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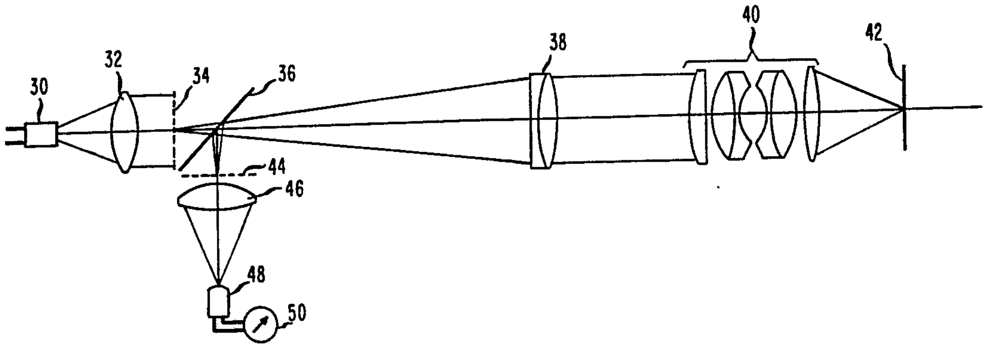

(57) Abstract

The correct focus for an objective lens is determined by sending into the objective (40) a light pattern formed by light transmitting apertures in a first mask (34) at the focus of a collimator (38), reflecting the pattern back through the lens (40) and collimator (38) to a second mask (44) having a pattern of apertures corresponding to that of the first light pattern and measuring the light passing through said second mask.

* See back of page

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METHOD AND APPARATUS FOR CHECKING LENS FOCUS

BACKGROUND OF THE INVENTION

1. Field of the invention

This invention relates to optical instruments for checking the correct lens-to-image distance in optical systems including motion picture and still cameras as well as video cameras and other optical systems including the human eye.

2. Prior art optical instruments for checking the infinity position of a camera objective lens are known where an autocollimator positioned at the front or long conjugate end of the objective lens sends a beam of light through the objective lens to the film plane of the camera and onto the camera film or onto a front-surface mirror located in that plane. The image of a reticle, usually in the form of cross hairs in the autocollimator, is reflected back through this combination to an eyepiece. When the reticle and its image are perceived, in the eyepiece, to be in the same plane, the lens is properly focused at infinity. Results using an autocollimator are not generally satisfactory for precision focusing for the reason that the interpretation of what is seen in the eyepiece is highly subjective. Different observers will select different settings for the infinity position depending upon (1) the residual spherical and chromatic aberrations left in the objective under test, and (2) the degree and type of departure from high acuity of the observer's eye.

OBJECT OF THE INVENTION

It is the principal object of this invention to provide a method and means for establishing in a non-subjective manner the focus position of an objective lens whereby all users will find the same setting consistently and accurately.

STATEMENT OF THE INVENTION

In accordance with the principal form of the present invention, a first mask consisting of one or more openings in an otherwise opaque substrate is illuminated by a light source. Light passes through the opening or openings in this first, or transmitting, mask, past a beam splitter, through the autocollimator lens, through the objective lens under test, is reflected from the image plane of the camera back through the objective lens under test and through the autocollimator lens, is reflected from the beam splitter onto a second, or receiving mask having an opening or openings corresponding to those in the first mask and coaxial with the first mask. Light passing through the hole or holes in the first mask thereby passes through the corresponding hole or holes in the second mask and on to a photo diode or other light detector. When the lens under test is out of focus the images of the hole or holes in the first reticle are correspondingly defocused or spread out when they reach the second mask so that only part of the light flux reaches the photo diode. When the objective lens is in its proper focus, the returned images of the hole or holes are sharply focused and substantially all the light flux reaches the photodiode. When the output of the diode, observed on a readout which may be digital or analog, is at its maximum, the lens is in exact focus.

THE DRAWING

In the drawings, Fig. 1 is a schematic drawing showing the autocollimator arrangement of the prior art.

Fig. 2 is a schematic drawing showing some of the elements of a simplified version of the principal form of the present invention.

Fig. 3 shows a general form of mask.

Fig. 4 shows the arrangement of round holes in the mask of Fig. 3.

Fig. 5 shows the mask arrangement of Fig. 3 using "x" shaped holes.

Fig. 6 shows a mask with a single hole.

Fig. 7 shows a beam splitting cube provided with masking on two faces.

Fig. 8 shows a preferred embodiment of the principal form of the invention.

Fig. 9 shows the arrangement of Fig. 8 rotated 90° about its axis.

Fig. 10 shows diagrammatically the signal-receiving electrical circuit for the embodiment of Figs. 8 and 9.

Fig. 11 is a masked beam splitter illustrating an alternative to the principal form of the invention.

Fig. 12 is a masked beam splitter illustrating another alternative to the present invention.

Fig. 13 shows a masked beam splitter cube incorporating displaced transmitting masks for use with the system shown in Figs. 8 and 9.

Fig. 14 shows a lens focuser employing the optical systems of Figs. 2 to 13.

Fig. 15 shows a lens focuser adapted for experimental opthamology.

In the conventional prior art autocollimator system of Fig. 1, a lamp 10 and condenser 12 illuminate a reticle 14 in the short conjugate image plane of a collimator lens 16. Light reaches lens 16 by reflection from a beam splitting plate 18. Collimated light from lens 16 enters the objective 20 under test, is focused on and reflected from mirror 22 in the camera gate, not shown, back through lens 16 and beam splitter 18 to an image plane 24 which may be defined by a cross hair or by a opaque frame. An eyepiece 26 permits simultaneous viewing of the crosshair and the image of reticle 14. When both of the latter are seen as being equally sharp, that is, in the same plane, objective 20 is focused at infinity. However, it is difficult to ascertain when this condition is reached for the reasons stated above in connection with the prior art.

Fig. 2 shows, diagrammatically, and in simplified form, the functional elements of the principal form of the present invention. A light emitting diode (LED) 30, emitting preferably in the green, and condenser 32, illuminate an opaque transmitting mask 34 provided with one or more openings to be described. Light passing through the mask and through a beam splitting plate 36 is made collimating by collimator lens 38. The collimated, or parallel, light from lens 38 enters and passes through objective 40 which is under test and is reflected from surface 42 which may be film in the camera, a ground glass or similar image plane element, a charge coupled device, video tube face or a first surface mirror. The reflected light passes again through collimator lens 38, is reflected by beam splitter 36 and focused on an apertured receiving mask 44 identical to mask 34. Light passing through mask 34 is collected by condenser lens 46 and focused on a photo diode 48, the output of which is read on a meter or other readout device 50.

It is obvious that the pattern of light passing through apertured sending mask 34 will be focused on the pattern of apertured receiving mask 44. If objective 40 is correctly focused at infinity, substantially all the light passing through the openings in mask 34 will pass through corresponding openings in mask 44, resulting in showing a high level on readout 50. If objective 40 is not focused at infinity, the image of the apertures in mask 34 will be diffused and larger than at infinity focus, and less light will enter the openings. The level on readout 50 will be correspondingly lower, depending upon the degree of defocus.

For systems operating in the visible band of the spectrum, green-emitting LEDs are preferred, although tungsten lamps with an appropriate filter may be employed if requirements for low power input are not important. For systems operating in the infrared band of the spectrum, near-IR LED's would be substituted for those operating in the visible range.

The aperture or apertures in the mask can take varied forms, some of the preferred arrangements being shown in Figs. 3, 4, 5 and 6. Fig. 3 shows diagrammatically the general pattern or locations of holes 54 in a mask 52.

When circular holes are employed they are spaced uniformly and with alternating rows preferably staggered as shown in Fig. 4. By way of example, one mask used in the inventions has a hole area approximately 7 x 10mm. Within this are several hundred holes each 0.1mm in diameter and spaced approximately 0.4mm apart. Other useful arrangements employ circular holes 0.2mm to 1.0mm diameter on 1mm to 4mm centers.

Figure 5 shows a second embodiment of the mask. Here, the apertures 56 are "x" shaped, with alternate rows staggered as shown. The width of the open arms can vary from 0.1 to 0.4mm and the spacing between the apertures can vary widely so that the mask may carry from one to several hundred "x" shaped apertures. Many other shapes, such as triangular, square and rectangular, are also suitable.

Figure 6 shows a simple mask utilizing a single aperture 58, here shown as circular. While this embodiment functions adequately it is not as sensitive to the presence of aberrations in the objective under test as are the embodiments of Figs. 4 and 5 which can indicate the presence, for example, of astigmatism through changes in readout levels which occur close to the correct, infinity, setting. Such indications serve as a guide to the user regarding any adjustments or offsets which may be required.

An indication of the sensitivity of the present invention to departures from correct focus is the change in readout level of 20 millivolts when the objective under test is defocused 30 microns from infinity position. In this specific example a 130mm focal length collimator lens with 25mm aperture was used to test a 25mm focal length objective.

In some applications, especially those where the lens focuser is subject to rough usage, a beam splitting cube 60 shown in Fig. 7 is preferable to the beam splitting plate 36 and masks 34 and 44 shown in Fig. 2. Any relative movement between the masks and beam splitter are eliminated, and the cube presents a better geometry for anchoring to the interior of the instrument in comparison with the plate type beam splitter. Once fastened during manufacture, the cube will retain its integrity almost indefinitely. The cube consists of a pair of 45° - 90° - 45° prisms 62 and 64 cemented together, with an evaporated beam splitting layer 66 at the interface. Transmitting face 68 of portion 62 of the cube carries the mask pattern which receives light from the LED and face 70 on portion 64 of the cube caries the mask pattern through which light is received and passes to the photodiode. The mask patterns may be produced using well known techniques employing evaporated chromium, photography or xerography.

Figures 8 and 9 show a preferred embodiment of the principal form of the invention. Here, a pair 72 of LEDs and a condenser lens 74 illuminate off-axis masks 76 and 78 which are separated axially an equal amount in front of and in back of the focal point of the collimator 82. Light passing through masks 76 and 78 and through beam splitter 80 is collimated by collimator 82, passes through lens 84 under test and is reflected at the image plane 86 back to beam splitter 80. Here, the light from mask 76 is directed through mask 88 and condenser 90 onto phototransistor 92, and the light from mask 78 is directed through mask 89 and condenser 91 onto phototransistor 94. Phototransistors 92 and 94 have associated with them light emitting diodes 96 and 98, respectively, for a purpose to be described. Light emitting diodes 72 are pulsed in phase at a rate of 1 to 48 times per second by an oscillator 100 as shown on the diagram of Fig. 9.

A cube beam splitter similar to that shown in Fig. 7, but with the preferred embodiment of Figs. 8 and 9 is shown in Fig. 13. Here, the transmitting face consists of an upper half 68 corresponding to upper mask 78 of Figs. 8 and 9 and a lower half 68a corresponding to lower mask 76 of Figs. 8 and 9. Lower half 68a is a separate piece of glass or other optical material cemented to the receiving face of the beam splitting cube. Dash lines 69 indicate the plane of focus of collimating less 82.

In order to avoid unduly complicating Fig. 9, the electronics at the receiving end of the system are shown in Fig. 10. In this figure, the output of phototransistor 92 is fed to an amplifier 102 and the output of photo transistor 94 is fed to an amplifier 104. The outputs of these amplifiers are fed to a comparator 106 which drives a display 108. Because masks 78 and 76 are respectively just inside and just outside of the focal plane of the collimator lens the outputs of phototransistors 92 and 94 will have different outputs. These differences will be measured by the comparator resulting in an appropriate display.

Phototransistors 92 and 94 have associated with them light emitting diodes 96 and 98 respectively. The light outputs of LEDs 96 and 98 are coupled to phototransistors 92 and 94 respectively. LEDs 96 and 98 are powered by d.c. feedback drives 110 and 112 respectively. These LEDs perform important functions: compensation for stray light, compensation for temperature changes, and compensation for the difference is sensitivity level of phototransistors 92 and 94.

An alternate form of the present invention involves a masking combination which is in a sense opposite to that described in connection with Figs. 1 to 10. In these figures the transmitting and receiving masks are both positive, i.e, the transmitting mask carries holes through which light passes to the receiving mask which has corresponding holes. In such a positive-positive system correct lens focus is indicated by a maximum of light flux passing through the receiving mask.

The present invention will also operate as a positive-negative system, a negative-positive system, and even as a negative-negative system. In a positive-negative system the illuminated or sending mask would still be an opaque member provided with holes such as in Figs. 4, 5 and 6. The receiving mask would be transparent except for opaque dots or other shapes corresponding to the shapes of the light transmitting holes in the sending mask and laid out in an identical pattern. the output of the receiving phototransistor would be a minimum when the objective under test was in correct focus, and would increase with increasing departure from correct focus. An example of a positive-negative system as employed with a beam splitting cube 114 is shown in Fig. 11. Here the cube 114 shows holes 116 at its illuminated face, forming a positive sending mask and opaque dots 118 similarly placed on the output face to form a negative receiving mask.

A negative-positive system in which the sending mask is transparent with opaque dots or other shapes, and the receiving mask is opaque with light transmitting holes or other shapes presents difficult stray light problems. It is also less efficient than the positive-negative system as regards signal level, and is therefore a less desirable form of mask combination. It can be visualized by interchanging the holes and dots in Fig. 11.

A negative-negative system is inefficient unless the opaque dots 118 are made extremely large as in Fig. 12; at that point this less desirable arrangement would approximate a positive-positive system.

An example of a lens focuser employing the optical systems of Figs. 2 to 12 is shown in Fig. 14. A generally tubular body 120 carries at one end collimator lens 82 in an axially movable mount 122 calibrated to permit checking the focusing scale readings on the objective lens under test. A removable cover 124 permits access to the mask, beam splitter and light sources. A readout 126 indicates the condition of focus of the lens under test. In the readout of this particular embodiment, three LEDs are used. When the central LED 128 is lit the objective under test is in focus; if the objective is not in focus one of the two other LEDs will light indicating that the objective is focused either inside or outside the proper correct plane.

The present invention is readily usable in experimental opthalmics where it is necessary to know in a continuous, real-time manner, the effect on focusing of the eye, of medications used internally or topically, of radiation of various intensitites and wavelengths of light and of external forces such as gravity or absence of gravity. As shown in Fig. 15, light leaving collimator lens 82 is reflected by beam splitter 130 into an eye 132 under test. The source of light in focus tester 120 may be in the near infrared to avoid unwanted ocular reactions to radiation form the focus tester. The focusing reaction of the eye under test as it is subjected to a source of stress, radiation, pressure or other conditions is readily measured.

I claim

1. A device for establishing the correct focus for an objective lens comprising a source of light, a first, patterned light transmitting, mask illuminated by said source, a beam splitter, a collimating lens receiving light from said first mask via said beam splitter for directing collimated light to and through an objective lens under test, receiving light reflected back through the objective lens being tested, and directing said reflected light to said beam splitter and through a second, patterned light receiving, mask corresponding to said first mask, and measuring the light passing through said second mask.

2. A device as claimed in Claim 1, said light transmitting and light receiving masks comprising opaque surfaces carrying one or more light transmitting holes.

3. A device as claimed in Claim 1, said first and second masks comprising a grid of uniformly spaced holes.

4. A device as claimed in Claim 3, said holes being circular in shape.

5. A device as claimed in Claim 3 said holes being cross-shaped.

6. A device as claimed in Claim 3, said holes being cross shaped and at a 45 degree angle to the vertical.

7. A device as claimed in Claim 1, said beam splitter being in the form of a plate.

8. A device as claimed in Claim 1 said beam splitter comprising a cube, each of two faces of which carry a mask.

9. A device as set forth in Claim 1, wherein said patterned first and second masks have identical light transmitting patterns.

10. A device as set forth in Claim 1, wherein the light transmitting pattern of said second patterned mask is the optical negative of the light transmitting pattern of said first patterned mask.

11. A device for establishing the correct focus for an objective lens comprising a source of light, a first light transmitting mask illuminated by said source of light and located off-axis in one direction, a second light transmitting mask illuminated by said source of light and located off-axis in the opposite direction, a collimating lens receiving light from said masks, one of said first and second light transmitting masks located a small distance inside the focal plane of said collimating lens and the second of said light transmitting masks located a small distance beyond the focal plane of said collimating lens, a beam splitter between said light transmitting masks and said collimating lens for directing light returned through said collimating lens to first and second light receiving masks, said first light receiving mask being displaced off-axis in the same direction and amount as the first light transmitting mask and in the plane of focus of the collimating lens, said second light receiving mask being displaced off axis in the same direction and amount as the second light transmitting mask and in the plane of focus of the collimating lens, light from said first and second light receiving masks being received by first and second light sensors respectively.

12. A device as claimed in Claim 9, the output of said light sensors being amplified and fed to a comparator.

13. A device as claimed in Claim 10, the output of said comparator activating a display.

14. A device as claimed in Claim 9, said device including light emitting diodes for illuminating said light receiving masks.

15. A device as claimed in Claim 12, the light output of said light emitting diodes being controlled by the output levels of said first and second light sensors.

16. A device for establishing the correct focus for an objective lens comprising a source of light, a first light

transmitting mask illuminated by said source, said first mask carrying a light transmitting pattern, a beam splitter, a collimating lens receiving light from said first mask via said beam splitter for directing collimated light to an objective lens under test, receiving light reflected from the image plane of the objective back through the objective under test, and directing said reflected light to said beam splitter and to a second mask, said second mask carrying a negative light transmitting pattern relative to said first mask, and measuring the light passing through said second mask.

17. A method for checking the focus of an image forming objective lens comprising the steps of: projecting into the objective lens a light pattern of given size and intensity; comparing the size and intensity of the light pattern as reflected back from the image plane of the objective lens with the size and intensity of the light pattern as projected; and determining from such comparison the state of focus of the objective lens.

18. A method for checking the focus of an objective lens comprising the steps of: projecting into the long conjugate end of the objective lens a pattern of collimated light of given size and intensity; reflecting the pattern of light back from the image plane of the objective lens; comparing the size and intensity of the reflected light pattern with the size and intensity of the projected light pattern; and determining from such comparison the state of focus of the objective lens.

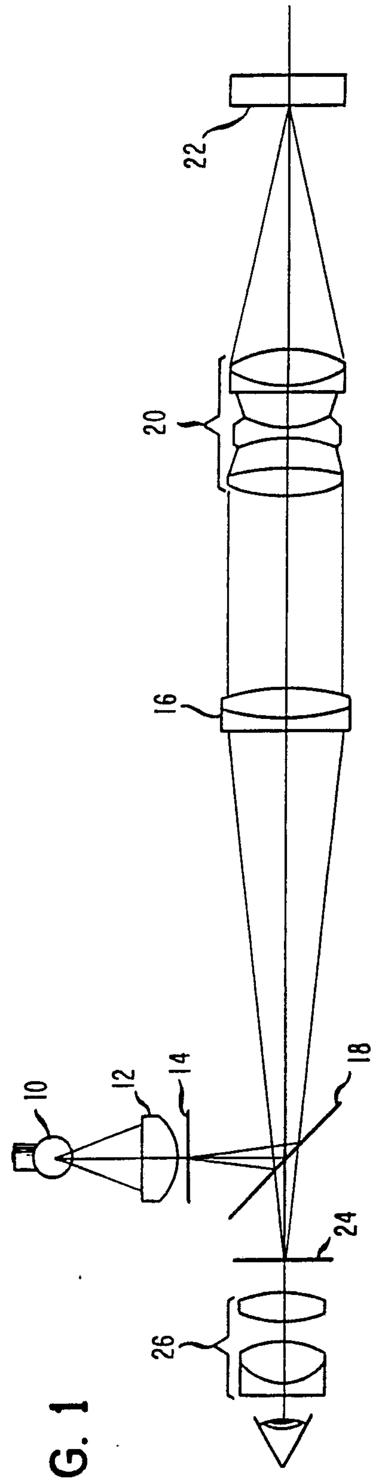

FIG. 1

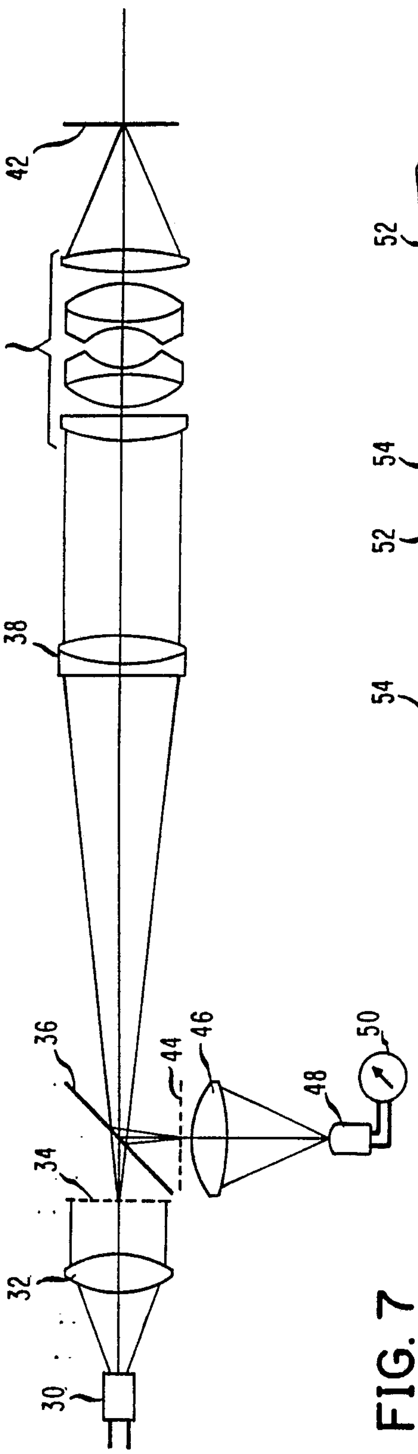

FIG. 2

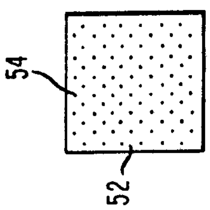

FIG. 3

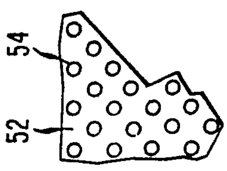

FIG. 4

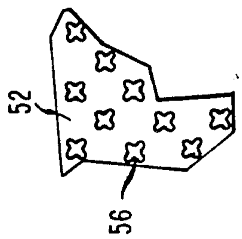

FIG. 5

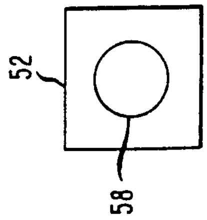

FIG. 6

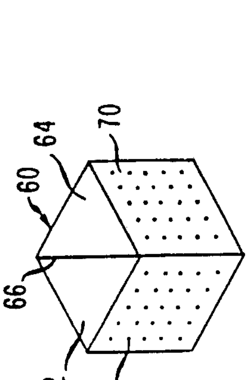

FIG. 7

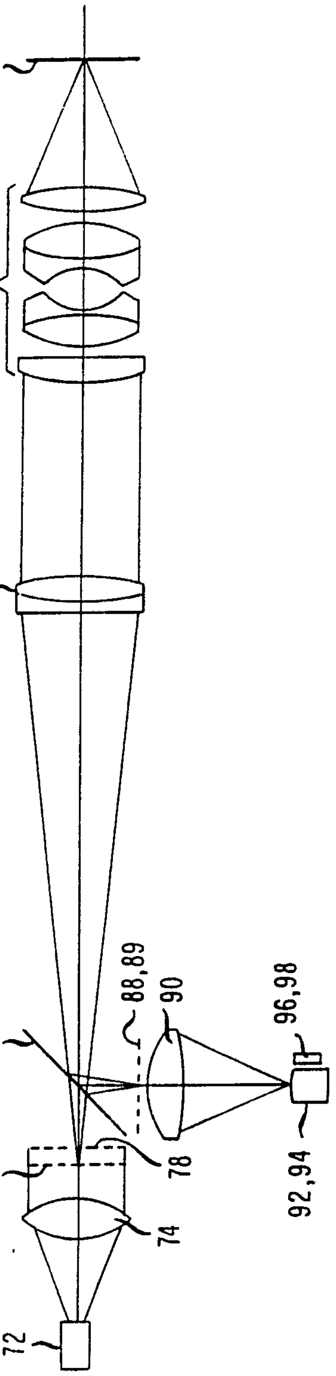

FIG. 8

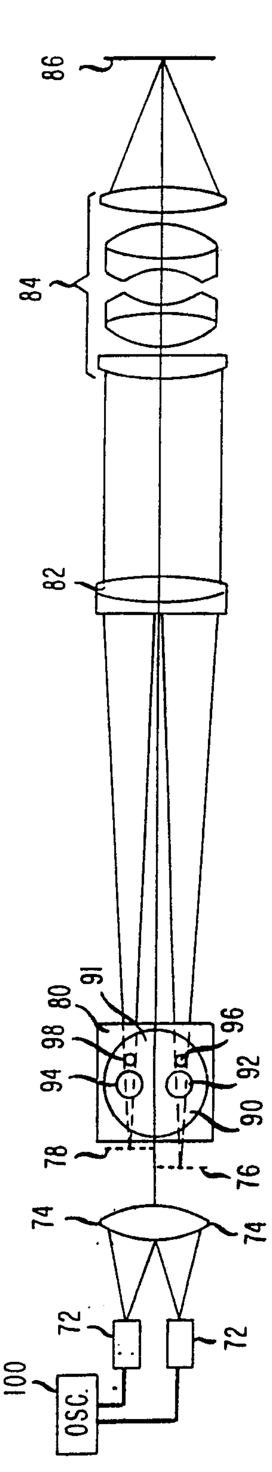

FIG. 9

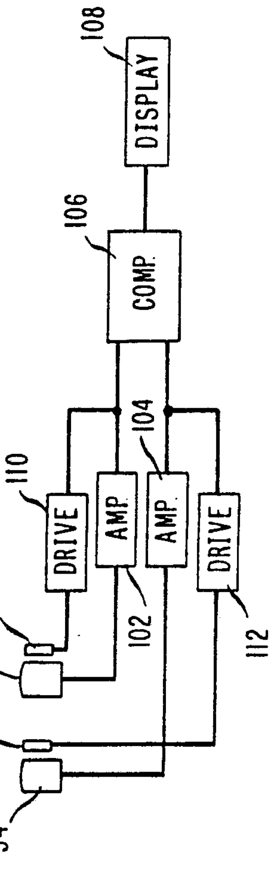

FIG. 10

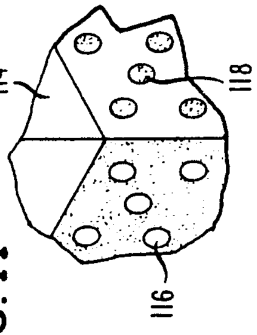

FIG. 11

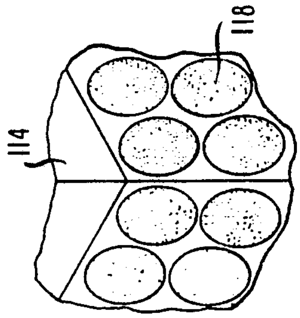

FIG. 12

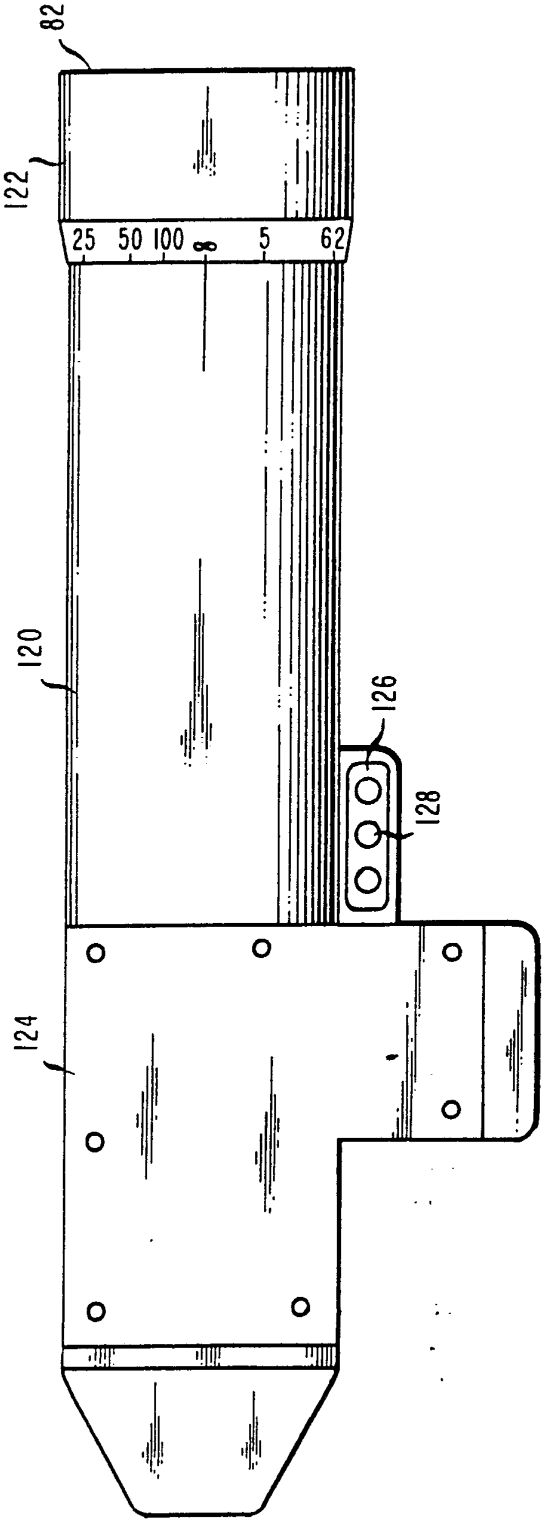

FIG. 14

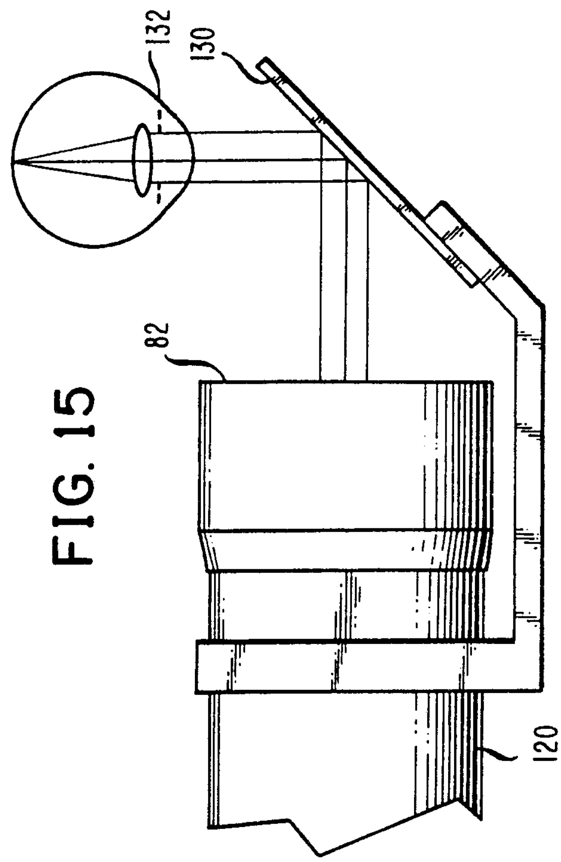

FIG. 15

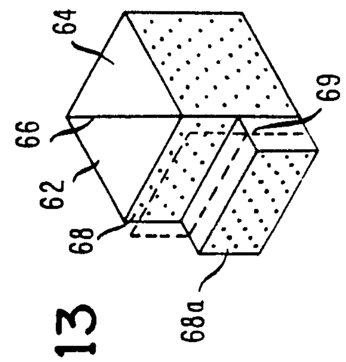

FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/05136

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5) : G01J 1/00 , G01J 1/20, G01B 9/00

U.S. CL: 356/121; 356/122; 250/201.4

II FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S. CL.	356/121, 122, 123, 124, 125, 399, 400 250/204, 201.4, 201.7 350/461, 464; 351/211, 212.

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	U.S. A, 4,538,062 Shishido 27 August 1985. Figures 9-12; Column 10 lines 41-50.	1,2,4,7,8, 9-16, 17,18
Y	US, A, 4,614,864 WU 30 September 1986. Figures 1 and 3.	3, 5, 6,
A	U.S. A, 4,674,838 Hieber et al 23 June 1987. Figures 1-6.	2,3,4,5,6,

* Special categories of cited documents: [15]

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
10 January 1991	08 FEB 1991
International Searching Authority [1]	Signature of Authorized Officer
ISA/US	For HOA PHAM NGUYEN NGOC-HO INTERNATIONAL DIVISION

Form PCT/ISA/210 (second sheet) (May 1986)