INCORPORATING AN AFOCAL VARIATOR OPTICAL SYSTEM, and U.S. Pat. No. 4,988,173 entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM.

In other known prior art, Hillman U.S. Pat. No. 2,937,570 discloses a telescope system in which the image forming lenses are moved in order to focus the system. That is, focusing is accomplished by moving the objective lens relative to the focusing lens, both of which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a central, modular position of an afocal variator, nor by determining the optical effect of an afocal variator and incorporating its front and rear elements into the image-forming optics, but still retaining a central modular element which is non-image-forming and essentially non-formula-specific.

Matsumura U.S. Pat. No. 4,318,585 discloses an optical system with an afocal focusing group, but in which the afocal focusing group is a Galilean telescope rather than an afocal variator. Furthermore, the system as taught by Matsumura does not incorporate the front, rear or front and rear elements of an afocal variator into the calculation and formulation of the image forming optics.

Quendreff French Patent 2,572,545 teaches the use of a zoom lens to make enlarged pictures, and also teaches the use of various art known mechanical devices for connecting together optical modules. However, it neither teaches nor suggests the use of an afocal variator, nor of a system in which one or more of the outer optical elements of an afocal variator are subsumed into the formula-specific, image-forming optics.

It is thus seen that, while the use of varios and variators have been taught by the applicant in conjunction with front and rear refractive optical systems, and front and rear partially-obscured reflective optical systems, the use of a partial variator system in conjunction with both a front optical system and with a rear optical system, in which either the front optical system, the rear optical system, or the front and rear optical systems provide one or more optical element in conjunction with a partial variator system in order to complete and to form an afocal variator system, has not been previously taught or suggested by the known prior art.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide a modular optical system in which a centrally located partial afocal variator optical system module which lacks either a front optical element, or a rear optical element, or both a front and a rear optical element, is combined with a front and a rear optical system module; whereby, by dint of either the front optical system module, or the rear optical system module, respectively, or both the front and the rear optical system modules, either a subsumed front optical element or a subsumed rear optical element or both a subsumed front and subsumed rear optical element are provided to complete the partial afocal variator optical system module which is then, by movement of the negative optical element in the partial afocal variator optical system module, is now capable of functioning to alter the active focal length of the combined system.

It is another object of the present invention to provide at least the central negative element of an afocal variator system within a modular optical system in which the front optical element, or the rear optical element, or both the front and rear optical elements of the afocal variator optical system are provided by the front optical system module, or the rear optical system module, or the combination of the front optical system module and the rear optical system module, whereby the central negative element of the afocal variator system becomes subsumed and incorporated into an image-forming, formula-specific optical system.

It is another object of the present invention to reduce the number of optical elements in a modular afocal variator optical system in which a centrally located afocal variator optical system is combined with a front optical system module in combination with a rear optical system module, thereby reducing the cost of such a modular system.

Another object of the present invention is to produce optical systems with the essential characteristics of an optical system containing a separate, individual afocal variator, thereby reducing the total number of transmissive optics and as a result, reducing the semi-opaque losses caused by additional lens elements the optical device is used at specific light wavelengths, for example, when used with ultraviolet light wavelengths.

Another object of the present invention is to derive optical systems essentially equal to those incorporating a separate afocal variator module, combined with a front optical system module and a rear optical system module, thereby permitting the custom design of the front and rear afocal variator lens elements by including them into the image-forming, formula-specific optics surrounding a central modular, non-formula-specific, negative lens system.

Another object of the present invention is to provide a negative lens system which is suitable for use in an afocal variator, and which is capable of being moved toward or away from an associated front optical module, rear optical module, or both a front and rear optical module image-forming, formula-specific optical system, which the associated front optical module, rear optical module, or front and rear optical modules providing the optical elements which are required, along with the movable negative lens system to form an afocal variator.

Another object of the present invention is to provide such a partial afocal variator module which is simple in construction and design.

Another object of the present invention is to provide a partial afocal variator module focusing means for use with refractive, partially-obscured reflective and combined refractive/partially obscured reflective optical devices.

The foregoing objects of the present invention are obtained by providing an afocal optical module simulator which can be used in conjunction with at least two other optical modules to simulate an afocal variator optical system. Such an afocal optical module simulator is comprised of an optical module having a front end and a rear end, such as a fixed length tube, and which includes within that optical module simulator a movable negative lens. The front end of the afocal optical module simulator includes a mechanism for receiving and securing a front optical module, which front optical module includes as its rear most element a positive lens system which will be located juxtaposed to, but spaced from, the movable negative lens within the optical module simulator. In a similar manner, the rear end of the afocal optical module simulator includes a mechanism for receiving and securing a rear optical module, which rear optical module includes as its front most element a positive lens system which will be located juxtaposed to, but spaced from, the movable negative lens within the optical module simulator.

In such a system, a front optical system provides an optical element adjacent to the front of the movable negative central optical element, and/or a rear optical system provides an optical element adjacent to the rear of the movable negative central optical element, which front and/or a rear optical system can be connected in combination to vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension of any system, and without the need to change the position of any lens other than the central movable negative optical element, and without the need to change the lenses of the front or rear optical systems. Such an optical system or optical instrument essentially has the focusing characteristics of a modular afocal variator focusing system as taught by applicant's the above identified patents.

In preferred embodiments this is accomplished by first calculating and formulating a modular optical system or optical instrument which includes an afocal variator as the focusing means between a front optical system and a rear optical system; and then, by a process of subsumation, which includes the incorporation of the rear, the front, or the rear and the front optical elements, respectively, of the associated front, or rear, or front and rear optical system, to thereby effectively design and complete the afocal variator optical system. Stated another way, the front and rear image-forming, formula-specific optics of the front, the rear, or the front and the rear optical elements of the afocal variator system may be provided by the front optical system, the rear optical system, or the front optical system and the rear optical system. By providing one or two of the afocal variator elements from the associated front and/or from the associated rear optical systems, the central negative lens system of the original afocal variator may remain essentially unchanged in the system, with virtual disregard to formula-specificity. The movable central negative lens of the original afocal variator thereby becomes an independent modular component.

Within the total optical device, the negative modular component of the present invention can be so positioned and controlled that it is capable of operating like an afocal variator optical module by being moved continuously towards and away from the front optical system module, and towards and away from the rear optical system module of a total optical system device or instrument. This is due to the fact that the front and/or rear optical system modules, having been subsumed into and incorporated with the movable central negative modular component of the present invention, so that such front and/or rear optical system modules provide optical powers and characteristics of either the front optical system module, or the rear optical system module, or both the front optical system module, and rear optical system module of the theoretical afocal variator system upon which the total optical system device or instrument is predicated, all while the length of the total optical system device remains substantially constant.

It is thus seen that the system of the present invention uses an independent non-image forming movable negative central lens system module, which together with the front and/or rear modular imaging systems, provides essentially the same system function as such a modular system in which a complete, independent afocal variator modular optical system is present. Since the front and rear image-forming optical system modules surrounding the afocal variator movable negative lens module incorporate and subsume the characteristics of a complete afocal front and/or rear lens systems of the afocal variator, the central movable negative modular system is virtually the same as an afocal variator in which the front and/or rear lenses were not subsumed and incorporated from a front and/or rear optical module to form an afocal variator module.

As taught by applicant's above related applications, an afocal variator focusing means provides a ranging of the front conjugate focus of an optical device, while the rear conjugate that is formed after the rear imaging lens remains spatially constant. This operative factor substantially defines the operative nature of an optical system or device that incorporates an afocal variator focusing means. Consequently, by this definition, the configuration and embodiments of the present invention are in strict compliance, as the present invention does not alter the fact that only the front conjugate ranges while the rear conjugate that is formed after the rear imaging lens system remaining spatially constant from the focal plane. For example, the afocal variator focusing means is distinct from the focusing means taught by Hillman, in which the rear-most imaging system moves to focus and does not maintain itself at a constant rear distance from the focal plane. Consequently, the present invention fully maintains the characteristics of an optical device which otherwise incorporates a total modular afocal variator focusing means, as distinguished from the present use in which a modular negative component is used as an optical focusing means. In either case, the modular central negative lens system. functions the same; it cannot "distinguish" between its use in a total modular afocal variator and when the front, rear or front and rear lens systems of a modular afocal variator focusing means are subsumed and incorporated into the front and rear image-forming, formula-specific optical systems. Essentially, the modular central negative lens system can be defined as having been designed to operate for the "afocal variator condition" whether in a total afocal variator modular focusing means, or when one or more of the original afocal variator's systems are, by art-known computational, empirical and experimental methods, subsumed and incorporated into front and rear imaging optics. The essential factor is that an afocal condition be met as the condition upon which the design of the negative central element modular and effective functions are predicated so that the net effective result of the use of the central negative modular lens system is the same as when used in a total modular afocal variator.

Although the present invention has been described as having a modular central movable negative lens system, and may continue to be described as such, it is possible to build the present invention with a modular central positive lens system, just as it is possible to build total afocal variators with positive central systems and negative outer lens systems. However, such a positive central system construction would be less variable and less efficient than when a negative modular central element is used.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination and elements as herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate complete preferred embodiments of the present invention according to the best modes presently devised for the practical application of the principles thereof, and in which:

FIG. **1** illustrates an exploded diagrammatic view, partially in section and partially broken away of the prior art modular afocal variator system.

FIG. **2** is an exploded diagrammatic view, partially in section and partially broken away, which illustrates the present invention in which a movable negative lens of an afocal variator optical system module is positioned between a front optical system module and a rear optical system module, each of which provide an optical element to complete the afocal variator optical system.

FIG. **3** is an exploded diagrammatic view, partially in section and partially broken away, which illustrates the present invention in which a movable negative lens of an afocal variator optical system module is positioned between a front optical system module and a rear optical system module, and in which only the front optical system module provides an optical element to complete the afocal variator optical system.

FIG. **4** is an exploded diagrammatic view, partially in section and partially broken away, which illustrates the present invention in which a movable negative lens of an afocal variator optical system module is positioned between a front optical system module and a rear optical system module, and in which only the rear optical system module provides an optical element to complete the afocal variator optical system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

Referring to FIG. **1** there is shown in exploded view a priori art optical system, generally **10** consisting of three major modular components which are designed for substantial permanent connection to one another, a front modular optical system **12**, an afocal variator modular optical system **14**, shown in cross-section, and a rear modular optical system **16** shown partially broken away. As illustrated, the afocal variator optical system **14** consists of a fixed length tube **20** in which there is located a front positive lens **22**, a central negative lens element **24**, in this case a negative doublet, and a rear positive lens **26**. Front positive lens **22** and rear positive lens **26** are secured to tube **20** in a manner such that the distance between them is substantially fixed. However, negative lens **24** is located within tube **20** and constructed in such a manner that it can be moved continuously within tube **20** up and back between front lens **22** and rear lens **26**. That is, negative lens **24** is capable of being moved towards and away from front lens **22** and is also capable of being moving towards and away from rear lens **26**. All of this is made possible by the system for holding the lenses of the afocal variator optical system **14**. This holding system may consist of tube **20**, as shown, or of any other lens holding system, such as a lens positioning platform system of the type that is well known in the art, or the like. As shown, tube system **20** includes front connecting means, in this case a series of female threads **28** and rear connecting means, in this case a series of male threads **30**, to which front optical system **12** and rear optical system **16** can be appropriately connected by means of their own male and female thread connectors **32** and **34**, respectively. Negative lens **24** may be moved within tube **20** by any art known means for providing continuous linear motion to a lens.

Now referring to FIG. **2**, there is shown the present invention in which both the front positive lens **22** and the rear positive lens **26** of the afocal variator have been removed, and in which lenses **42** and **46** have been placed at the rear of tube **12** and at the front of tube **16**, respectively. Lens **42** in tube **12** preferably has the combined optical characteristics of its original optical module and of lens **22** of FIG. **1**, while lens **46** preferably has the combined optical characteristics of the original optical module of tube **16** and of lens **26**. Note that the central lens module **24** is not altered. In effect, the system of FIG. **2** has reduced the total number of lenses in the system by two, but has maintained the characteristics of the light beam as it goes to and from the central negative lens module.

For example, in the prior art, of FIG. **1**, the afocal variator may be surrounded by a +75 mm positive lens **52** and a +75 mm lens **16**. Now, by removing lenses **22** and **26**, as shown in FIG. **2**, the essential characteristics of the original can be maintained. This is accomplished by replacing lens **12** (+75 mm) with a +50 mm lens **42**. This can be done with the front lens because replacement lens **42** +50 mm is essentially equal to the combined optical characteristic of the (removed) front lens **22** and the former lens **12**. In a similar manner, by replacing lens **16** (+75 mm) with a +50 mm lens **46**; essentially, the replacement +50 mm lens is equal to the combined optical characteristic of the (removed) rear lens **26** and the former lens **16**. Significantly, both the front and rear focuses change, while the rear conjugate remains constant, therefore, by definition, the system is operating as predicated upon the "afocal variator condition."

Now referring to FIG. **3**, there is shown the present invention in which only the front positive lens **22** of the afocal variator has been removed, and a new lens system **42** has been placed at the rear of tube **12**. Lens system **42** in tube **12** now has the combined optical characteristics of the lens of tube **12** and of lens **22** of FIG. **1**. Note that the central lens module **24** and the rear lens module **16** are not altered from that of FIG. **1**. In effect, the configuration of FIG. **3** has reduced the total number of lenses, as compared to FIG. **1** by at least one, but has maintained the characteristics of an afocal variator condition, the light beam as it goes to and from the central negative lens module **24**. As in FIG. **2**, lenses **12** (+75 mm) and **22** are replaced with a +50 mm lens **42**, which replacement lens **42** +50 mm is essentially equal to the combined optical characteristic of the (removed) front lens **22** and the former lens system **12**. Significantly, the front focus changes, while the rear conjugate remains constant, which therefore, by definition, causes the system to operate upon the "afocal variator condition."

Referring now to FIG. **4**, there is shown the present invention in which only the rear positive lens **26** of the afocal variator has been removed, and a new replacement lens **46** has been placed in the front of tube **16**. Lens **46** in tube **16** now has the combined optical characteristics of the original lens in tube **16** and of lens **26** of FIG. **1**. Note, that in this embodiment the central lens module **24** and the front lens module **12** is not altered from that of FIG. **1**. In effect, we have again, as in FIG. **3**, reduced the total number of lenses in the system, as compared to FIG. **1**, by one, but have maintained the characteristics of the light beam as it goes to and from the central negative lens module **24**. For example, by replacing lens **16** (+75 mm) with a +50 mm lens **46**; essentially, the replacement +50 mm lens is equal to the combined optical characteristic of the (removed) rear lens **26** and the former lens **16**. Significantly, both the front focus changes, while the rear conjugate **46** remains constant, therefore, by definition, the system is operating as predicated upon the "afocal variator condition."

The partial afocal variator optical module **14** of the present invention has independent utility as an optical module which carries at least a negative lens system which is suitable for use in an afocal variator. The central variator optical module **14** also has utility because any displacement of the central lens **24** can be correlated to analogous reciprocal values of range, aberration effect, refractive effect and, possibly, dispersive effect. For example, when module **14** is positioned in a functioning optical system, movement of the central lens **24** of module **14** can be linked to a gauge, potentiometer, piezo-electric device, LED, LCD, or other art-known display system, in order to determine useful values for range-finding. Furthermore, such displacement of the central lens **24** of module **14** can be used to determined refractive properties, for example, when the module **14** of the present invention is incorporated in an eye refractometer.

Additionally, module **14** may be a product in itself, which may interface with other optical products, limited only by physical demands, so that existing optical products may be retrofitted with module **14** of the present invention. For example, module **14** of the present invention may be used to correct telescopical cameras, including satellite borne telescopes with which it is compatible.

Module **14** could also act as a supporting device to connect various optical devices. For example, module **14** could be used to connect the bottom frame of a microscope with the top observation tube, whereby module **14** of the present invention could effect the focus of the entire microscope.

It is thus seen that the present invention provides a modular optical system in which a centrally located partial afocal variator optical system module, which module lacks either a front optical element, or a rear optical element, or both a front and a rear optical element, is combined with a front and a rear optical system module; whereby, by dint of either the front optical system module, or the rear optical system module, respectively, or both the front and the rear optical system modules, either a front optical element or a rear optical element or both a front and the rear optical element are provided to complete the partial afocal variator optical system module. Then, by movement of the negative optical element in the partial afocal variator optical system module, it is now capable of functioning to alter the active focal length of the combined system. It is also seen that the present invention also provides at least the central negative element of an afocal variator system within a modular optical system in which the front optical element, or the rear optical element, or both the front and rear optical elements of the afocal variator optical system are subsumed by the front optical system module, or the rear optical system module, or the combination of the front optical system module and the rear optical system module, whereby the central negative element of the afocal variator system becomes subsumed and incorporated into an image-forming, formula-specific optical system. It is additionally seen that the present invention reduces the number of optical elements in a modular afocal variator optical system in which a centrally located afocal variator optical system is combined with a front optical system module in combination with a rear optical system module, thereby reducing the cost of such a modular system, and permitting the custom design of the front and rear afocal variator lens elements by including them into the image-forming, formula-specific optics surrounding a central modular, non-formula-specific, negative lens system. In addition the present invention provides a negative lens system which is suitable for use in an afocal variator, and which is capable of being moved toward or away from an associated front optical module, rear optical module, or both a front and rear optical module image-forming, formula-specific optical system, which the associated front optical module, rear optical module, or front and rear optical modules providing the optical elements which are required, along with the movable negative lens system to form an afocal variator. This has been taught to be accomplished by first calculating and formulating a modular optical system or optical instrument which includes an afocal variator as the focusing means between a front optical system and a rear optical system; and then, by a process of subsumation, which includes the incorporation of the rear, the front, or the rear and the front optical elements, respectively, of the associated front, or rear, or front and rear optical system, to thereby effectively design and complete the afocal variator optical system. It is thus seen that the system of the present invention has taught an independent non-image forming movable negative central lens system module, which together with the front and/or rear modular imaging systems, provides essentially the same system function as such a modular system in which a complete, independent afocal variator modular optical system is present. Since the front and rear image-forming optical system modules surrounding the afocal variator movable negative lens module incorporate and subsume the characteristics of a complete afocal front and/or rear lens systems of the afocal variator, the central movable negative modular system is virtually the same as an afocal variator in which the front and/or rear lenses were not subsumed and incorporated from a front and/or rear optical module to form an afocal variator module. While the invention has been particularly shown, described and illustrated in detail with reference to preferred embodiments and modifications thereof, it should be understood by those skilled in the art that the foregoing and other modifications are exemplary only, and that equivalent changes in form and detail may be made therein without departing from the true spirit and scope of the invention as claimed, except as precluded by the prior art.

The invention in which an exclusive right is claimed is defined by the following claims:

1. An optical system for use with a front optical system, or with a rear optical system, or with both a front optical system and a rear optical system, for focusing such optical systems, comprised of:

a partial afocal variator system including a body having a fixed length, said body having a front end and a rear end; and

an optical element carried by said fixture, said optical element adapted for movement towards and away from said front end and said rear end of said fixed length body; whereby said partial afocal variator system and said moveable optical element when combined with a front optical system, or with a rear optical system, or with both a front optical system and a rear optical system provide the focusing characteristics of a modular afocal variator focusing system.

2. The optical system of claim **1** in which said hollow body has a front connecting element and a rear connecting element to which a front optical system and a rear optical system may be connected.

3. The optical system of claim **2** in which said body is hollow, and said moveable optical element moves within said hollow body.

4. The optical system of claim **3** in which either a front optical system, a rear optical system, or both a front optical system and a rear optical system provide one or more optical elements in conjunction with said partial afocal variator system in order to complete and to form an afocal variator optical module with said partial afocal variator system.

5. A partial afocal variator optical module simulator which can be used in conjunction with a front optical system, or with a rear optical system, or with both a front optical system and a rear optical system to simulate the focusing characteristics of an afocal variator optical system, comprised of:

an optical module having a fixed length body, said body having a front end and a rear end, and which includes negative lens which is adapted for movement towards and away from said front end and said rear end of said fixed length body, said front end of said optical module including means for receiving and securing a front optical module, and said rear end of said optical module including means for receiving and securing a rear optical module; whereby said partial afocal variator system and said moveable optical element, when combined with a front optical system, or with a rear optical system, or with both a front optical system and a rear optical system provide the focusing characteristics of a modular afocal variator focusing system.

6. The optical system of claim **5** in which said optical module is a fixed length hollow tube body, said moveable negative optical element being within said tube.

7. The partial afocal variator optical module simulator of claim **6** in which a front optical module is secured to said means for receiving and securing a front optical module, said front optical module including as its rear most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said partial afocal variator optical module simulator, and in which a rear optical module is secured to said means for receiving and securing a rear optical module, said rear optical module including as its front most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said partial afocal variator optical module simulator; which said front optical system provides an optical element connected to said front of said afocal variator optical module simulator, and said rear optical system provides an optical element adjacent to the rear of said afocal variator optical module simulator, which in combination vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension of any system, and without the need to change the position of any lens other than the central movable negative optical element, and without the need to change the lenses of the front or rear optical systems; whereby the combined optical system has the focusing characteristics of a modular afocal variator focusing system.

8. The optical system of claim **7** in which the movable negative central optical element is so positioned and controlled that it is capable of operating like an afocal variator optical module by being moved continuously towards and away from the front optical system module, and towards and away from the rear optical system module of a total optical system device or instrument.

9. The partial afocal variator optical module simulator of claim 6 in which a front optical module is secured to said means for receiving and securing a front optical module, said front optical module including as its rear most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said partial afocal variator optical module simulator, and in which a positive lens system is located within said rear of said partial afocal variator optical module simulator juxtaposed to, but normally spaced from, said movable negative lens.

10. The partial afocal variator optical module simulator of claim 6 in which a rear optical module is secured to said means for receiving and securing a rear optical module, said rear optical module including as its front most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said partial afocal variator optical module simulator, and in which a positive lens system is located within said front of said partial afocal variator optical module simulator juxtaposed to, but normally spaced from, said movable negative lens.

11.A partial afocal variator optical module simulator which can be used in conjunction with a front optical system, or with a rear optical system, or with both a front optical system and a rear optical system to simulate an afocal variator optical system, comprised of:

an optical module having a fixed length hollow tube body, said body having a front end and a rear end, said front end of said optical module including means for receiving and securing a front optical module, and said rear end of said optical module including means for receiving and securing a rear optical module; a movable negative lens within said tube;

a front optical module secured to said means for receiving and securing a front optical module, said front optical module including as its rear most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said tube; and

a rear optical module secured to said means for receiving and securing a rear optical module, said rear optical module including as its front most element a positive lens system which will be located juxtaposed to, but normally spaced from, said movable negative lens within said partial afocal variator optical module simulator; wherein, said front optical module provides an optical element connected to said front of said afocal variator optical module simulator, and said rear optical module provides an optical element adjacent to the rear of said afocal variator optical module simulator, which in combination vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension of any system, and without the need to change the position of any lens other than the central movable negative optical element, and without the need to change the lenses of the front or rear optical systems; whereby the combined optical system has the focusing characteristics of a modular afocal variator focusing system.

* * * * *

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United States Patent [19]

Margolis

[11] Patent Number: 5,191,469

[45] Date of Patent: Mar. 2, 1993

[54] AFOCAL VARIATION FOCUSING SYSTEM FOR MIRRORED OPTICAL SYSTEMS

[76] Inventor: H. Jay Margolis, 704 Mohawk Dr., #15, Boulder, Colo. 80303

[21] Appl. No.: 606,045

[22] Filed: Oct. 30, 1990

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 342,179, Apr. 4, 1989, Pat. No. 5,054,896, which is a continuation-in-part of Ser. No. 286,307, Dec. 19, 1988, Pat. No. 4,988,173, which is a continuation-in-part of Ser. No. 169,271, May 17, 1988, abandoned.

[51] **Int. Cl.**[5] **G02B 23/00**

[52] **U.S. Cl.** **359/366**; 359/399; 359/425; 359/432; 359/435

[58] **Field of Search** 359/744, 425, 426, 432, 359/785, 786, 787, 435, 405, 399

[56] **References Cited**

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4,318,585 3/1982 Matsumura 359/425
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5,054,896 10/1991 Margolis 359/676

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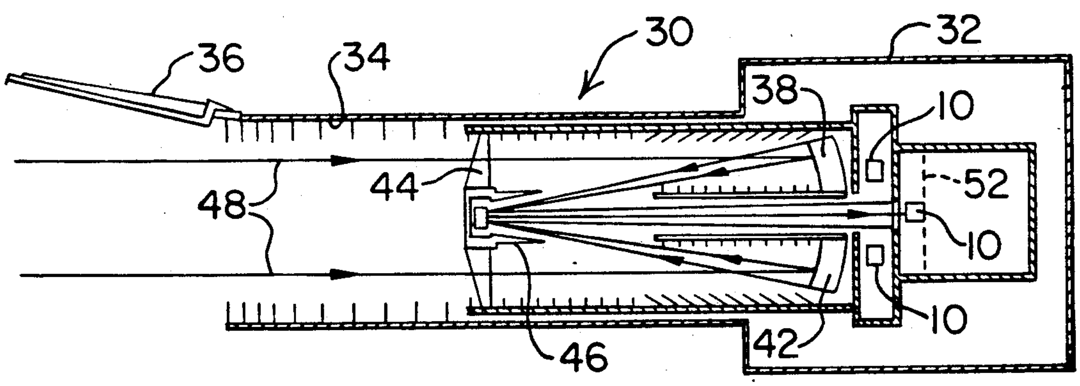
Attorney, Agent, or Firm—Donald W. Margolis

[57] **ABSTRACT**

In this system a module carries an afocal variator optical system, and to which module a front partially-obscured reflecting telescopical system and a rear system module can be substantially permanently connected in combination to vary the actual focal length of the front partially-obscured reflecting telescopical system in conjunction with a rear system module without the need to physically change the length dimension of any system, or without the need to change the mirror position or positions of the front module. A partially-obscured reflecting telescopical system is defined as any selected from the group Newtonian, Cassegrain, Ritchey-Chretien, Gregorian and any of their derivatives, including catadioptric derivatives, such as Maksutov and Schmidt types, in which the incoming light is obscured by a central disk with reflecting obverse side, diagonal mirror or pickoff mirror essentially on-axis to the incoming light.

18 Claims, 1 Drawing Sheet



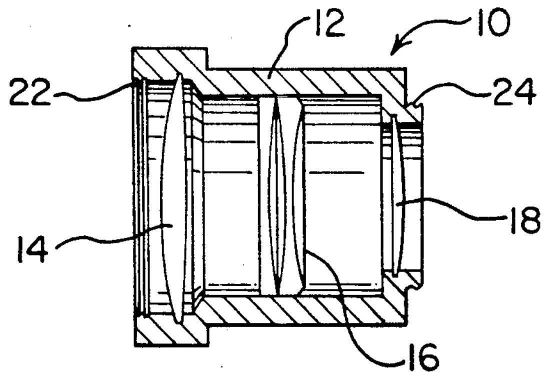


FIG. 1. PRIOR ART

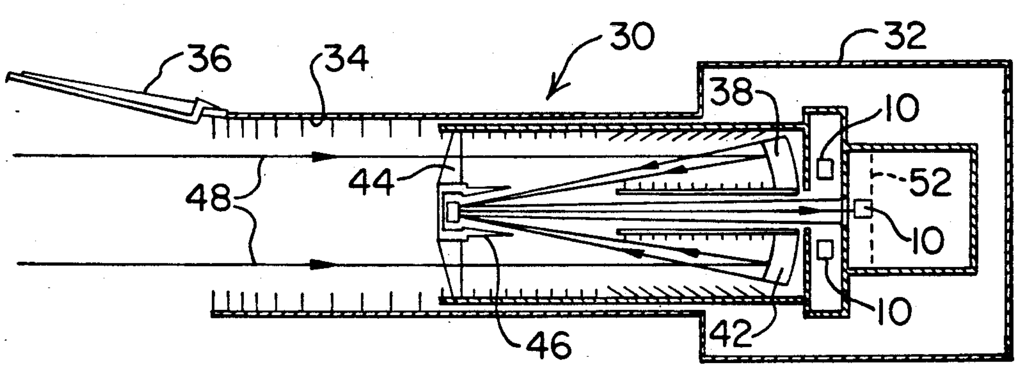


FIG. 2.

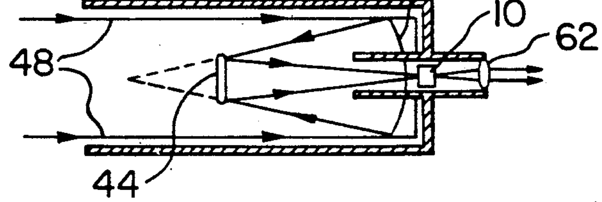


FIG. 3.

AFOCAL VARIATION FOCUSING SYSTEM FOR MIRRORED OPTICAL SYSTEMS

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 342,179, now U.S. Pat. No. 5,054,896, entitled CONTINUOUSLY FOCUSABLE MICROSCOPE INCORPORATING AN AFOCAL VARIATOR OPTICAL SYSTEM filed by H. Jay Margolis on Apr. 4, 1989, which is in turn a continuation-in-part of U.S. patent application Ser. No. 286,307, now U.S. Pat. No. 4,988,173, entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on Dec. 19, 1988, which is in turn a continuation-in-part of U.S. patent application Ser. No. 169,271, also entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on May 17, 1988, and now abandoned.

BACKGROUND OF THE INVENTION

a) Field of the Invention

This invention relates to an afocal variation focusing system for use with mirrored optical systems, and especially for partially-obscured reflecting telescopical systems.

b) Discussion of the Prior Art

"Varios" and "variators" are well known and useful optical systems. Such systems have found use primarily in zoom lens systems and in projectors, for example, to change the size of a projected image on a screen, but not to focus the image. In many instances, such vario and variator devices have been used, in combination with a front refracting optical system and a rear system module in slide projectors. In some instances, they have been used in combination with both a front refracting system and a rear refracting system module. However, in all known instances such optical systems which incorporate vario and variator optical systems have been used with refractor optical systems to alter the size of an image or to focus it, but not to focus the image of a front partially-obscured reflecting telescopical system.

Afocal variators of the specific type described in the present application have been known and in commercial use and on sale, by themselves, for at least seventeen years, for example for use in projector lenses to alter the size of a projected image on a screen. However, while afocal variator optical systems of the specific type disclosed herein, have been previously known in the art, such afocal variator optical systems are not known to have been previously used in the art to focus partially-obscured reflective telescopical systems in the manner disclosed, provided and claimed by the present application, as opposed to the prior art use to alter image size, or to focus refractor optical systems in which the afocal variator is positioned between front and rear optical element modules, as distinguished from use with partially-obscured reflecting telescopical systems in which the rear module is not another optical element, but is a light-reactive material, located at the final focal plane. Many of the latter uses are taught by applicant in the Related Applications listed above.

It is thus seen that while the use of varios and variators, either alone, or in combination with either a front refractive optical system and a rear refractive optical system are known, they are not known to have been used in combination with a front partially-obscured reflective telescopical system to alter active focal length so as to act as a focusing system, as opposed to a system for altering image size or focus when positioned between the elements of a complete, operational refractive optical system.

In the past, where it has been desired to alter the focal length of partially-obscured reflecting telescopical systems, this has usually been accomplished by continuously or discretely changing the length of the optical system, or by changing the location of a mirror relative to the length of the optical system, or by changing the position of one mirror relative to another, or by moving a tube in or out to subtract or add mechanical length between one mirror relative to another. Additionally, lens systems have been used to either focally compress or focally expand the light path of such telescopical systems, but such lenses are formula-specific and alter the telescopical focus within predictable limits, becoming essential parts of the imaging system itself. Altering focal length of partially-obscured reflecting telescopes without utilizing the imaging system, or changing the length of the optical system, or changing the position or location of a mirror or mirrors within a partially-obscured reflective optical system has not been known in the prior art.

In other known prior art, Hillman U.S. Pat. No. 2,937,570 discloses a telescope system in which the image forming lenses are moved in order to focus the system. That is, focusing is accomplished by moving objective lens and focusing lens, which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a portion of an afocal variator, nor by moving a portion of any other non-image forming modular optical lens system. Furthermore, this reference discloses a "formula-specific" optical system in which the lenses are all calculated and assembled to work together to form a telescope. It does not include an independent optical lens system module which is non-image forming. It does not include a central afocal variator module which does not comprise a portion of the image-forming optics. If any of the movable lenses of any of the systems taught by Hillman were removed, the entire system would be affected, very probably to the point that the system would no longer function for its intended purpose.

Matsumura U.S. Pat. No. 4,318,585 discloses an optical system with an afocal focusing group, but in which the afocal focusing group is a Galilean telescope system rather than an afocal variator.

Quenderff French Patent 2,572,545 teaches the use of a zoom lens to make enlarged pictures, and also teaches the use of various art known mechanical devices for connecting together optical modules. However, it neither teaches nor suggests the use of an afocal variator module as a focusing element within a partially-obscured reflective optical system.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide an optical system in which an afocal variator optical system alters the active focal length of a partially-obscured reflecting telescopical system in combination with a rear system module which is light-reactive.

It is another object of the present invention to provide a module which carries an afocal variator optical system, to which module both a front partially-obscured reflective and a rear module which carries a light-reactive material, while substantially permanently connected in combination, can be moved in or out of the optical axis of the partially-obscured reflecting telescopical system whereby one afocal variator can be exchanged for another, all the time the support for such variators is held in substantially permanent combination.

Another object of the present invention is to provide such a module which carries an afocal variator optical system which consists of a front positive lens system and a rear positive lens system which are positioned in substantially fixed spaced relation to one another, and a negative lens which is positioned between such fixed front positive and rear positive lenses, and which lens is designed and supported in the module in such a manner that it is capable of being moved toward and away from the front positive lens or toward and away from the rear positive lens.

Another object of the present invention is to provided such a module which is simple in construction and design and which lends itself to the substantially permanent attachment of both a front partially-obscured reflecting telescopical system and a rear system module carrying a light-reactive material.

Another object of the present invention is to provide ground-based partially-obscured reflecting telescopes with a means of focusing, whereby no movement of the mirror elements is necessitated, thereby reducing the costs of such telescopes.

Another object of the present invention is to provide space-borne partially-obscured reflecting telescopes with a means of focusing whereby no movement of the mirror elements is necessitated, thereby reducing the costs of such telescopes.

It is another object of the present invention to provide a means of correcting misfigured partially-obscured reflecting telescopical systems composed of two or more mirrors, which suffer from inappropriate reciprocity of one mirror with another, whereby the resetting of one mirror with another may produce a better result, in which case the new result may be a premature or extra-mature focal plane, the remaining of which to the predetermined original focal plane would be possible by means of the present invention.

It is also an object of the present invention to utilize one or more module afocal variator optical systems composed of different refractive, dispersive and spectrally-transmitting materials, whereby a wide range of electro-magnetic wavelengths can be alternately focused by moving one module out of the optical axis and replacing it by art-known means with another, all the while the support system containing such module modules remains substantially permanent.

The foregoing objects of the present invention are obtained by providing an optical system which has the ability to vary the actual focal length of a front partially-obscured reflecting telescopical system in combination with a rear element module supporting a light-reactive material, without the need to physically change the length dimension, or the need to change the positions of a mirror, mirrors or lens in a front partially-obscured reflecting telescopical system. In preferred embodiments this is accomplished by the provision of a module which carries an afocal variator optical system which includes in optical series a first positive lens system, a negative lens system, and a second positive lens system; a front partially-obscured reflecting telescopical system located in optical series in front of the first positive lens system of the afocal variator and supported in a substantially permanent housing one or more module, and a rear element module located in optical series to the rear of the second positive lens system of the afocal variator and in substantially permanent attachment to the housing of the module support system. Within the afocal variator, the negative lens system is so positioned and so controlled that it is capable of being moved continuously either towards and away from the first positive lens system and towards and away from the second positive lens system of the afocal variator optical system and the length of the module remains substantially constant.

A partially-obscured reflecting telescopical system is defined as any selected from the group Newtonian, Cassegrain, Ritchey-Chretien, Gregorian and any of their derivatives, including catadioptric derivatives, such as Maksutov and Schmidt types, in which the incoming light is obscured by a central disk with reflecting obverse side, diagonal mirror or pick-off mirror essentially on-axis to the incoming light.

In one preferred embodiment of the present invention an optical system is provided which may be used as a space-borne astronomical telescope imaging onto a light reactive element in the form of a charge coupled (CCD) pixel array. A front partially-obscured reflecting telescopical system, in this case a Ritchey-Chretien type of 57.6 meters focal length, has its mirrors set in permanent relation for near-focus can be exactly achieved by telemetry from the earth. This is accomplished by providing the optical system of the present invention with said Ritchey-Chretien partially-obscured reflecting telescopical system and a rear module of light-reactive material, in this case, a CCD array or multiple CCD arrays.

In another preferred embodiment, the present invention may be used to correct an existing space-borne partially-obscured reflecting telescope which has been orbited with an incorrectly-figured mirror or mirrors. As a result, the best focus would then exhibit spherical aberration. By supporting the optical system of the present invention on instrument modules designed to be inserted into such telescopes by astronauts or space robots, an astronomical telescope not originally incorporating the afocal optical system of the present invention can be retro-fit. By optically moving the secondary and main mirror of the Ritchey-Chretien space-borne telescope to a new reciprocal relation, the present invention could reposition the focal plane in fact onto the previously-calculated focal plane of the space-borne astronomical telescope.

The system of the present invention uses an independent non-image forming modular optical afocal variator lens system which does not comprise a portion of the image-forming optics in the partially obscured reflecting telescopical systems in which it is included. The system of the present invention is not formula-specific. If the afocal variator of the present invention, which includes a movable lens for purposes of focusing the entire system, were initially included in a partially obscured reflecting telescopical systems, and then subsequently removed in its entirety, the remaining partially obscured reflecting telescopical systems modules would be substantially unaffected, and the remaining system components would still function for their intended purpose as a partially obscured reflecting telescopical system.

The afocal variator module of the present invention can be put into substantially any partially obscured reflecting telescopical optical system into which it can be physically fit with substantial disregard for formula specificity. If the afocal variator module were to be removed from the modular optical systems of the present invention, it would not substantially change the characteristics of the optical system in which it had formerly been placed. For example, where the afocal variator module is positioned in a partially obscured reflecting telescopical system between a front reflecting mirror system and a rear light sensitive system it can be used to focus the telescope. However, if the afocal variator lens system of the present invention were to be removed from such a telescope the remaining system would still function as a partially obscured reflecting telescopical system.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination, and elements as herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate complete preferred embodiments of the present invention according to the best modes presently devised for the practical application of the principles thereof, and in which:

FIG. 1 is a diagrammatic view which illustrates the prior art fixed length afocal variator optical system module which is used in the practice of the present invention;

FIG. 2, shows a cross-sectional, diagrammatic representation of one form of a partially obscured reflecting telescope, or other mirrored optical system in which a focusing module is located in combination with such other components as are required to provide a focusable partially obscured reflecting telescope, or other optical system.

FIG. 3, is a cross-sectional, diagrammatic representation of another form of a partially obscured reflecting telescope.

DESCRIPTION OF THE PRIOR ART

Referring to FIG. 1 there is shown, primarily for reference purposes, the basic teaching of the parent applications, of which this application is a continuation-in-part. Shown in is an optical system, consisting of an afocal variator modular optical system 10, shown diagrammatically, in cross-section. As illustrated, the afocal variator optical system 10 consists of a fixed length tube 12 in which there is located a front positive lens system 14, a central negative lens system 16, in this case a negative doublet, and a rear positive lens 18. Front positive lens 14 and rear positive lens 18 are secured to tube 12 in a manner such that the distance between them is substantially fixed. However, negative lens 16 is located within tube 12 and constructed in such a manner that it can be moved continuously within tube 12 up and back between front lens 14 and rear lens 18. That is, negative lens 16 is capable of being moved towards and away from front lens 14 and is also capable of being moving towards and away from rear lens 18. Negative lens 16 may be moved within tube 12 by a linear slider, a helical slider, or by any other art known means for providing continuous linear motion to a lens.

The foregoing is made possible by the system for holding the lenses of the afocal variator optical system 10. This holding system may consist of tube 12, as shown, or of any other lens holding system, such as a lens positioning platform system of the type that is well known in the art, or the like. As shown, tube system 12 includes front connecting means, in this case a series of female threads 22 and rear connecting means, in this case a series of male threads 24, to which a front optical system (not shown) and rear optical system (not shown) can be appropriately connected by means of their own respective male and female thread connectors.

Any of the lenses in the afocal variator 10 can be constructed of multiple elements, for example, the front positive lens 14 of three elements, the central negative lens 16 of four elements and the last positive lens 18 of two elements, and so on, as long as the system consists of a positive-movable negative-positive optical system module, and not the combination of optical elements used.

The combination of an afocal variator optical system module 10 with a front optical system module, not shown, as taught by the parent applications, is believed to have the unique feature of altering or varying the actual focal length of such a front optical system, whether in the form of a real image, as provided by a positive lens, or in the form of a virtual image as provided by a negative lens or a convex mirror. The resulting variation of the focal length effects the convergence or divergence of the light which exits from afocal variator 10, and therefore of the light (or image) which exits from the rear of afocal variator optical system 10. This allows the focus of the system to be changed without changing the length of the overall system or of any modular element in the system, and without changing the mirrors or lenses in the front or rear of the afocal variator modular system 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now referring to FIG. 2, there is shown the present invention in which a cross-sectional diagrammatic representation of a portion of the Hubbel Space Telescope 30, is set forth. The Hubbel system 30 is a Ritchey-Chretien form of Cassegrain partially obscured reflecting telescope. A housing 32 is provided to which the telescope system is mounted. Housing 32 also includes such support instrumentation, energy systems, communication systems, and other art known elements, not shown, as are required to operate the Hubbel system 30. A telescope support tube 34 is connected to support housing 32. Support tube 34 includes, at one end, a remotely operated trap door 36, which can be opened or closed by remote command to allow light to enter the telescope support tube 34.

Within the telescope support tube 34 at an end opposed to trap door 36, is a primary reflecting mirror 38. Primary mirror 38 is concave and includes a central opening 42. Within support tube 34, intermediate trap door 36 and primary concave reflecting mirror 38, is located a secondary convex mirror 44. Secondary mirror 44 includes on its surface which faces primary mirror 38 a series of art known light baffles 46. Electromagnetic radiation, such as light, as indicated by the arrows 52 enter telescope support tube 34, bypass secondary mirror 44, impinge upon primary mirror 38, are collimated and reflected from secondary mirror 44 and pass through central opening 42 in primary mirror 38 to focal plane 52.

Focal plane 52 carries light reactive elements or material, such as CCD pixel array. In normal operations, the geometry defining the location of mirrors 38, 46, and focal plane 52, are such that a focused image is displayed at focal plane 52 for subsequent processing, e.g. transmission, formation of a photograph, or viewing by an observer. Should the geometry and the location of the mirrors 38, 46, and focal plane 52, be miscalculated, the images received at focal plane 52 will be distorted or incomplete or otherwise incapable of providing a coherent image at focal plane 52. Were the system as remote, for example in orbit around the earth, correction of such focusing problems will be both difficult and expensive. However, by locating an afocal variator module 10, either actually, or actually displaced, as shown in FIG. 2, the distorted images can be easily focused onto focal plane 52.

Referring now to FIG. 3, another form of Cassegrain telescope system is shown, in which like parts have like numbers. However, in this modification, the system is intended for viewing through a lens system 62. As with the system of FIG. 2, an afocal variator module 10 may be located within the system for use in correcting any focusing distortion.

In another embodiment, not shown, the present invention may be used as a replacement for the "repeater" telescopes commonly used in space-borne wide field/planetary cameras and other cameras which require secondary, supplemental focusing devices to focally compress, expand, aberrationally control and refocus, the light from a main telescope. These repeaters are usually on the order of 30% contrast loss and a further coarsening of the Airy disc pattern. For example, the present invention could have been, or could be used, to focus the Wide Field/Planetary camera of the Hubbel Space Telescope, replacing the existing obscured small Ritchey-Chretien repeater telescopes presently utilized. Since the optical system of the present invention is taught as an unobstructed system, the contrast losses and coarsening of the Airy disc pattern would not be affected by a central obstruction. This would result in a contrast increase, as well as a smaller spot size for the Airy disc, thereby improving the resolution of the camera with respect to the main telescope.

The Afocal Variator can be used with supplemental options either in front, in back, either or both, to correct for spherical aberration, astigmatism, coma and other optical aberrations, as well as optics so positioned to achieve focal expansion or compression.

It is therefore seen that the present invention provides an optical system in which the afocal variator optical system of the present invention alters the focal length, and therefore, the power of front partially-obscured reflecting telescopical system. This modifies the front partially-obscured reflecting telescopical system as if either an infinite number of lenses had been put in the place of the afocal variator to either focally compress or expand the focal length of said telescope, or as though a substantial variable length of separation is provided between the front partially-obscured reflecting telescopical system and the rear module supporting a light-reactive material.

To summarize, the modular afocal variator module of the present invention can be positioned in any operational optical instrument between a front optical system and a rear optical system, provided that there is enough physical space to do so, and it can and will then serve to focus that instrument to some degree or another.

While the invention has been particularly shown, described and illustrated in detail with reference to preferred embodiments and modifications thereof, it should be understood by those skilled in the art that the foregoing and other modifications are exemplary only, and that equivalent changes in form and detail may be made therein without departing from the true spirit and scope of the invention as claimed, except as precluded by the prior art.

What is claimed is:

1. A modular optical system including in combination a front element module which carries an all-mirror reflective optical system and a rear system module which carries a light-reactive material, and wherein said front element module and said rear element module together define an operational optical instrument, and a module which carries a lens system, said lens system module being intermediate said front element module and said rear element module, the actual focal length of said all-mirror reflective element module carried by said front element module varied with respect to said light-reactive material carried by said rear module, without changing the length dimension of the modular optical system, without changing the length dimension of the modules, without changing the mirror or mirrors of the front module, and without changing the position of the rear module, wherein the improvement comprises: said optical system carried by said lens system module includes an afocal variator, and wherein connecting means are carried by said lens system module, whereby said lens system module, said front element module, and said rear element module can be connected in optical series.

2. The modular optical system of claim **1**, in which said front module is of such size, that said afocal variator carried by said lens system module can be optically connected in series to said front module while also being mechanically connected to said front module.

3. The modular optical system of claim **1**, wherein said all-mirror reflective element is selected from the group consisting of single-element positive reflector, single-element negative reflector, Newtonian telescopical system, Cassegrainial telescopical system, Ritchey-Chretien telescopical system or Gregorian telescopical system, all of which contain primary and secondary mirrors, said secondary mirrors partially obscuring the total amount of incoming light entering said systems.

4. The modular optical system of claim **1**, wherein said rear element module's light-reactive material is selected from any of the group consisting of a photographic plate or emulsion, a video sensor, a charged-coupled device (CCD), an image intensifier, an ultraviolet detector or sensor, an infrared detector or sensor.

5. The modular optical system of claim **2**, wherein said rear element module's light-reactive material is selected from any of the group consisting of a photographic plate or emulsion, a video sensor, a charged-coupled device (CCD), an image intensifier, an ultraviolet detector or sensor, an infrared detector or sensor.

6. The modular optical system of claim **1**, wherein said negative lens in said afocal variator optical system is a negative doublet lens.

7. The modular optical system of claim 2, wherein said negative lens in said afocal variator optical system is a negative doublet lens.

8. The optical system of claim 1, wherein the said rear element module is selected from a light-tight box, a camera or a supportive panel or screen.

9. The optical system of claim 2, wherein the said rear element module is selected from a light-tight box, a camera or a supportive panel or screen.

10. The modular optical system of claim 1, wherein said lens system module can be moved in or out of the optical axis with respect to the rear element module.

11. The modular optical system of claim 2, wherein said lens system module can be moved in or out of the optical axis with respect to the rear element module.

12. The modular optical system of claim 1, wherein said lens system module may be used alternately with another lens system module, the lens elements of which are composed of a material or materials with different refractive indices, dispersive characteristics and special transmittance from the original lens system module.

13. The modular optical system of claim 2, wherein said lens system module may be used alternately with another lens system module, the lens elements of which are composed of a material or materials with different refractive indices, dispersive characteristics and special transmittance from the original lens system module.

14. The modular optical system of claim 2, in which the front element module mirror or mirrors are maintained in permanently fixed position.

15. The modular optical system of claim 1, in which the module afocal variator is positioned in front of any of the group consisting of a flat mirror, a negative mirror, a positive mirror, a shutter device, a prism, a repeater telescope of Newtonian, Cassegrainian, Ritchey-Chretien or Gregorian or off-axis catoptric configuration an optical flat, a single positive lens, a doublet positive lens having its convex surface forward, a doublet positive lens having its convex surface rearward, a double convex doublet positive, a double concave doublet positive, a single negative lens, a doublet negative lens having its convex surface forward, a doublet negative lens having its convex surface rearward, a convex doublet negative lens, a double concave doublet negative lens, at least two spaced apart lens systems which provide a positive optical effect, and at least two spaced apart lens systems which provide a negative optical effect, all of which are positioned in front of the focal plane of the modular optical system.

16. The modular optical system of claim 2, in which the module afocal variator is positioned in front of any of the group consisting of a flat mirror, a negative mirror, a positive mirror, a shutter device, a prism, a repeater telescope of Newtonian, Cassegrainian, Ritchey-Chretien or Gregorian or off-axis catoptric configuration an optical flat, a single positive lens, a doublet positive lens having its convex surface forward, a doublet positive lens having its convex surface rearward, a double convex doublet positive, a double concave doublet positive, a single negative lens, a doublet negative lens having its convex surface forward, a doublet negative lens having its convex surface rearward, a convex doublet negative lens, a double concave doublet negative lens, at least two spaced apart lens systems which provide a positive optical effect, and at least two spaced apart lens systems which provide a negative optical effect, all of which are positioned in front of the focal plane of the modular optical system.

17. An integrated optical system including in optical series an afocal variator optical system as a module, a front element module which carries an all-mirror optical system and a rear system module which carries a light-reactive material which said front element module and rear element module together define an operational optical instrument, said integrated optical system having the ability to have its actual focal length vary without the need to physically change the length dimension of any of its said constituent optical system elements, without the need to physically change the mirror position or positions in the front element module, without the need to physically change the position of the rear module, wherein: said module afocal variator optical system element includes in optical series a first positive lens, a negative lens and a second positive lens, said negative lens being so positioned and so controlled that it is capable of being moved towards and away from said first positive lens and towards and away from said second positive lens, and wherein the distance between said first positive lens and said second positive lens of said afocal variator optical system element remains substantially constant.

18. An integrated optical system including in optical series an afocal variator optical system as a module, a front element module which carries a catadioptric optical system and a rear system module which carries a light-reactive material which said front element module and rear element module together define an operational optical instrument, said integrated optical system having the ability to have its actual focal length vary without the need to physically change the length dimension of any of its said constituent optical system elements, without the need to physically change the mirror position or positions, lens or lens positions, in the front element module, without the need to physically change the position of the rear module, wherein: said module afocal variator optical system element includes in optical series a first positive lens, a negative lens and a second positive lens, said negative lens being so positioned and so controlled that it is capable of being moved towards and away from said first positive lens and towards and away from said second positive lens, and wherein the distance between said first positive lens and said second positive lens of said afocal variator optical system element remains substantially constant.

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United States Patent [19]

Margolis

[11] **Patent Number: 5,054,896**

[45] **Date of Patent: Oct. 8, 1991**

[54] **CONTINUOUSLY FOCUSABLE MICROSCOPE INCORPORATING AN AFOCAL VARIATOR OPTICAL SYSTEM**

[75] Inventor: **H. Jay Margolis**, Boulder, Colo.

[73] Assignee: **Infinity Photo-Optical Corporation**, Boulder, Colo.

[21] Appl. No.: **342,179**

[22] Filed: **Apr. 24, 1989**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 286,307, Dec. 19, 1988, Pat. No. 4,988,173, which is a continuation-in-part of Ser. No. 169,271, May 17, 1988, abandoned.

[51] **Int. Cl.**[5] **G02B 15/00;** G02B 7/04; G02B 21/00

[52] **U.S. Cl.** **359/379;** 359/676; 359/823

[58] **Field of Search** 350/423, 518, 519, 255

[56] **References Cited**

U.S. PATENT DOCUMENTS

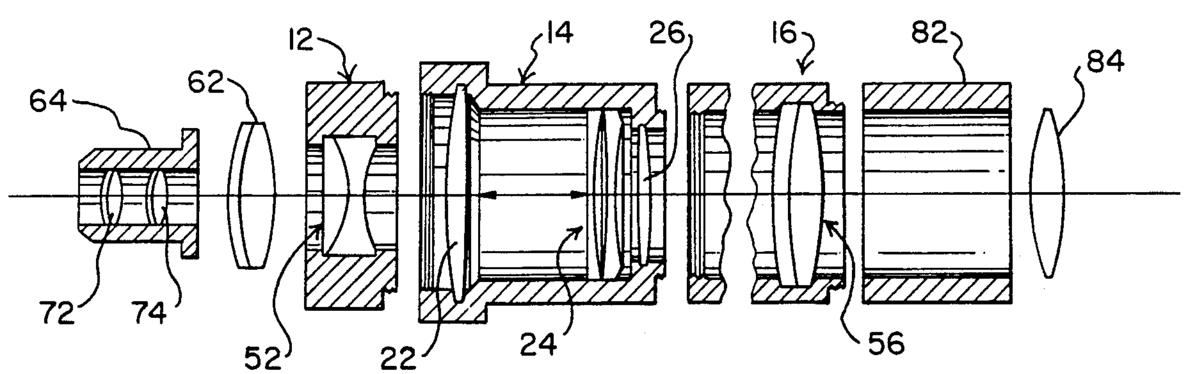
4,318,585 3/1982 Matsumura 350/518

Primary Examiner—Bruce Y. Arnold
Assistant Examiner—Rebecca D. Gass
Attorney, Agent, or Firm—Donald W. Margolis

[57] **ABSTRACT**

The combination in optical series of a microscope objective lens system with a first positive lens system, and a focusing module, all in combination with one another and with such other components as are required to provide a microscope image, allows the user of such a microscope, to continuously alter the active focal relationships of the microscope by continuously varying the afocal variator and the distance of the microscope objective lens system from the object which is undergoing examination, and all without the need to physically change the length dimension of the microscope system, and without the need to change the positions of any of the lenses outside of the afocal variator, and without the need to change the microscope objective lens. The focusing module includes, a front negative lens system, an afocal variator optical system, and a rear positive optical system. The afocal variator optical system includes in optical series a front positive lens, a negative lens, and a rear positive lens. Within the afocal variator optical system the negative lens is so positioned and so controlled that it is capable of being moved continuously either towards and away from the first positive lens and towards and away from the second positive lens, all while the distance between the first positive lens and the second positive lens of the afocal variator optical system remains substantially constant, whereby the user of such a microscope may continuously vary the focus of the microscope.

7 Claims, 1 Drawing Sheet



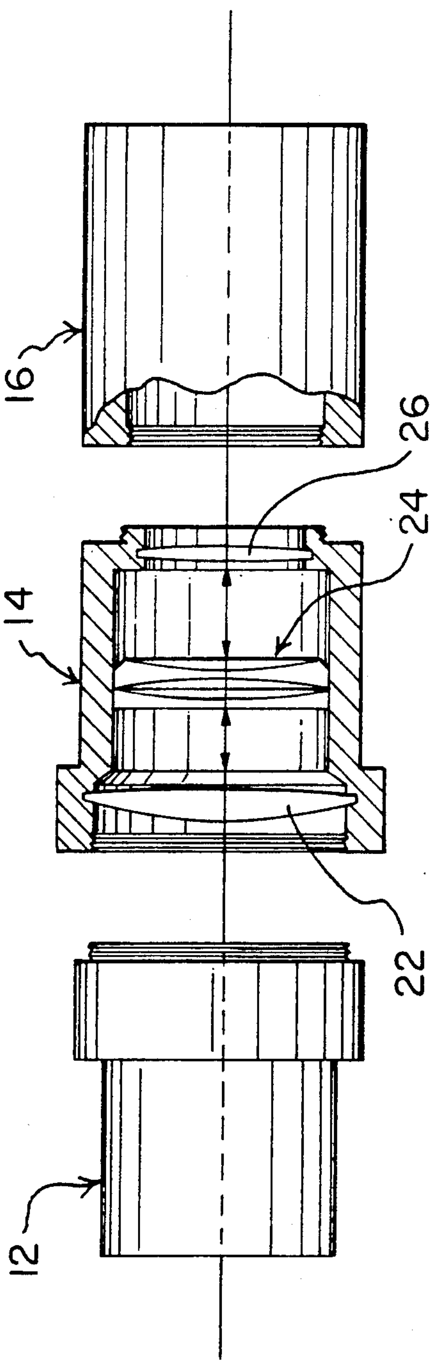


FIG. 1.-PRIOR ART

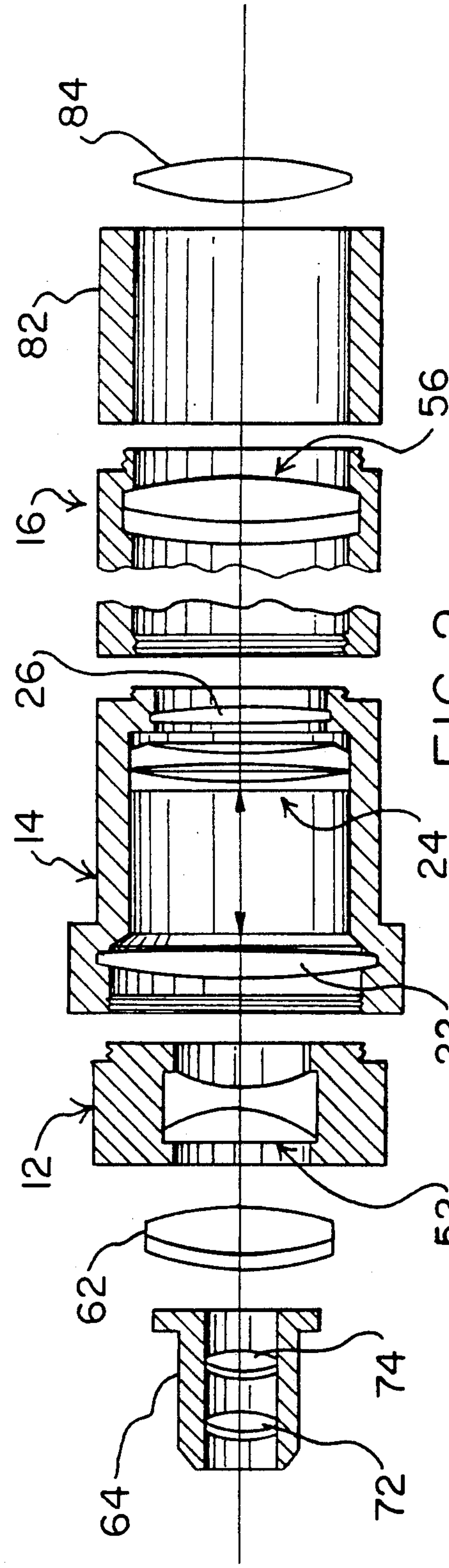


FIG. 2.

CONTINUOUSLY FOCUSABLE MICROSCOPE INCORPORATING AN AFOCAL VARIATOR OPTICAL SYSTEM

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Ser. No. 286,307 entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on Dec. 19, 1988, now U.S. Pat. No. 4,988,173 which is in turn a continuation-in-part of U.S. Pat. Application Ser. No. 169,271, also entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on May 17, 1988, and now abandoned.

BACKGROUND OF THE INVENTION

1. a) Field of the Invention

This invention relates to a continuously focusable microscope system which incorporates an afocal variator system.

2. b) Discussion of the Prior Art

Microscopes have been in use for centuries. In the past, where it has been desired to alter the focus of microscope systems, this has usually been accomplished over a short range by continuously or discretely changing the length of the optical system of the microscope, or in discrete ranges by changing the location or type of objective lens system in the front, or of any lens system which may be present in the rear, or both the front and rear optical lens systems, if any. Altering microscopical system focal length without utilizing the objective lens system, or changing the length of the optical system, or changing the location or type of lens system in either the front or rear optical system is not believed to be known in the prior art. Continuously focusable microscope systems are not known to applicant. "Varios" and "variators" are well known and useful optical systems. Such systems have found use primarily in zoom lens systems and in projectors, for example, to change the size of a projected image on a screen, but not to focus the image. In many instances, such vario and variator devices have been used, in combination with a front optical system or a rear optical system. In some instances they have even been used in combination with both a front optical system and a rear optical system. However, in all instances known to applicant such optical systems which incorporate vario and variator optical systems have been used to alter the size of an image, but not to focus the image, and are used and usually only function at relatively short back focal distances.

Afocal variators of the specific preferred type described in the present application have been known and in commercial use and on sale, by themselves, for at least fifteen years, for example for use in projector lenses to alter the size of a projected image on a screen. However, while afocal variator optical systems of the specific type disclosed herein, have been previously known in the art, such afocal variator optical systems are not known to have been previously used in the art to focus microscope systems.

In the known prior art, Hillman U.S. Pat. No. 2,937,570 discloses a telescope system in which the image forming lenses are moved in order to focus the system. That is, focusing is accomplished by moving objective lens and focusing lens, which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a portion of an afocal variator, nor by moving a portion of any other non-image forming modular optical lens system. Furthermore, this reference discloses a "formula-specific" optical system in which the lenses are all calculated and assembled to work together to form a telescope. It does not include an independent optical lens system module which is non-image forming. It does not include a central afocal variator module which does not comprise a portion of the image-forming optics. If any of the movable lenses of any of the systems taught by Hillman were removed, the entire system would be affected, very probably to the point that the system would no longer function for its intended purpose.

In Quenderff French Patent 2,572,545 the use of a zoom lens to make enlarged pictures, and also teaches the use of various art known mechanical devices for connecting together optical modules. However, it neither teaches nor suggests the use of a central afocal variator module as a focusing element.

Therefore, while afocal variator optical systems have been previously known in the art, such afocal variator optical systems are not known to have been previously used in the art to focus microscope systems in the manner disclosed, provided and claimed by the present application. More, specifically such afocal variator optical systems have not been used at a relatively long back focus distance, as opposed to their prior art use to alter image size at a fixed focal plane. It will be seen, that while the use of varios and variators, either alone, or in combination with either a front optical system or a rear optical system are known, they are not known to have been used to provide a microscope system. More specifically, the combination in optical series of a microscope objective lens system with a first positive lens system, a first negative lens system, an afocal variator, and a positive rear optical system, all in combination with one another and with such other components as are required to provide a microscope image, allows the user of such a microscope, to continuously alter the active focal relationships of the microscope by continuously varying the afocal variator and the distance of the microscope objective lens system from the object which is undergoing examination, and all without the need to physically change the length dimension of the microscope system, and without the need to change the positions of any of the lenses outside of the afocal variator, and without the need to change the microscope objective lens. This is quite different than the use of a variator system to alter image size at a fixed focal plane, such as a zoom lens.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide a continuously focusable microscope system in which an afocal variator optical system, in combination with a front and rear optical system, is incorporated to alter the active focal length, and thereby the focus of the microscope system.

It is another object of the present invention to provide a microscope system which carries an afocal variator optical system to provide a relatively long back focus distance to thereby provide a continuously focusable system.

Another object of the present invention is to provide such a microscope system which includes in optical series a microscope objective lens system, a first positive lens system; and a focusing module which consists of a front positive lens system, an afocal variator optical system, and a rear positive lens, all in combination with one another and with such other components as are required to provide a microscope image, which combination allows the user of such a microscope, to continuously alter the active focal relationships of the microscope by continuously varying the afocal variator and the distance of the microscope objective lens system from the object which is undergoing examination, and all without the need to physically change the length dimension of the microscope system, and without the need to change the positions of any of the lenses outside of the afocal variator, and without the need to change the microscope objective lens.

Another object of the present invention is to provide such a microscope system in which the focusing module includes an afocal variator which consists of a second positive lens system, and a positive rear lens system, which second positive lens system and positive rear optical system are positioned in substantially fixed spaced relation to one another, and a negative lens which is positioned between such fixed second front positive lens and such rear positive lens, and which negative lens is designed and supported in the afocal variator in such a manner that it is capable of being moved toward and away from the second front positive lens or toward and away from the rear positive lens.

It is also an object of the present invention to provide such a microscope system which has a range of magnification which varies from about 0.2 times at about 15.2 cm (6 inches) to approximately 8.5 or 9.0 times at 0.8 cm (0.3 inch), approximately a 45 to 1 ratio, and which can be effectively used at infinity.

It is another object of the present invention to provide such a microscope system having a high depth of field.

Another object of the present invention is to provide such a microscope system using such a focusing module including an afocal variator, which microscope system is simple in construction and design.

It is yet another object of the present invention to provide such systems which are simple and inexpensive to produce.

The foregoing objects of the present invention are obtained by providing a microscope system which has the ability to vary the actual focal length of the system without the need to physically change the length dimension of the microscope system, or the need to change the lens system or lens position of the front optical system or the rear optical system, if any, or the need to change the lenses of the front optical system or in the rear optical system, if any. As used throughout this application, "afocal variator optical system" shall mean an optical system which includes in optical series a positive lens (which will sometimes be referred to as the "second positive lens" or the "front positive lens"), a negative lens (which will sometimes be referred to as the "second negative lens"), and another positive lens (which will sometimes be referred to as the "third positive lens" or the "rear positive lens"). Within the afocal variator, the negative lens is so positioned and so controlled that it is capable of being moved continuously either towards and away from the front (second) positive lens and towards and away from the rear (third) positive lens, all while the distance between the front positive lens and the rear positive lens of the afocal variator optical system and the length of the afocal variator remains substantially constant. Further, as used throughout this application, the term "focusing module" shall mean an optical system which includes in optical series a negative lens system (which will sometimes be referred to as the "first negative lens"), located in optical series in front of the afocal variator and a rear positive optical system (which will sometimes be referred to as the "fourth positive lens"), which is located in optical series to the rear of the afocal variator.

In preferred embodiments of the present invention there is provided the combination, in optical series, of a microscope objective lens system, a first positive lens system, and a focusing module, all in combination with one another and with such other components as are required to provide a continuously focusable microscope image. In substantially all uses of the present invention, the components of the microscope system, and especially the components of the focusing module are substantially permanently connected together in a manner which maintains the components of the system in optical series and as a unit having a substantially fixed length. In the preferred embodiment of the present invention disclosed herein a microscope system is provided which has the ability to provide a high depth of field and to focus from infinity to about a fraction of an inch.

While not known with scientific certainty, it is believed that the present invention provides a microscope system in which the afocal variator optical system alters the focal length, and module"shall mean an optical system which includes in optical series a negative lens system (which will sometimes be referred to as the "first negative lens" , located in optical series in front of the afocal variator and a rear positive optical system (which will sometimes be referred to as the "fourth positive lens"), which is located in optical series to the rear of the afocal variator.

In preferred embodiments of the present invention there is provided the combination, in optical series, of a microscope objective lens system, a first positive lens system, and a focusing module, all in combination with one another and with such other components as are required to provide a continuously focusable microscope image. In substantially all uses of the present invention, the components of the microscope system, and especially the components of the focusing module are substantially permanently connected together in a manner which maintains the components of the system in optical series and as a unit having a substantially fixed length. In the preferred embodiment of the present invention disclosed herein a microscope system is provided which has the ability to provide a high depth of field and to focus from infinity to about a fraction of an inch.

While not known with scientific certainty, it is believed that the present invention provides a microscope system in which the afocal variator optical system alters the focal length, and therefore intercepts various focal planes of the microscope objective lens system in conjunction and combination with the fourth positive lens system. It is believed that this modifies the microscope system as if either an infinite number of lenses had been put in the place of the afocal variator optical system, or as though a substantial variable length of separation is provided between the front elements of the optical system and the rear elements of the optical system. Therefore, for example, where there is provided the combination, in optical series, of a microscope objective lens system, a first positive lens system, and a focusing module, all in combination with one another, it is believed that the change in the focal length of the microscope objective system, the first positive lens, and the front (first) negative lens in the focusing module which is caused by the afocal variator optical system provides a substantially infinite number of forward conjugate foci in combination with the rear (fourth) positive lens system, thereby providing a continuously focusable microscope system.

The system of the present invention is not formula-specific. It uses an independent non-image forming afocal variator lens system which does not comprise a portion of the image-forming optics in the microscope systems in which it is included. If the afocal variator of the present invention, which includes a movable lens for purposes of focusing the entire system, were removed in its entirety, the remaining system modules would be substantially unaffected, and the remaining system components could still function as a microscope when used at close range and with an appropriate front conjugate lens system. Therefore, the microscope systems of the present invention, without the focusing module, and in combination with a specific objective lens optical systems, could still be used as a microscope.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination, and elements as herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate complete preferred embodiments of the present invention according to the best modes presently devised for the practical application of the principles thereof, and in which:

FIG. **1** is an exploded diagrammatic view, partially broken away, which illustrates a prior art fixed length afocal variator optical system module of the present invention in which positioned between a front optical system module and a rear optical system module, for connection therewith; and

FIG. **2** is a species of FIG. **1**, shown in exploded view, is a microscope system in which a microsnrnobjective lens system, a first positive lens system, and a focusing module are in combination with one another and with such other components as are required to provide a continuously focusable microscope image.

DESCRIPTION OF THE PRIOR ART

Referring to FIG. **1** there is shown, primarily for reference purposes, the basic teaching of the parent applications, of which this application is a continuation-in-part U.S. Pat. Application Ser. No. 286,307 entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on Dec. 19, 1988, now U.S. Pat. No. 4,988,173 issued Jan. 29, 1996, which is in turn a continuation-in-part of U.S. Pat. Application Ser. No. 169,271, also entitled MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM filed by H. Jay Margolis on May 17, 1988, and now abandoned. Shown in exploded view is an optical system, generally **10** consisting of three major modular components which are designed for substantial permanent connection to one another, a front modular optical system **12**, an afocal variator modular optical system **14**, shown broken away, and a rear modular optical system **16** shown partially broken away. As illustrated, the afocal variator optical system **14** consists of a fixed length tube **20** in which there is located a front positive lens **22**, a central negative lens **24**, in this case a negative doublet, and a rear positive lens **26**. Front positive lens **22** and rear positive lens **26** are secured to tube **20** in a manner such that the distance between them is substantially fixed. However, negative lens **24** is located within tube **20** and constructed in such a manner that it can be moved continuously within tube **20** up and back between front lens **22** and rear lens **26**. That is, negative lens **24** is capable of being moved towards and away from front lens **22** and is also capable of being moved towards and away from rear lens **26**.

The foregoing is made possible by the system for holding the lenses of the afocal variator optical system **14**. This holding system may consist of tube **20**, as shown, or of any other lens holding system, such as a lens positioning platform system of the type that is well known in the art, or the like. As shown, tube system **20** includes front connecting means, in this case a series of female threads **28** and rear connecting means, in this case a series of male threads **30**, to which front optical system **12** and rear optical system **16** can be appropriately connected by means of their own respective male and female thread connectors **32** and **34**. Negative lens **24** may be moved within tube **20** by a linear slider, a helical slider, or by any other art known means for providing continuous linear motion to a lens. While not preferred in the practice of the present invention, both front optical system module **12** and rear optical module system **16** may carry substantially any known lens system.

The combination of an afocal variator optical system module **14** with a front optical system module **12**, as taught by the parent applications, is believed to have the unique feature of altering or varying the actual focal length of front optical system **12**, whether in the form of a real image, as provided by a positive lens, or in the form of a virtual image as provided by a negative lens. The resulting variation of the focal length effects the convergence or divergence of the light which enters rear optical system **16**, and therefore of the light (or image) which exits from rear optical system **16**. This allows the focus of the system to be changed without changing the length of the overall system or of any modular element in the system, and without changing the lenses in the front or rear modular system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Now referring to FIG. **2**, there is shown the present invention in which the system serves as a continuously focusable microscope having a wide range of magnification and a high depth of field. In this species, afocal variator optical system module **14** is substantially the same as that shown in FIG. **1**, although negative lens **24** is shown located substantially adjacent rear positive lens **26**. In this system, afocal variator optical system module **14** is connected to a front optical system **12** which includes a negative achromat doublet **52**, while rear optical system **16** includes a positive achromat **56**, also in the form of a doublet. Together, front optical system **12** including negative achromat doublet **52**, afocal variator optical system **14**, and rear optical system **16** including positive achromat **56** form the "focusing module". Located in front of front optical system **12** is a positive lens, in this case a positive achromat doublet **62**, while in front of that is a microscope objective lens system **64**. Objective lens system **64** consists in this example of a pair of positive achromat doublets **72** and **74**, although substantially any objective lens system may be used in this system. Elements **82** and **84**, representative of a tube and an eye piece lens, respectively, are also illustrated; however any other art known elements may be provided to complete the microscope.

In one preferred embodiment of the present invention front optical system **12** includes a front lens **52** of about −109, a positive achromat doublet **62** of about +50 mm, and an objective lens system **64** with about a 10 mm focal length, and rear optical system **16** including a conjugate lens **56** of about +75, provides about a 260 mm tube-length behind rear optical system **16**, forming an intermediary image in the plane at that distance. The system of FIG. **2** using the elements just described has been found to allow focusing from infinity to about 0.8 cm (0.3 inch) with a final primary magnification of about 8.5 or 9.0 times, while providing, even at the closest focus, a substantial depth of field.

In this specific embodiment, as in the copending applications of applicant, the afocal variator optical system acts as though it is changing the distance between the front lens systems and the rear lens systems without any actual change in the length dimension of the system. It also provides the ability to choose between four variables for the best effects of each, such as magnification, depth of field, working distance and resolution. The back focal length can vary but is approximately 260 mm from the rear of rear lens system **16** to the image plane of the microscope. The back focal length is so long it can be adapted to interface with substantially any observation tube or observation means now known. As described above, one of the ranges of magnification varies from 0.2 times at 6 inches to approximately 8.5 or 9.0 times at 8 mm, thereby providing approximately a 1 to 45 ratio of magnification in that range. The ratio can be increased if used at an initial longer stand off distance, and focus can be achieved at distances greater than 6 inches, and in fact to infinity.

While not shown in FIG. **2**, the addition of art known diaphragms between the afocal variator optical system **14** and positive achromat lens **56** in rear optical system **16** will enhance the ability of the system to obtain an excellent depth of field and control aberrations. Unlike so many other microscope systems, the optical systems of the present invention which are combined with the afocal variator do not appear to be limited, other than by compatibility, by the material from which the lenses are composed, the refractive indices of the lenses, the light dispersive characteristics of the lenses, or the radii of the lenses.

It is therefore seen that the present invention provides a continuously focusable microscope system in which an afocal variator optical system, in combination with a front and rear optical system forms a focusing module which may be incorporated to alter the active focal length, and thereby the focus of microscope system to provide a relatively long back focus distance, and a continuously focusable system. The microscope system of the present invention includes in optical series a microscope objective lens system, a first positive lens system, and a focusing module which consists of a front negative lens system, an afocal variator optical system, and a rear positive lens, all in combination with one another and with such other components as are required to provide a microscope image. This combination of optical elements and systems allows the user of such a microscope, to continuously alter the active focal relationships of the microscope by continuously varying the afocal variator and the distance of the microscope objective lens system from the object which is undergoing examination, and all without the need to physically change the length dimension of the microscope system, and without the need to change the positions of any of the lenses outside of the afocal variator, and without the need to change the microscope objective lens. The microscope system of the present invention is found to provide an exceptionally high depth of field. The microscope system of the present invention is simple in construction and design and inexpensive to produce.

While the invention has been particularly shown, described and illustrated in detail with reference to preferred embodiments and modifications thereof, it should be understood by those skilled in the art that the foregoing and other modifications are exemplary only, and that equivalent changes in form and detail may be made therein without departing from the true spirit and scope of the invention as claimed, except as precluded by the prior art.

What is claimed is:

1. A microscope system which includes an afocal variator, comprising, in optical series:

means for providing a microscope objective lens system;

means for providing a positive lens system for use as a microscope objective; and

a focusing module, wherein said focusing module includes, in optical series, a front negative lens system, an afocal variator, and a rear portion lens system, wherein said afocal variator carried by said focusing module includes in optical series a first positive lens, a negative lens, and a second positive lens, and wherein further said negative lens within said afocal variator is so positioned and so controlled that it is capable of being moved continuously towards and away from said first positive lens, and towards and away from said second positive lens, all while the distance between said first positive lens and said second positive lens of said afocal variator remains substantially constant.

2. The optical system of claim **1** wherein said negative lens in said afocal variator optical system is a negative doublet lens.

3. The optical system of claim **1**, wherein said front negative lens system is a negative achromat doublet.

4. The optical system of claim **3**, wherein said rear positive lens system is a positive achromat doublet.

5. The optical system of claim **4**, wherein said positive lens system is a positive achromat doublet.

6. The optical system of claim **1**, wherein said rear positive lens systems is a positive achromat doublet.

7. The optical system of claim **1**, wherein said positive lens system which is in optical series intermediate said microscope objective lens system and said focusing module is a positive achromat doublet.

* * * * *

United States Patent [19]
Margolis
[11] Patent Number: 4,988,173
[45] Date of Patent: Jan. 29, 1991

[54] MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM

[76] Inventor: **H. Jay Margolis**, 704 Mohawk Dr., #15, Boulder, Colo. 80303

[21] Appl. No.: **286,307**

[22] Filed: **Dec. 19, 1988**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 169,271, Mar. 17, 1988, abandoned.

[51] **Int. Cl.**[5] **G02B 15/02**; G02B 15/15
[52] **U.S. Cl.** **350/423**; 350/422
[58] **Field of Search** 350/423, 422, 464

[56] **References Cited**

U.S. PATENT DOCUMENTS

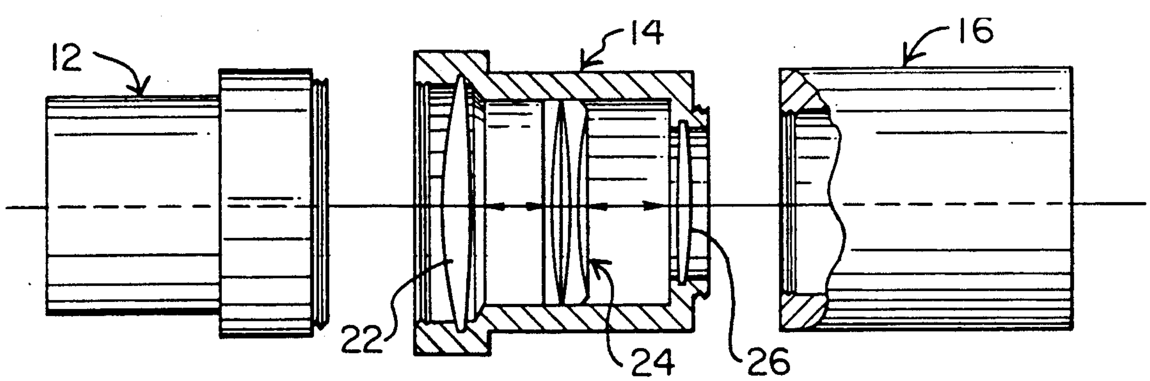
4,426,135 1/1984 Hashiya 350/422

Primary Examiner—Bruce Y. Arnold
Assistant Examiner—Rebecca D. Gass
Attorney, Agent, or Firm—Donald W. Margolis

[57] **ABSTRACT**

A modular optical system is provided in which a central element which carries an afocal variator optical system is provided, and to which central element both a front optical system and a rear optical system can be substantially permanently connected in optical series in combination. The modular optical system has the ability to vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension or the lens position or the lenses of the front optical system. The afocal variator optical system includes in optical series a first positive lens, a negative lens, and a second positive lens. Within the afocal variator optical system the negative lens is so positioned and so controlled that it is capable of being moved continuously either towards and away from the first positive lens and towards and away from the second positive lens, all while the distance between the first positive lens and the second positive lens of the afocal variator optical system remains substantially constant. The afocal variator optical system is located and supported by a system which includes front and rear end connecting means for substantially permanently connecting it with the front optical system and rear optical system, respectively. Means are also provided in conjunction with the front optical system and the rear optical system to allow their susbstantially permanent connection to the afocal variator support system.

18 Claims, 1 Drawing Sheet



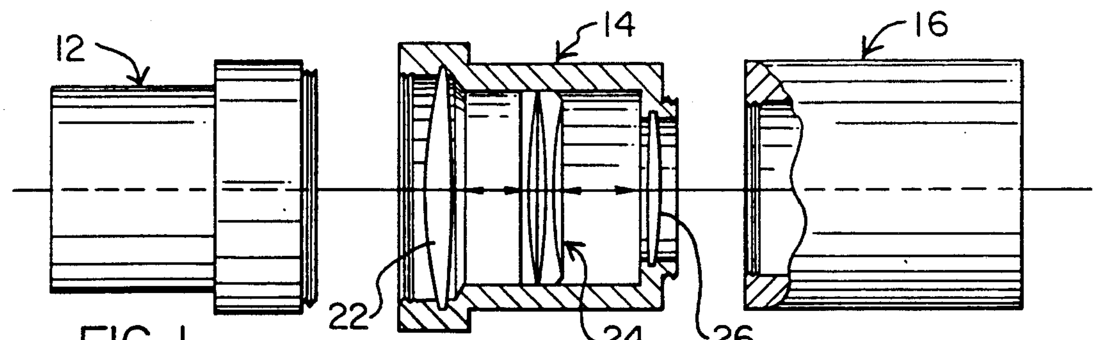


FIG. 1.

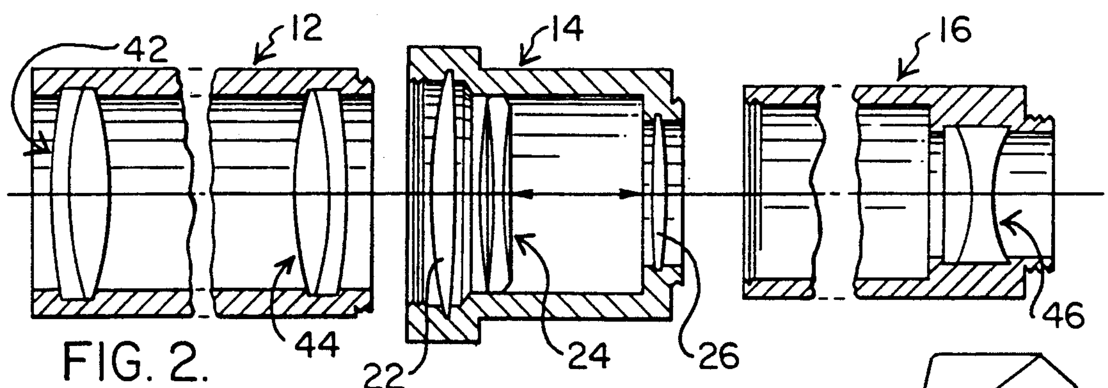


FIG. 2.

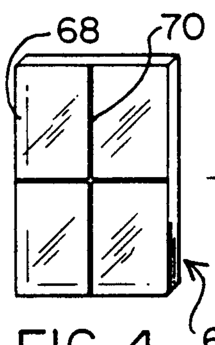


FIG. 4.

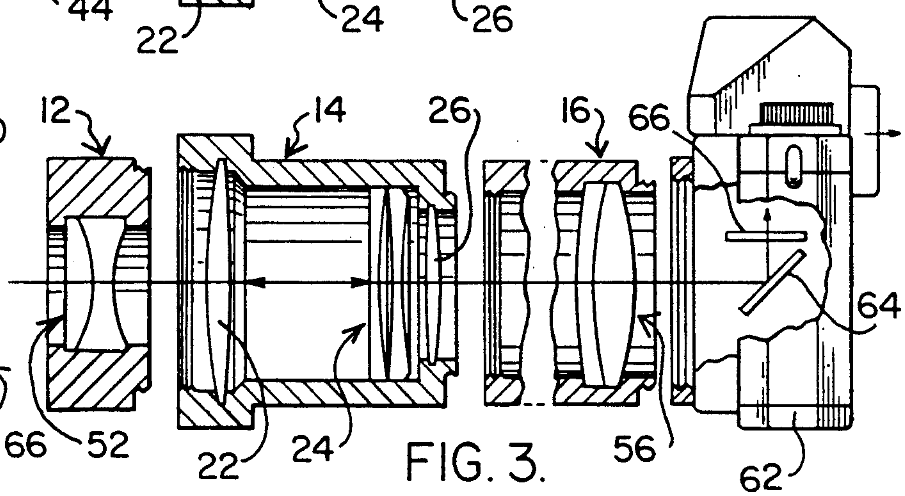


FIG. 3.

MODULAR AFOCAL VARIATOR OPTICAL FOCUSING SYSTEM

This is a continuation-in-part of application Ser. No. 169,271 filed Mar. 17, 1988, now abandoned.

BACKGROUND OF THE INVENTION

(a) Field of the Invention

This invention relates to a modular optical imaging system. More specifically it relates to such a system in which a central element which carries an afocal variator optical system is provided, and to which central element both a front optical system and a rear optical system can be substantially permanently connected in combination to vary the actual focal length of the front optical system in conjunction with the rear optical system without the need to physically change the length dimension of any system, or without the need to change the lens position, or without the need to change lenses of the front or rear optical systems.

(b) Discussion of the Prior Art

"Varios" and "variators" are well known and useful optical systems. Such systems have found use primarily in zoom lens systems and in projectors, for example, to change the size of a projected image on a screen, but not to focus the image. In many instances, such vario and variator devices have been used, in combination with a front optical system or a rear optical system. In some instances they have even been used in combination with both a front optical system and a rear optical system. However, in all known instances such optical systems which incorporate vario and variator optical systems have been used to alter the size of an image but not to focus the image, and are used and usually only function at relatively short back focal distances.

Afocal variators of the specific type described in the present application have been known and in commercial use and on sale, by themselves, for at least fifteen years, for example for use in projector lenses to alter the size of a projected image on a screen. However, while afocal variator optical systems of the specific type disclosed herein, have been previously known in the art, such afocal variator optical systems are not known to have been previously used in the art to focus optical systems in the manner disclosed, provided and claimed by the present application, as opposed to the prior art use to alter image size at a fixed focal plane.

It is thus seen that while the use of varios and variators, either alone, or in combination with either a front optical system or a rear optical system are known, they are not known to have been used in combination with both a front optical system and a rear optical system to alter active focal length so as to act as a focusing system as opposed to a system for altering image size at a fixed focal plane, such as a zoom lens.

In the past where it has been desired to alter focal length, this has usually been accomplished by continuously or discretely changing the length of the optical system, or by changing the location or type of imaging lenses in the front or rear, or in both front and rear optical systems. Altering focal length without utilizing the imaging lens system, or changing the length of the optical system, or changing the location or type of lenses in either the front or rear optical system has not been known in the prior art.

In the known prior art, Hillman U.S. Pat. No. 2,937,570 discloses a telescope system in which the image forming lenses are moved in order to focus the system. That is, focusing is accomplished by moving objective lens and focusing lens, which are part of the telescope's "formula-specific" objective imaging system. Focusing is not accomplished or taught to be feasible by moving a portion of an afocal variator, nor by moving a portion of any other non-image forming modular optical lens system. Furthermore, this reference discloses a "formula-specific" optical system in which the lenses are all calculated and assembled to work together to form a telescope. It does not include an independent optical lens system module which is non-image forming. It does not include a central afocal variator module which does not comprise a portion of the image-forming optics. If any of the movable lenses of any of the systems taught by Hillman were removed, the entire system would be affected, very probably to the point that the system would no longer function for its intended purpose.

Quenderff French Patent No. 2,572,545 the use of a zoom lens to make enlarged pictures, and also teaches the use of various art known mechanical devices for connecting together optical modules. However, it neither teaches nor suggests the use of a central afocal variator module as a focusing element.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide an optical system in which an afocal variator optical system alters the active focal length of a front optical system in combination with a rear optical system.

It is another object of the present invention to provide a central element which carries an afocal variator optical system, to which central element both a front optical system and a rear optical system can be substantially permanently connected in combination.

Another object of the present invention is to provide such a central element which carries an afocal variator optical system which consists of a front positive lens and a rear positive lens which are positioned in substantially fixed spaced relation to one another, and a negative lens which is positioned between such fixed front positive and rear positive lenses, and which negative lens is designed and supported in the central element in such a manner that it is capable of being moved toward and away from the front positive lens or toward and away from the rear positive lens.

Another object of the present invention is to provide such a central element which is simple in construction and design and which lends itself to the substantially permanent attachment of both a front optical system and a rear optical system.

It is yet another object of the present invention to provide an element which carries an afocal variator optical system, which element has the capability of allowing the substantially permanent connection to it, in combination, of a front optical system and a rear optical system.

It is also an object of the present invention to provide such an optical system with the ability to focus from infinity to about 3 cm (1.2 inches).

It is another object of the present invention to provide such an optical system having a high depth of field.

It is yet another object of the present invention to provide a optical system which provides both the ability to focus from infinity to about 3 cm (1.2 inches) and the ability to provide a high depth of field.

It is yet another object of the present invention to provide such systems which are simple and inexpensive to provide.

The foregoing objects of the present invention are obtained by providing a modular optical system which has the ability to vary the actual focal length of a front optical system in combination with a rear optical system, without the need to physically change the length dimension, or the need to change the lens position of the front or rear optical system, or the need to change the lenses of the front or rear optical system. In preferred embodiments this is accomplished by the provision of a central element which carries an afocal variator optical system which includes in optical series a first positive lens, a negative lens, and a second positive lens; a front lens system located in optical series in front of the first positive lens of the afocal variator and in substantially permanent attachment to the central element, and a rear optical system located in optical series to the rear of the second positive lens of the afocal variator and in substantially permanent attachment to the central element. Within the afocal variator, the negative lens is so positioned and so controlled that it is capable of being moved continuously either towards and away from the first positive lens and towards and away from the second positive lens, all while the distance between the first positive lens and the second positive lens of the afocal variator optical system and the length of the central element remains substantially constant. In substantially all instances of the present invention, the afocal variator optical system is located and supported by a central element system which includes front end connecting means for substantially permanently connecting with the front optical system and rear end connecting means for substantially permanently connecting with the rear optical system. In a similar manner, means are provided in conjunction with the front optical system and in conjunction with the rear optical system to allow their substantially permanent connection to the central element.

In one preferred embodiment of the present invention an optical system is provided which may be used as either a long range microscope or as a telescope and which has the ability to provide a high depth of field and to focus from infinity to about 3.2 cm. This is accomplished by providing the optical system of the present invention with a front optical system having a negative lens and a rear optical system having a positive lens.

In another preferred embodiment an optical system is provided which may be used as a telescope. This is accomplished by providing the optical system of the present invention with a front optical system having a positive lens and a rear optical system having a negative lens.

It is therefore seen that the present invention provides an optical system in which the afocal variator optical system of the present invention alters the focal length, and therefore the power of the front optical systems by altering its focal length, either individually, or in combination with a rear optical system. This modifies the optical system as if either an infinite number of lenses had been put in the place of the afocal variator optical system, or as though a substantial variable length of separation is provided between the front optical system and the rear optical system. Therefore, for example, where the front optical system is a positive lens system, and the rear optical system is a negative lens system, the change in the focal length of the positive lens system by the afocal variator optical system provides substantially an infinite number of forward conjugate foci with respect to the rear negative lens system, thereby providing a focusable telescope system.

The system of the present invention uses an independent non-image forming modular optical afocal variator lens system which does not comprise a portion of the image-forming optics in the modular optical systems in which it is included. The system of the present invention is not formula-specific. If the afocal variator of the present invention, which includes a movable lense for purposes of focusing the entire system, were removed in its entirety, the remaining system modules would be substantially unaffected, and the remaining system components would still function for their intended purpose.

The afocal variator module of the present invention can be put into substantially any optical system into which it can be physically fit with substantial disregard for formula specificity. If the afocal variator module were to be removed from the modular optical systems of the present invention, it would not substantially change the characteristics of the optical system in which it had formerly been placed. For example, where the afocal variator module is positioned in a telescope between a front negative lens system and a rear positive lens system it can be used to focus the telescope. However, if the afocal variator lens system of the present invention were to be removed from the telescope the remaining system would still function as a telescope.

It is therefore seen that the present invention provides a modular system in which an afocal variator optical system module, including means for substantially permanently connecting a front optical system module, and means for substantially permanently connecting a rear optical system module.

These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description, showing the contemplated novel construction, combination, and elements as herein described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiments of the herein disclosed invention are meant to be included as coming within the scope of the claims, except insofar as they may be precluded by the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate complete preferred embodiments of the present invention according to the best modes presently devised for the practical application of the principles thereof, and in which:

FIG. 1 is an exploded diagrammatic view, partially broken away, which illustrates the present invention in which a fixed length afocal variator optical system module is positioned between a front optical system module and a rear optical system module, for substantially permanent connection therewith;

FIG. 2 is a species of FIG. 1, shown in exploded view, in which the front optical system module carries a pair of spaced apart positive achromats and the rear optical system module carries a negative achromat;

FIG. 3 is yet another species of FIG. 1, shown in exploded view, in which the front optical system module carries a negative lens and the rear optical system module carries a positive achromat which is shown in association with a reflex camera body which includes a reflecting element and a clear screen with a reference reticle; and

FIG. 4 is an enlarged top perspective view of the clear screen of FIG. 3 showing one form of reference reticle.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 there is shown in exploded view an optical system, generally 10 consisting of three major modular components which are designed for substantial permanent connection to one another, a front modular optical system 12, an afocal variator modular optical system 14, shown broken away, and a rear modular optical system 16 shown partially broken away. As illustrated, the afocal variator optical system 14 consists of a fixed length tube 20 in which there is located a front positive lens 22, a central negative lens 24, in this case a negative doublet, and a rear positive lens 26. Front positive lens 22 and rear positive lens 26 are secured to tube 20 in a manner such that the distance between them is substantially fixed. However, negative lens 24 is located within tube 20 and constructed in such a manner that it can be moved continuously within tube 20 up and back between front lens 22 and rear lens 26. That is, negative lens 24 is capable of being moved towards and away from front lens 22 and is also capable of being moving towards and away from rear lens 26. All of this is made possible by the system for holding the lenses of the afocal variator optical system 14. This holding system may consist of tube 20, as shown, or of any other lens holding system, such as a lens positioning platform system of the type that is well known in the art, or the like As shown, tube system 20 includes front connecting means, in this case a series of female threads 28 and rear connecting means, in this case a series of male threads 30, to which front optical system 12 and rear optical system 16 can be appropriately connected by means of their own respective male and female thread connectors 32 and 34.

Negative lens 24 may be moved within tube 20 by a linear slider, a helical slider, or by any other art known means for providing continuous linear motion to a lens.

Both front optical system module 12 and rear optical module system 16 may carry substantially any known lens system. They may include an optical flat, a single positive lens, a doublet positive lens having its convex surface forward, a doublet positive lens having its convex surface rearward, a double convex doublet positive, a double concave doublet positive, a single negative lens, a doublet negative lens having its convex surface forward, a double negative lens having its convex surface rearward, a double convex doublet negative lens, a double concave doublet negative lens, two or more spaced apart lens elements which provide a positive optical effect, and two or more spaced apart lens elements which provide a negative optical effect.

The combination of an afocal variator optical system module 14 with a front optical system module 12, as taught by the present inventor, has the unique feature of altering or varying the actual focal length of front optical system 12, whether in the form of a real image, as provided by a positive lens, or in the form of a virtual image as provided by a negative lens. The resulting variation of the focal length effects the convergence or divergence of the light which enters rear optical system 16, and therefore of the light (or image) which exits from rear optical system 16. This allows the focus of the system to be changed without changing the length of the overall system or of any modular element in the system, and without changing the lenses in the front or rear modular system.

In one preferred embodiment, front positive lens 22 and rear positive lens 26 of the afocal variator optical system 14 are, for example, each about +160 mm lenses, while the negative lens 24 is about a −80 mm doublet. The movement of negative lens 24 up and back between front positive lens 22 and rear positive lens 26 alternatively increases or decreases the effective focal length of the optical system. In the example illustrated and just described, the effective focal length can be made to vary from a factor of about 0.8, when negative lens 24 is at its closest point adjacent to front lens 22, to a factor of about 1.3 when negative lens 24 is at its closest point adjacent to rear lens 26. When negative lens 24 is halfway between front positive lens 22 and rear positive lens 26 of equivalent power, the afocal variator system has a relative factor of 1.0. It is therefore seen that, in the system which has just been detailed, the movement of negative lens 24 within afocal variator optical system 14 operates to provide an analog to an increased or decreased virtual image without varying the length of the afocal variator system, without the need to physically change the length dimension of either the front or the rear module system, or without the need to change the lens position, or without the need to change the lenses of the front or rear optical module systems.

Positioning afocal variator optical system 14 between front and rear optical systems 12 and 16, serves to optically separate front optical system 12 and rear optical system 16. When negative lens 24 within the afocal variator optical system is moved, this provides an optical analog of a change in the distance between front optical system 12 and rear optical system 16. However, this is accomplished without the actual physical change in the distance between front optical system 12 and rear optical system 16 toward and away from one another. The result is that the focus of the combined front optical system 12, afocal variator optical system 14, and rear optical system 16 is effectively alterable without changing the length dimension or distance between any module.

Now referring to FIG. 2, a specific preferred embodiment of the present invention is provided. In this species, afocal variator optical system 14 is substantially the same as that shown in FIG. 1, although negative lens 24 is shown located substantially adjacent front positive lens 22. In the system of FIG. 2. front optical system 12 is shown as including two spaced apart doublet achromats 42 and 44. Also in this embodiment, rear optical system 16 is shown as including a negative achromat 46, in the form of a doublet which consists of a plano/concave lens having its concave surface rearwardly facing.

The system of FIG. 2 functions as a telescope, enlarging distant objects as viewed through rear optical system 16. The afocal variator optical system 14 alters the effective focal length of the light passing through lenses 42 and 44 with respect to rear lens 46. This is due to the fact that in this embodiment the afocal variator optical system provides a rear focal plane at a predetermined position. As the rear conjugate focal plane is held constant the front conjugate focus will vary accordingly, thereby allowing the afocal variator optical system to act essentially as a fixed length internal focusing device. Therefore, for example, in the embodiment of FIG. 2, where the rear lens 46 is a negative achromat of about −109 mm, the telescope has ability to focus from about 2.4 meters (8 feet) to about 50.8 cm (20 inches).

Now referring to FIG. 3, there is shown yet another variation of the present invention in which the system can serve as either a close focusing telescope or as a long working distance microscope. In this species, afocal variator optical system module **14** is substantially the same as that shown in FIG. **1**, although negative lens **24** is shown located substantially adjacent rear positive lens **26**. In this system, afocal variator optical system module **14** is substantially permanently connected to a front optical system **12** which includes a negative achromat doublet **52**, while rear optical system **16** includes a positive achromat **56**, also in the form of a doublet. Using a rear conjugate of about 180 mm, the system of FIG. **3** has been found to allow focusing from infinity to approximately 3.2 cm (1.2 inches), while providing, even at the closest focus, a substantial depth of field.

While not shown in FIG. 3, the addition of art known diaphragms between the afocal variator optical system **14** and positive achromat lens **56** in rear optical system **16** will enhance the ability of the system to obtain an excellent depth of field. In one specific embodiment of the system of FIG. **3**, an afocal variator having the lens types described above is utilized, while the front optical system **12** includes a front negative lens of about −109 mm and lens **56** in rear optical system **16** is a positive 75 mm lens. Again, in this modification, the afocal variator optical system acts as though it is changing the distance between the front lens systems and the rear lens systems without any actual change in the length dimension of the system. Utilizing lenses of this type and magnitude it is found that the system of FIG. **3** has the ability to focus from about infinity to about 1.25 inches (3.1 cm), and also to provide a substantial depth of field.

As further illustrated in FIG. **3**, this form of the lens system of the present invention is shown in association with a to-be-focused apparatus, in this case reflex camera **62**. For use in focusing, camera body **62** includes diverting reflector **64** and reticle **66** in the optical path. In this instance reticle **66** consists of a transparent screen **68** carrying cross-hairs **70** on its top surface, in this case of the type shown in additional detail in FIG. **4**.

The foregoing is applicable to any form of reflex camera or other through the lens focusing apparatus. Diverting reflector **64** may be a mirror or any equivalent reflecting device. While reference reticle **68** is shown in the form of a cross-hair, other forms of reticle may be used.

This application of the present invention in conjunction with a reticle equipped apparatus, such as reflex camera **62**, permits positive, accurate and definite focusing to be determined aerially by eye by the user in visible light, or by sensors known in the art for visible and non-visible light wavelengths in conjunction with embodiments of the invention which can be equated to any known focal length commonly used in photography or electronic imaging. This is possible using optical devices of the present invention, which include an intermediate afocal variator, because the focal lengths of such devices change significantly enough for focus to be observed quickly and positively as an aerial image in the viewfinder of the camera. By comparison, in the prior art, using conventionally-focusing optical systems, such a reflex camera utilizes a translucent screen, such as a ground glass, to act as a plane of common reference with the non-reflex image or film plane. Because of the ability of the optical system of the present invention to focus quickly by substantial focal length variator, no such translucent screen is required to act as a plane of common reference. Aerial image focusing of equipment using a modular afocal variator optical focusing system equipped optical systems described herein, provides a brighter (non-diffused) image to the user, thereby resulting in the ability of a user to quickly and positively determine focus, even under adverse low-light conditions.

Conventionally focusing lenses of standard or wide-angle focal length (e.g., for the 35 mm format, of 28 mm or 50 mm focal length) are substantially impossible to focus aerially with a positive assurance of accuracy. Some photographic optics, particularly of long focal length type, such as telephoto lens systems, can be approximately focused aerially, at distances other than near infinity or infinity itself; however, the small tolerance of focus observed through such conventionally-focusing optics are not accurate or reliable. Therefore, it has been the practice in the art, to use additional aids such as microprisms, anamorphic cylinders or split-image wedges for reliable focusing.

To summarize, the modular afocal variator module of the present invention can be positioned in any operational optical instrument between a front optical system and a rear optical system, provided that there is enough physical space to do so, and it can and will then serve to focus that instrument to some degree or another.

Unlike so many other optical systems, the optical systems of the present invention which are combined with the afocal variator do not appear to be limited, other than by compatibility, by the material from which the lenses are composed, the refractive indices of the lenses, dispersive characteristics, or the radii of the lenses. While threaded connections between the modular optical systems have been shown, any other art known connecting system, such as bayonet connectors, slip rings, set pins, dovetail, flange and the like may be used to provide the substantially permanent connections between the modules.

While the present invention has been shown and described with respect to specific variations, its principles have many other uses. These uses include the use of the system of the present invention as a replacement bellows for photographic cameras, a focuser for microscope cameras, for optical range finding, as a focuser for standard, compound and stereo microscopes to provide effective changes of tube length, without actual changes in the length dimension; as an adapter for parfocalization to allow a portion of one type of microscope and its tube accessories to be coupled with another portion of another microscope as a focuser for telephoto lenses, as a focuser for light in a microscope or other illumination system, and as a focuser of microscopes and other condensing systems.

It is therefore seen that the present invention provides a an optical system in which a specific form of afocal variator optical system alters the active focal length of a front optical system in combination with a rear optical system. It also provides a central element which carries an afocal variator optical system, to which central element both a front optical system and a rear optical system can be substantially permanently connected in combination. It further provides such a central element which carries an afocal variator optical system which consists of a front positive lens and a rear positive lens which are positioned in substantially fixed spaced relation to one another, and a negative lens which is positioned between such fixed front positive and rear positive lenses, and which negative lens is designed and supported in such a manner that it is capable of being moved toward and away from the front positive lens or toward and away from the rear positive lens. Furthermore it provides such a central element which is simple in construction and design and which lends itself to and has the capability of allowing the substantially permanent attachment, in combination, of both a front optical system and a rear optical system. Furthermore it has the capability of providing an optical system which provides both the ability to focus from infinity to about 3 cm and the ability to provide a high depth of field. Such systems may be simple and inexpensive to provide.

While the invention has been particularly shown, described and illustrated in detail with reference to preferred embodiments and modifications thereof, it should be understood by those skilled in the art that the foregoing and other modifications are exemplary only, and that equivalent changes in form and detail may be made therein without departing from the true spirit and scope of the invention as claimed, except as precluded by the prior art.

What is claimed is:

1. A modular optical system including in combination a front element module which carries a lens system and a rear element module which carries a lens system, said front element module and said rear element module together define an operational optical instrument, and a central element module which carries a lens system, said central element module being intermediate said front element module and said rear element module, said modular optical system has the ability to have the actual focal length of said lens system carried by said front element module varied in conjunction with said lens system carried by said rear lens system module wherein the improvement comprises:

said optical system carried by said central element module carries an afocal variator, and wherein connecting means are carried by said central element module, said front element module and said rear element module, whereby said element modules can be connected in optical series.

2. The modular optical system of claim 1, wherein said afocal variator carried by said central element module includes in optical series a first positive lens, a negative lens, and a second positive lens, and wherein further said negative lens within said afocal variator is so positioned and so controlled that it is capable of being moved continuously towards and away from said second positive lens, all lens, and towards and away from said second positive lens. All while the distance between said first positive lens and said second positive lens of said afocal variator remains substantially constant.

3. The modular optical system of claim 2, wherein said negative lens in said afocal variator is a negative doublet lens.

4. The modular optical system of claim 1, wherein said central element module includes front end connecting means and rear end connecting means for connecting said central element module with said front element module and with said rear element module, respectively.

5. The optical system of claim 1, wherein said front lens system which is carried by said front element module and said rear lens system which is carried by said rear element module are each selected from the group consisting of an optical flat, a single positive lens, a doublet positive lens having its convex surface forward, a doublet positive lens having its convex surface rearward, a double convex doublet positive, a double concave doublet positive, a single negative lens, a doublet negative lens having its convex surface forward, a doublet negative lens having its convex surface rearward, a convex doublet negative lens, a double concave doublet negative lens, a lens system which is comprised of two or more spaced apart lenses which together provide a positive optical effect, and a lens system which is comprised of two or more spaced apart lenses which together provide a negative optical effect.

6. The optical system of claim 1, wherein other focusable optical equipment is present, and said rear element module includes rear end connecting means, and is connected to said other optical equipment by said rear end connecting means; whereby, said optical system of claim 12 is capable of quick aerial focusing of such other focusable optical equipment.

7. The optical system of claim 6, wherein said other focusable optical equipment is a reflex camera body.

8. The optical system of claim 7, wherein said reflex camera body includes a reflecting element and a reticle in optical series with said rear element module.

9. An integrated optical system including in optical series an afocal variator as a central element, a front optical system element containing at least one lens and a rear optical system element containing at least one lens, said front optical system and said rear optical system together define a substantially operational optical system, said integrated optical system having the ability to have its actual focal length vary, wherein:

said afocal variator central element includes in optical series a first positive lens, a negative lens and a second positive lens, said negative lens being so positioned and so controlled that it is capable of being moved towards and away from said first positive lens and towards and away from said second positive lens, and wherein the distance between said first positive lens and said second positive lens of said afocal variator element remains substantially constant.

10. The modular optical system of claim 9, wherein said negative lens in said afocal variator central element is a negative doublet lens.

11. The optical system of claim 9 wherein said afocal variator central element includes a front end and a rear end, and means for connecting are included in combination with said afocal variator central element front end and rear end for connecting said afocal variator central element with said front optical system element and with said rear optical system element.

12. The optical system of claim 11 wherein said means for connecting said front of said central afocal variator element to said front optical system element and with said rear optical system element is selected from the group consisting of a cylindrical female thread, a cylindrical male thread, bayonet connectors, slip rings, set pins, dovetail connectors, and flange connectors.

13. The modular optical system of claim 9, wherein said central element includes front end connecting means and rear end connecting means for substantially permanently connecting said central element with said front optical system element and said rear optical system element, respectively.

14. The optical system of claim 9 wherein said front optical system element and said rear optical system

element are each selected from the group consisting of an optical flat, a single positive lens, a doublet positive lens having its convex surface forward, a doublet positive lens having its convex surface rearward, a double convex doublet positive, a double concave doublet positive, a single negative lens, a doublet negative lens having its convex surface forward, a doublet negative lens having its convex surface rearward, a convex doublet negative lens, a double concave doublet negative lens, a lens system which is comprised of two or more spaced apart lenses which together provide a positive optical effect, and a lens system which is comprised of two or more spaced apart lenses together provide a negative optical effect.

15. The optical system of claim **9**, wherein other focusable optical equipment is present, and said rear element module includes rear end connecting means, and is connected to said other optical equipment; whereby, said optical system of claim **9** is capable of quick aerial focusing of such other equipment.

16. The optical system of claim **15**, wherein said other focusable optical equipment is a reflex camera body.

17. The optical system of claim **16**, wherein said reflex camera body includes a reflecting element and a reticle in optical series with said optical system.

18. An integrated optical system including in optical series an afocal variator as a central element, a front optical system element containing at least one lens, and a rear optical system element containing at least one lens, wherein:

said afocal variator central element includes in optical series a first positive lens, a negative lens and a second positive lens, said negative lens being so positioned and so controlled that it is capable of being moved towards and away from said first positive lens and towards and away from said second positive lens, and wherein the distance between said first positive lens and said second positive lens of said afocal variator remains substantially constant; and

wherein further, other focusable optical equipment is present, and said rear element module is connected to said other focusable optical equipment and is capable of quick aerial focusing of such other equipment.

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