350-410 SR
XR 3,868,504

United States
Anderson

[11] 3,868,504
[45] Feb. 25, 1975

[54] **MODULAR BIOCULAR EYEPIECE FOR THERMAL IMAGE SYSTEMS**

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[22] Filed: **Sept. 20, 1973**

[21] Appl. No.: **399,016**

[52] **U.S. Cl.**..... **250/213 VT**, 313/65, 313/92 LF
[51] **Int. Cl.** ... **H01j 29/18**, H01j 31/26, H01j 31/50
[58] **Field of Search** ..... 250/213 VT; 313/92 LF, 313/65; 350/69

[56] **References Cited**

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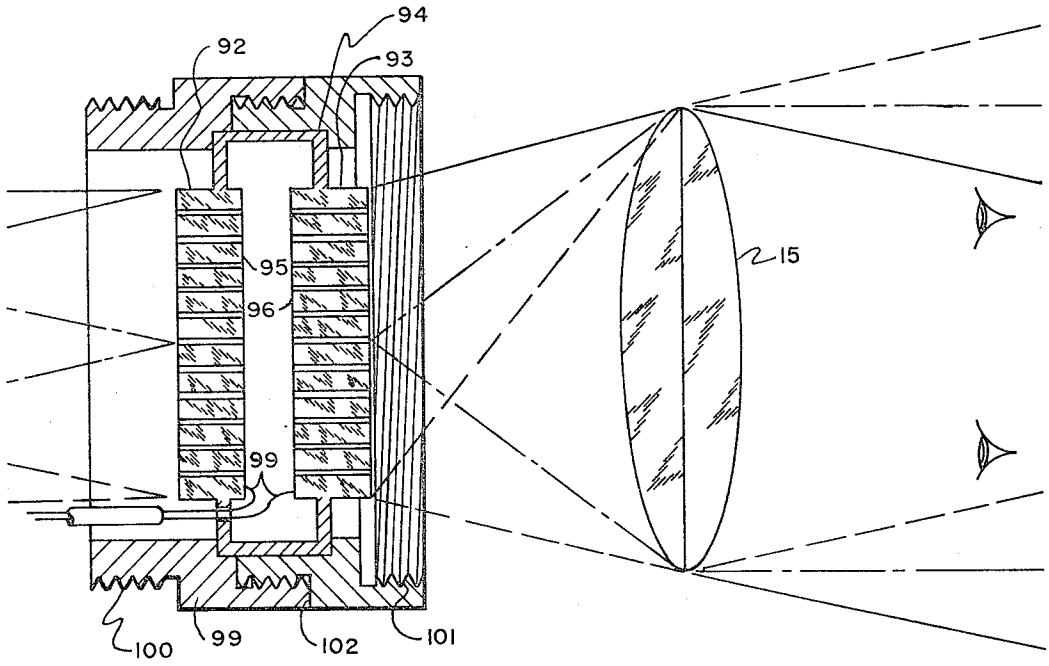
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Primary Examiner—James W. Lawrence
Assistant Examiner—T. N. Grigsby
Attorney, Agent, or Firm—Robert P. Gibson; Nathan Edelberg; John E. Holford

[57] **ABSTRACT**

A biocular viewing system for thermal (far infrared) viewers is provided by matching an eyepiece developed for an image intensifier to the low intensity image produced by light emitting diodes. A simplified image intensifier with gain sacrificed provides a low cost matching unit.

5 Claims, 13 Drawing Figures



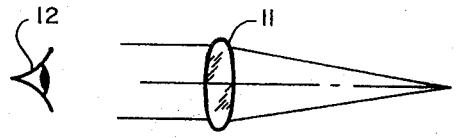


FIG. 1a

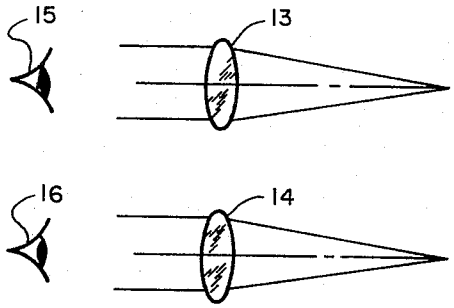


FIG. 1b

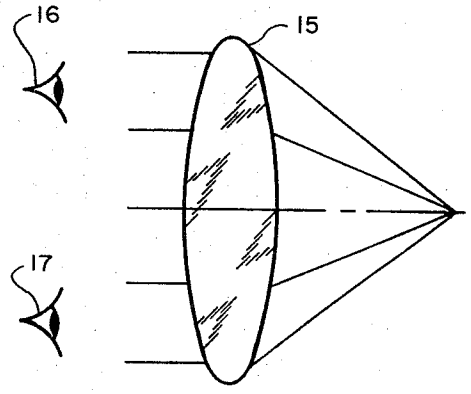


FIG. 1c

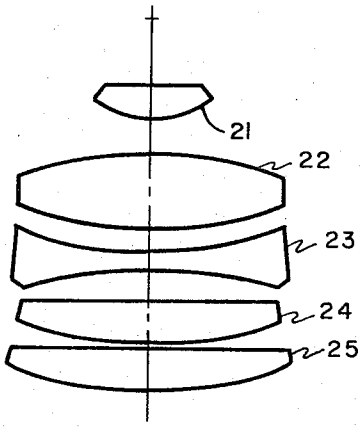


FIG. 2

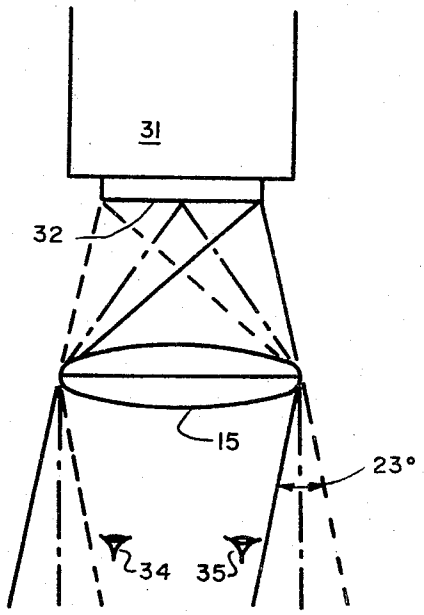


FIG. 3

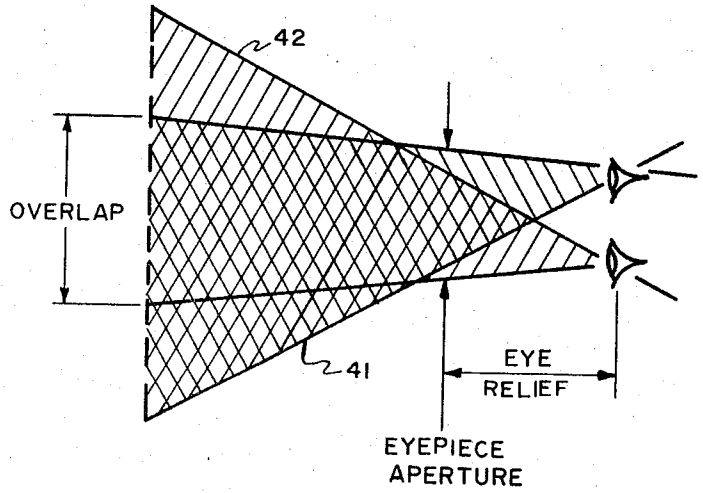


FIG. 4

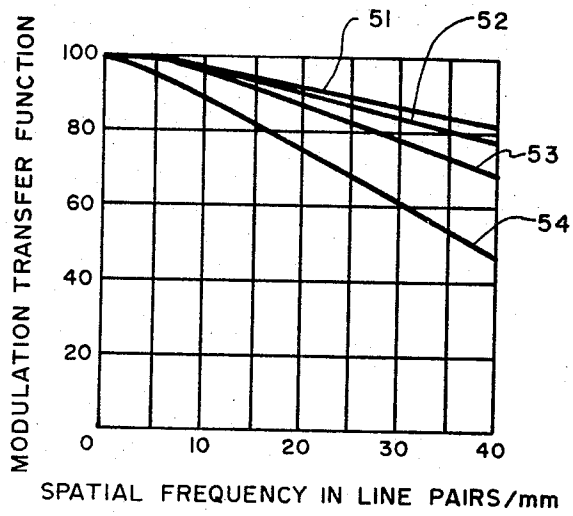

MODULATION TRANSFER FUNCTION
100
80
60
40
20
0
10
20
30
40
51
52
53
54
SPATIAL FREQUENCY IN LINE PAIRS/mm

FIG. 5

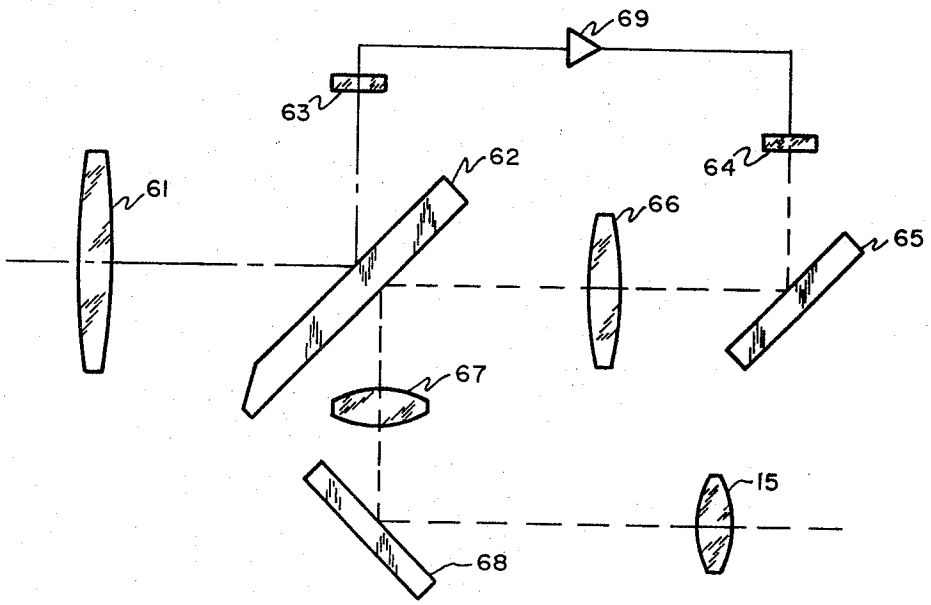

69
63
64
61
62
66
65
67
15
68

FIG. 6

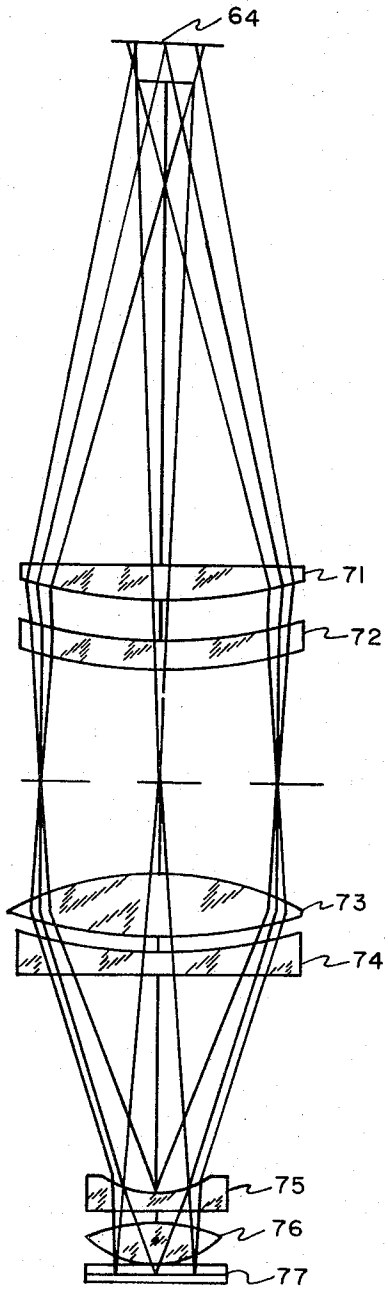


FIG. 7

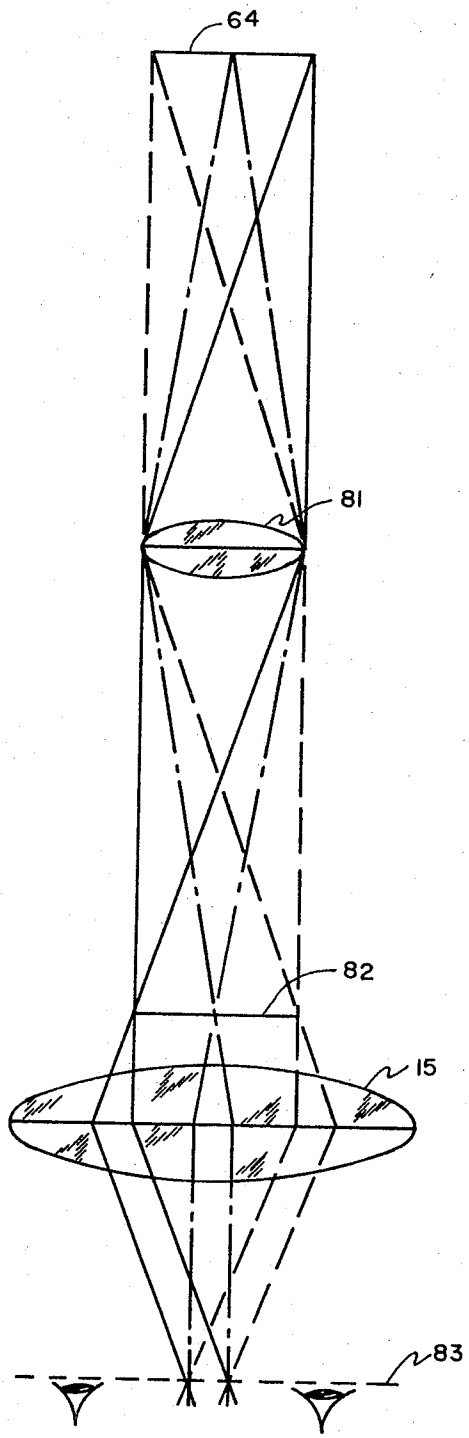


FIG. 8

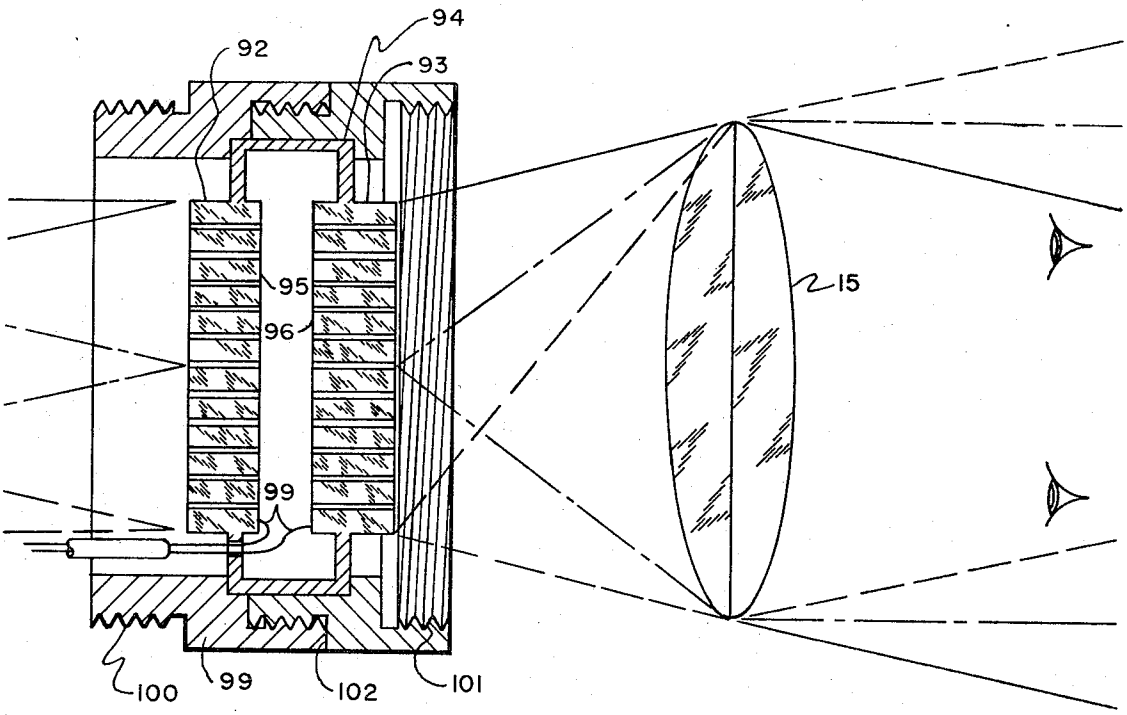
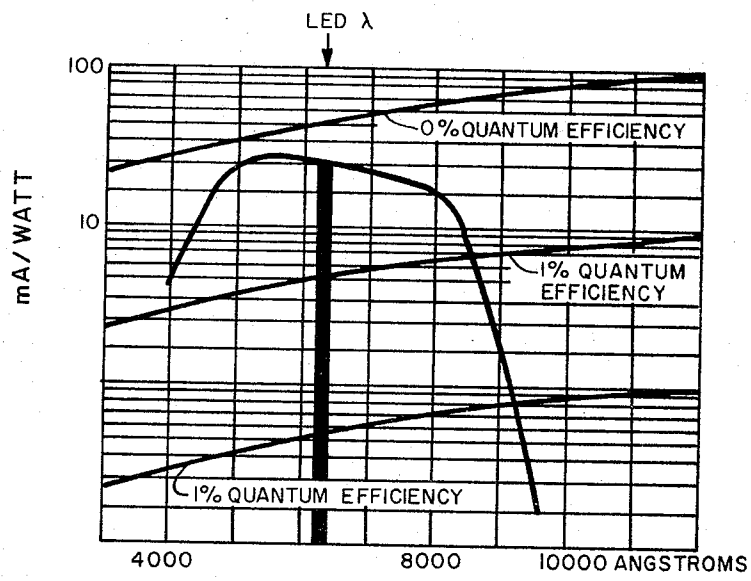


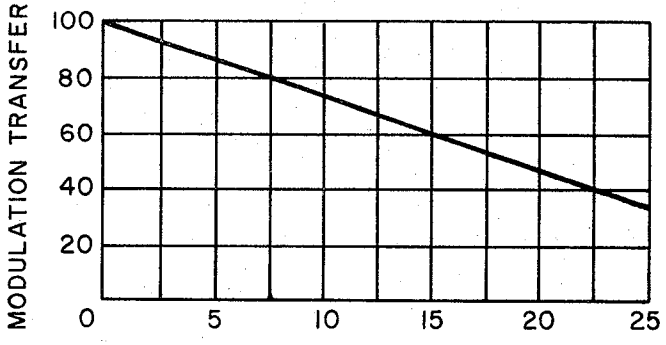
FIG. 9



S-20 PHOTOCATHODE

THIS SEMI-TRANSPARENT PHOTO-EMITTER CONVERTS LIGHT PROTONS INTO PHOTO-ELECTRONS

FIG. 10



DIODE TUBE MTF

(ITT SER NO. D4)

FIG. 11

MODULAR BIOCULAR EYEPIECE FOR THERMAL IMAGE SYSTEMS

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF INVENTION

Covert optical surveillance and detection systems principally for night operations is a rapidly expanding business. The best known work is related to military applications, but there are many applications in police activities, hunting, wild life studies and commercial operations.

These systems can be divided roughly into two types. The first use image intensifiers for the visible and near visible, and the second operate in the far-infrared. Image intensifier systems which utilize incident visible light enhanced by nearby ultraviolet and infrared are in a high state of development. These devices range from a small handheld type to ones with huge objective lenses that must be mounted on tripods. These devices must cover such a large field of interest that they must be viewed critically over long periods of time to efficiently utilize the information afforded. The display is the rather brilliant variety used in radar equipment and television emphasizing the green spectrum to which the eye is most sensitive. Monocular eyepieces were supplied in the original units and these were later replaced with biocular eyepieces. The latter eyepiece is so successful in reducing eye fatigue it may entirely replace the monocular type on large units, if its higher cost can be reduced sufficiently by mass production and value engineering.

The far infrared viewer is another night vision aid which also has unique daylight uses. These devices produces images based on the temperature difference in objects under surveillance and furnish information not perceived by the human eye under any ambient light condition. The state-of-the-art of thermal detectors, however, is not suited to intensifier tube direct view approaches. The most promising technique at present involves detector diodes and light emitting diodes in coupled pairs, with a scanning system to reduce the number of diodes, since these are still relatively expensive. Unfortunately, light emitting diode arrays do not have nearly the brightness of an image intensifier tube so that the eyepiece components of the two are not interchangeable. Monocular viewing of the thermal raster presentation at the low light level is extremely fatiguing to the human eye.

SUMMARY OF THE INVENTION

The present invention provides a solution to the above problem, by forming a compound system including both light emitting diodes and a novel image intensifier tube. The tube and its adapter fitting are shaped like a wafer to minimize the slight change in length of the optical path. The adapter fitting accepts lenses designed for image intensifier tubes, which includes biocular types.

BRIEF DESCRIPTION OF DRAWINGS

The invention is best understood with reference to the accompanying drawings wherein:

FIGS. 1*a*–1*c* show ray diagrams of three basic viewing systems;

FIG. 2 shows a side view of the elements which make up a biocular eyepiece designed for use with an image intensifier tube;

FIG. 3 shows a ray diagram of an image intensifier tube and a biocular eyepiece;

FIG. 4 shows a field of view overlap diagram for a biocular eyepiece;

FIG. 5 shows a graph of the Modulation Transfer Function for a biocular eyepiece;

FIG. 6 shows a schematic diagram of a typical far infrared viewing system;

FIG. 7 shows a ray diagram (unfolded) of the visual portion of the system from FIG. 6;

FIG. 8 shows a simplified ray diagram of the visual portion of the system from FIG. 6 with a biocular eyepiece added;

FIG. 9 shows the ray pattern resulting when an image intensifier tube is placed with its input face at the reticle plane in FIG. 8;

FIG. 10 shows a graph of the spectral response for an S-20 cathode with the spectral output of an LED superposed thereon; and

FIG. 11 shows a graph of the Modulation Transfer function for the matching image intensifier tube according to the present invention.

DESCRIPTION OF INVENTION

Referring to FIGS. 1*a*–1*c* the three basic systems of viewing an illuminated image with an eyepiece system are shown. The monocular system with one lens **11**, FIG. 1*a*, puts the stress entirely on one eye **12** while the other eye is dark adapted. Shifting from one eye to the other thus induces additional stress. The binocular system of FIG. 1*b*, using lenses **13** and **14** for both the right and left eye **15** and **16**, is better in terms of eye fatigue, but is still an uncomfortable arrangement that must be readjusted to the interpupillary distance of each observer. The biocular system of FIG. 1*c*, using a single large lens **15** with an exit pupil large enough for both eyes **16** and **17** requires no adjustment for different observers and with adequate eye relief is very comfortable. On occassion two viewers have used such a system without difficulty.

FIG. 2 shows a suitable commercially available biocular eyepiece. It has five elements **21–25** which provide color correction for a green phosphor peaked at 5,500 Angstroms. It is designed to image the 25mm diameter circular screen of an image intensifier tube with a 23° field of view. The lens has a speed of *f*/0.55. The exit pupil and eye relief are both 64mm. Distortion (barrel) is 4.4 percent. These and other characteristics of the lens are listed in Table I.

FIG. 3 shows the eyepiece **15** positioned in front of an image intensifier **31** with phosphor screen **32.** The focus is fixed at minus 2.5 diopters. A virtual image appears 15.8 inches from the eyes **34** and **35** (normal reading distance).

FIG. 4 illustrates the overlap of fields **41** and **42** presented to each eye. Since complete overlap requires an extremely large lens a tradeoff is customarily made between complete viewer contact and reasonable lens size. The lens system specified in Table I has approximately 80 percent overlap which still provides comfortable viewing for the operator.

FIG. 5 shows the image quality of the lens system in terms of the modulation transfer function. A 5mm stop is used to simulate the photopic eye aperture. The func-

tion is shown on axis, curve **52**; 14mm off axis, curve **53**; and 32mm of axis, curve **54**; compared with the maximum value permitted by the diffraction oimit curve **51**. The actual off axis operation is of course determined by viewers eye separation, i.e., somewhere between curves **53** and **54**.

A typical infrared scanning system with which the lens is used is shown in FIG. **6**. An IR objective lens **61** forms a thermal image on an array of detector diodes after reflection from a scan mirror **62**. The low frequency signals from the detectors are each amplified by a separate amplifier **69** and drive a light emitting diode (LED) **64**. The one dimensional light image of the latter diodes is redirected by just mirror **65** to the back surface of the scanning mirror **62** which is treated to reflect visible light. A second mirror **68** redirects the two dimensional visible image formed by the scanning mirror to an eyepiece **15**. Lenses **66** and **67** collimate the light reflected by the scanning mirror to reduce distortion.

FIG. **7** shows the visual optical relay from FIG. **6** in unfolded form. Elements **71** and **72** makeup lens **66** from FIG. **6** and elements **73–76** makeup lens **67**. The light output of the LEDs can be as low as 0.3 of a footlambert. To conserve size and weight an optically slow relay system (*f*/9.0) is used in the monocular system. Planar element **77** is a reticle plate.

FIG. **8** shows the result of adding an existing fast biocular lens **15** (0.55) in place of the normal monocular eyepiece. The entire optical relay from FIG. **7** is represented by lens **81**. A real image is formed at reticle plane **82**. The maximum separation of observable images at the viewing plane **83** is much less than the viewers eye separation, so that biocular viewing is impossible.

FIG. **9** shows a ray diagram of the system of FIG. **8** beginning at the reticle plane after an image intensifier tube **91** has been placed with its input face at the reticle plane, and the biocular eyepiece **15** is focused on its output face to provide the desired exit pupil/eye relief (see Table I). Other methods of correcting the optical mismatch shown in FIG. **8** are (1) to drive the LEDs harder and place a diffusing screen in the reticle plane (2) to increase the speed (i.e., lower the f/number) of the visual relay or (3) to substitute a cathode ray tube (CRT) display for the LEDs. LEDs are not yet available which will provide a factor of 100 increase in brightness as required by method (1) without seriously degrading their lifetime. Lowering the *f*/number requires an increase of size and weight that is intolerable for a portable system of this type. The use of a cathode ray tube requires complete redesign of the electronics to include a multiplexing system. Retrofitting existing units by this method would be tedious and costly.

Any existing image intensifier tube with adequate display area can be used for element **91** in FIG. **9**, but a novel tube of simple design has been devised especially for this application. The tube consists of two fiber optic backing plates of face plates **92** and **93** which provide better defined resolution of the images passing therethrough. These plates are commercially available and commonly used in intensifier tubes. A photocathode consisting, for example, of S–20 material (SbKNaCs) is deposited on the inner face of plate **92** and a phosphor screen which may be, for example a P–20 material (ZnCdSiAg) is deposited on the inner surface of plate **93**. The two plates are positioned so that the cathode and phosphor screen are in close proximity, about 1 millimeter apart. An annular closure and sealing member **94** is attached to the edges of the plates to maintain their spacing and permit evacuation of the space therebetween to approximately 10^{-6} torr. Both the cathode and anode (phosphor screen) are provided with thin conductive layers which pass high energy electrons, but act as light reflectors and ion barriers. Leads **99** connected these layers with external electrodes insulated from one another and sealed through the annular closure member **94**. An adapter ring **99** surrounds closure member providing female threads **100** at one end and male **101** threads at the opposite end so that it can easily be interposed between the infrared viewer and the biocular lens. The adapter and tube may both be threaded to engage one another or the adapter may consist of two sections secured by mating threads **102** for easy tube replacement. During operation on a voltage of approximately 8kv is maintained across the electrodes. The external faces of the tube are spaced only 17 mm apart thus adding very little to the length of the optical pattern.

FIG. **10** shows the conversion efficiency of S–20 cathode with the energy spectrum of a GaAs LED superposed. The excellent matching of the two is evident. Newer cathodes with different response characteristics are available, if the specifications of any far infrared viewer should become critical in this regard.

FIG. **11** shows a graph of the modulation transfer characteristic of the tube shown in FIG. **9**. The function falls off less rapidly than that of most conventional intensifier tubes and compares favorably with the function for passive elements like the biocular lens of FIG. **5**. Other characteristics of the tube are listed in Table II.

Obviously many variations of the above described structures will be immediately apparent to those skilled in the art, but the present invention is limited only to the extent defined in the claims which follow.

TABLE I

BIOCULAR CHARACTERISTICS

EXIT PUPIL/EYE RELIEF	64 mm/64mm
LENGTH	113mm
DIAMETER	83mm
WEIGHT	2.2 lbs
MAGNIFICATION	4.5 (at–2.5 diopt)
EFL	47mm
FORMAT SIZE	25mm
DISTORTION	4.4% barrel
FOV	23 degrees
APPARENT IMAGE DISTANCE	15.8 inches
COLOR CORRECTION	P-20
TRANSMISSION	86%
FIELD FLATNESS	⅛ diopter

TABLE II

DIODE TUBE CHARACTERISTICS

LENGTH	17mm
DIAMETER	47mm
WEIGHT	88.3 grams
MAGNIFICATION	IX
DISTORTION	negligible
RESOLUTION	57 lines/mm
GAIN	111 footlamberts/footcandle
CATHODE SENSITIVITY	506 microamperes/lambert
VOLTAGE	8.5KV

I claim:

1. A low gain image intensifier comprising:

a pair of thin transparent backing plates disposed in parallel with first and second opposed surfaces spaced apart less than one millimeter;

a photocathode and covering to said first surface;

an electro-luminescent phosphor screen and covering to said second surface first and second thin conductive layer means attached to and covering said screen and said photocathode to reflect light and provide a barrier to ions incident thereon;

a closure member sealed to the entire perimeter of each plate as the sole means of support and separation of said plates whereby only a hard vacuum is maintained between said plates; and

a pair of electrodes insulated from one another attached to said first and second thin conductive layers, respectively, and sealed through said closure member.

2. An image intensifier according to claim 1 wherein said backing plates are fiber-optic face plates.

3. An image intensifier according to claim 1 wherein a d.c. potential source of approximately 8 kilovolts is connected between said electrodes.

4. An image intensifier according to claim 1 wherein:

said photocathode and said screen are composed of S–20 type and P–20 type materials.

5. An image intensifier according to claim 1 further including:

an adapter ring engaging the edge portion only of said intensifier, said ring having male and female threads at its respective opposite ends, whereby said intensifier can be readily interposed between the housing and eyepiece of available image intensifier and infrared viewing devices.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,868,504

DATED : 25 February 1975

INVENTOR(S) : DAVID K. ANDERSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 5, after "photocathode" insert --attached to--; line 6, after "covering" delete "to"; line 6, after "screen" insert --attached to--; line 7, delete "to"; line 7, after "surface" insert a semicolon --;-- and begin a new paragraph.

Signed and sealed this 13th day of May 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

UNITED STATES PATENT OFFICE

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