VARIABLE ANAMORPHIC LENS AND METHOD FOR CONSTRUCTING LENS

This invention relates to lenses and more particularly relates to a variable power lens which provides variable cylindrical lens power and cylindrical lens rotation.

For cylindrical lens systems two descriptive specifications are required for their use. First, the desired cylinder power must be chosen. Secondly, the cylindrical lens must be rotated to its desired orientation. When this has been done, the desired difference in magnification of an image in each of two perpendicular directions is achieved.

When anamorphic lens systems are used, they are commonly used in combination with spherical optics. A common example of this is the phoropter or refractor used by ophthalmologists. When cylindrical lenses are conventionally used in combination with spherical optics, change of the effective focal length of the combined optics results.

This change of focal length of combined optics can best be understood by remembering that spherical objects can be emulated by crossing at 90° cylinder lenses of equal power. When a cylinder is used as an anamorphic insert in a spherical lens system, the effective total cylindrical component of the combined optics is changed. Change of the average spherical optic focal length results. For example, inserting a positive cylinder lens into a configuration of spherical optics having positive power will produce increased lens power on the average for the combination.

In addition to changing the effective spherical power of optics used in combination with anamorphic optics, the desired rotation of a cylinder is often hard to determine, especially where the diopter power of the cylinder correction is small. An example of this is the difficulty opticians commonly experience in determining the rotational alignment of an astigmatic correction to a patient's eye when the astigmatic correction is of extreme low diopter power. In essence the rotational alignment precision becomes dependent on the strength of the cylinder.

It is known to generate astigmatism by use of a variable power lens. Such a lens is disclosed in U.S. Pat. No. 3,305,294, issued Feb. 21, 1967, entitled "TWO ELEMENT VARIABLE POWER SPHERICAL LENS," to Luis W. Alvarez and U.S. Pat. No. 3,507,565, issued Apr. 21, 1970, entitled "VARIABLE POWER LENS AND SYSTEM" to Luis W. Alvarez and William E. Humphrey.

It will be understood that the cylinder optics there obtainable have many similar disadvantages to conventional cylindrical optics. It is necessary that the lens element or elements be rotated to achieve desired cylinder angular alignment. Difficulty in determining cylinder rotation alignment at low diopter cylinder power remains.

An anamorphic lens is disclosed which generates variable cylinder lens power and variable cylinder lens rotation over incremental viewpoints chosen through its surface. Cylinder power and rotation is a function of the displacement distance and angle of a viewpoint segment on the lens from a neutral viewpoint segment on the lens.

The lens element can be defined in terms of a thickness equation. A transparent lens media is chosen having two substantially parallel optic interfaces on either side with the transparent optical media of the lens therebetween. There is chosen an arbitrary "optic" axis which extends through the optic interfaces and through the transparent optical media substantially normal to the plane of the optic interfaces. Employing an orthogonal system of x, y, and z axes, the optic axis of the lens is taken to be the z axis and the effective optical thickness variation t is measured parallel to this axis. The optical thickness of the lens element varies over its surface. This thickness variation includes an effective optical thickness variation (t) defined by the lens equation in x and y Cartesian coordinates within which the characterizing terms are:

$$t = A\,[(x^3/3) - xy^2]$$

WHERE:

- x is distance along the x axis;
- y is distance along the y axis;
- A is a constant representative of the rate of lens power variation over the lens surface; and,
- t represents optical thickness as the effective lens thickness parallel to the optic axis, taking into account both the geometrical thickness of the lens element taken in the mean direction of light rays passing through the lens and the refractive index of the material of the lens element when formed.

Regarding optical thickness, if the lens material is of uniform refractive index, t (optical thickness) may be taken as the product of geometrical thickness times refractive index. Hence if there are variations in the refractive index, there will be compensating variations in the geometrical thickness.

It should be understood that the lens thickness here defined is a thickness variation which varies from place to place throughout the lens. This variation is dependent upon the x, y displacement of a point on the lens from an origin of reference.

It should be understood that the lens here disclosed can be generated with respect to virtually any known surface. This surface does not have to form one face of a lens. Moreover, the surface can be an imaginary surface either interior of the material of the lens, exterior of the material of the lens, or partially interior and partially exterior of the material of the lens. Of course, it is required that a thickness variation be present in the optical element which follows the proper dimension relationship of the equation set forth.

In addition to the terms set forth, the thickness equation of the lens may have other optical terms, provided that such optical terms shall not contain any power of x or of y higher than the second power or any power of xy other than the first power which has a coefficient of considerable magnitude relative to the constant A. Thus, the complete lens equation may be written:

$$t = A\,[(x^3/3) - xy^2] + Bx^2 + Cxy + Dy^2 + Ex + Fy + G$$

in which:

B, C, D, E, F, and G are constants that may be given any practical value, including zero.

In the circumstances wherein the two lens elements are employed together, the values of B, C, D, E, F, and G may not be the same in the thickness equation for the two elements. The magnitude of A should be the same in both equations with opposite algebraic signs.

It is also possible to express the equation of this invention in polar coordinates. Such an expression has the value: