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RANGEFINDER

This invention relates to rangefinders for electro-optically detecting the range of an object. The detection of the range may be an indication that the object is inside or outside of a certain range or an indication of the actual distance of the object.

U.S. Patent No. 3,617,128 describes a rangefinder in which light is transmitted towards the object whose range is to be determined. Light reflected by the object is received by an optical system which comprises an outer annular portion of a lens disposed about the light transmitter. The light transmitter includes a light source and its own lens. The light source is in a light-tight housing such that light generated in it does not directly reach photosensitive materials at the image plane of the optical system. Such a rangefinder has the disadvantages that it requires the light source to be shielded from the photosensitive materials, that as the optics of the transmitting and detecting components are separate the effective aperture of each is less than the sum of the whole, and that it is relatively complex to manufacture.

It is the object of the present invention to eliminate the above-mentioned disadvantages.

According to the present invention there is provided a rangefinder, for determining the range of an object, comprising a radiation emitter and detector means for detecting radiation generated by the emitter and reflected by the object, a single lens for directing radiation from the emitter forwardly, and for collecting reflected radiation and directing it backwardly to the vicinity of the detector means, the radiation emitter and detector means being located in or proximate the focal plane of the lens, and the effective aperture provided by the lens for the emitter and for the detector means being substantially coincident.

In one embodiment of the present invention the radiation directed forwardly by the single lens illuminates a first generally cylindrical volume of space, the detector receives through the lens radiation from a
5 second generally cylindrical volume of space. A third volume of space is common to the first and second volumes and extends a predetermined distance from the lens. Such an embodiment further includes means responsive to the detector means for detecting whether a reflecting object
10 lies in the third volume of space. Such an embodiment may provide an indication of whether an object is inside or outside a certain range. It has advantages in manufacturing simplicity, both in low number of parts and in reduced need for adjustment and calibration.

15 In another embodiment, the detector means includes two detectors located at different distances from the emitter. The two detectors signal the amplitude of light incident on them collected by the lens after having been reflected by the object. This embodiment further
20 includes means for processing the signals from the detectors to produce an output signal indicative of the object's distance.

Embodiments of the present invention will now be described, by way of example, with reference to the
25 accompanying drawings, in which:

FIG. 1 is a schematic ray diagram useful in describing the principle of operation of a single lens rangefinder device according to the present invention;

FIG. 2 is a perspective schematic representation
30 of a photographic camera having a single lens rangefinder device according to the

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present invention, partially broken away to reveal interior detail of the camera;

FIG. 3 is an enlarged portion showing details of the rangefinder device of the camera shown in FIG. 2;

FIG. 4 is a perspective schematic view of a light emitter and detector for use in an embodiment of the present invention, integrated on a common substrate;

FIG. 5 is a graph illustrating the spectral transmittances of an antireflection coating on the lens and an infrared filter employed with an embodiment of the present invention;

FIG. 6 is an electrical schematic diagram of the rangefinder control electronics shown in FIG. 2.

FIG. 7 is a schematic perspective view of a camera employing a rangefinder which is a second embodiment of the present invention;

FIG. 8 is a sectional side view of the rangefinder included in the camera illustrated in Fig. 7;

FIG. 9 is a front view of the emitter and detector portion of the rangefinder shown in Fig. 8;

FIG. 10 is a diagram illustrating by rays the light emitted to and reflected from an object by the rangefinder illustrated in Figs. 8 and 9;

FIG. 11 is a reflected-light-amplitude versus distance-from-detector curve for two different-distance objects;

FIG. 12 is a diagram illustrating signal processing circuitry usable in the camera illustrated in Fig. 7;

FIGS. 13 and 14 are views similar to Fig. 9 but showing different forms of the emitter and detector portion of the rangefinder; and

FIG. 15 is a cross-sectional view of one preferred integrated circuit form of emitter and detector panel useful in a rangefinder similar to that in FIG. 7.

Referring to FIG. 1, a first embodiment of the present invention includes a single lens 10. A light emitter, such as an LED 12 or a diode laser, is located near the focal point of the lens 10 so that light from the emitter is directed forwardly in a beam 14. A photodetector 16, such as a photodiode, is located near the light emitter and receives light directed backwardly by the lens to the vicinity of the detector, which light is directed towards the lens from objects within a field of view 17. The effective lens apertures for the detector and the emitter are substantially identical and coincident, so that both the detector and the emitter make full use of the light gathering power of the single lens. Light beam 14 and field of view 17 overlap in a detection region 18 which extends a predetermined distance D from lens 10. When LED 12 is activated, any object in beam 14 will be illuminated by radiation from the LED. If the object lies in detection region 18, the LED radiation reflected by the object will be viewed by photodetector 16, thereby causing an increase in the output signal of the photodetector. The output of photodetector 16 is sensed in a detection circuit, described below, to determine whether an object is located in detection region 18.

FIG. 2, shows a rangefinder, embodying the present invention, employed in a still camera 20 for exposing disc film. The camera includes a housing 22 having apertures for a viewfinder 24, an electronic flash 26, a taking lens 28, and an exposure control

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photosensor 30. The body of the camera is partially broken away to reveal that the taking lens 28 is provided with an auxiliary closeup lens 32, mounted for sliding movement into the optical path of the taking lens 28 to
5 change the focus of the taking lens from normal photography to closeup photography (e.g., three feet or closer). An electromagnetic actuator 34, such as a solenoid, or, more preferably, a planar actuator such as is described in U.S. Patent No. 4,024,552, is connected to
10 the closeup lens, for moving the closeup lens into and out of the optical path of the taking lens 28.

A rangefinder device embodying the present invention controls the position of the closeup lens 32. The rangefinder device includes a lens 36, an emitter 38,
15 which in the present case is a light emitting diode, and a detector 40, which in the present case is a photodiode. The light emitting diode and photodiode are electrically connected to an electronic control circuit 42 which drives electromagnetic actuator 34. The camera is provided with a
20 shutter release button 44.

As shown in FIG. 3, an extension 46 of the camera housing 22 forms the sides of an enclosure in which the emitter 38 and detector 40 are housed. Lens 36 covers the front of the enclosure. The back of the enclosure is
25 formed by a printed circuit board 48 which carries the emitter 38 and the detector 40 and the electronic control circuit 42. The printed circuit board is formed as part of a mild steel mechanism plate which is coated with a layer of electrically insulating material as described in
30 U.S. Patent No. 4,333,722. Printed circuit board 48 is attached to the back of the housing extension 46 by integral studs 50 extending through holes 52 in the circuit board.

In this embodiment, the emitter 38 and detector 40 are integrated on a common chip 54, see FIG. 4. The emitter/detector chip 54 is formed on a substrate 56 of n-type gallium arsenide in a conventional manner. The emitter and detector diodes are formed by p-type doped regions 58 and 60 respectively. Individual addressing electrodes 62 and 64 are formed on the top side of the emitter and detector diodes to make ohmic contact with the respective p-type regions thereunder. A common ground electrode 66 is formed on the rear of the chip. A slot 68 is formed, for example with a diamond saw, partway through the chip. A sheet 70 of light absorbing material, such as carbon loaded polymeric film, is fixed in the slot for optically isolating the emitter and the detector.

Preferably, lens 36 (see FIG. 3) is coated with an antireflection coating tailored for the wavelength of light emitted by the LED forming the emitter 38. The solid line 72 in FIG. 5, schematically illustrates the transmittance of such an antireflection coating optimized for an LED emitting in the infrared region of the spectrum at about 940 nm. An infrared transmissive filter 74 is placed over the photodiode detector 40 to tailor the response of the detector to wavelengths of light emitted by the LED, thereby increasing the signal-to-noise ratio of the rangefinding device. A suitable filter for this purpose is the Wratten 87 C Filter manufactured by the Eastman Kodak Company. The spectral transmission of the infrared transmissive filter is illustrated by the dashed line 76 in FIG. 5.

The electronic control circuit 42 will now be described with reference to FIG. 6. Control circuit 42 includes a camera control

logic circuit 78, comprising a programmed microcomputer, as is well known in the prior camera control art. The camera control logic circuit 78 receives an input from the shutter release button 44 to begin operation. The computer turns on an oscillator 80 that applies an AC voltage to the light emitting diode forming the emitter 38, causing the diode to emit a beam of light having an identifiable AC brightness component. The frequency of oscillator 80 is chosen to be compatible with the frequency response of the LED and to be distinguishable from the flicker frequencies associated with artificial illumination.

The signal generated by the photodiode forming the detector 40 is amplified and filtered in a band-pass filter 82 having a pass band centered about the oscillator frequency. The output of the band-pass filter 82 is applied to a trigger circuit 84, which provides a logic level output signal when the output of band-pass filter 82 exceeds a predetermined threshold. The threshold of trigger circuit 84 is set to substantially eliminate the possibility of triggering on noise such as cross-talk between the emitter and detector, caused for example by light reflected within the enclosure. The sides and back of the enclosure are painted black to further reduce this potential source of noise. Camera control logic circuit 78 receives the logic signal from trigger circuit 84 and controls a focussing drive control circuit 86 in response to the signal. The circuit 86 applies power to the electromagnetic actuator 34 (see FIG. 2) to move closeup lens 32 in or out of the optical path of the taking lens 28.

The camera control logic may also control camera exposure, receiving signals from a photometer 88 in controlling a shutter driver 90 in a known manner.

5 In the above embodiment, the following dimensions exist. The lens 36 is a 20 mm focal length F2.0 convex lens. The width of slot 68 in the emitter/detector chip 54 is approximately 150
10 microns, thereby spacing the LED and photodiode approximately 150 microns apart. The emitter 38 and detector 40 are located substantially in the focal plane of lens 36 and arranged substantially
15 symmetrically about the optical axis of lens 36. As a result of this arrangement, the detection region 18 (see FIG. 1) extends approximately 1.3 meters from the lens.

Figure 7 schematically illustrates a second embodiment of the present invention employed in a still camera 110 of a kind known in the art and
20 including a housing 111, aperture 112, taking lens 113, viewfinder 114, shutter release 115 and other conventional still camera mechanisms (not shown). In the illustrated still camera the rangefinder in accordance with the present invention and denoted
25 generally 120, is embodied as a rangefinder for controlling the position of the camera's taking lens 113.

The rangefinder 120 comprises, in general, a single lens 121 mounted in predetermined spaced
30 relation with respect to an emitter and detector panel 122 by support means 123. The details of the rangefinder 120 can be seen more clearly in Figures 8 and 9. The emitter and detector panel 122 comprises a light emitter 124 located on the optical axis of
35 the lens 121 and two concentric photodetectors



125 and 126, respectively, located at different distances from emitter 124. The emitter 124 and detectors 125 and 126 lie substantially in a common emitter and detector plane and are mounted generally coaxially with the optical axis 128 of lens 121, with the common emitter and detector plane substantially normal to axis 128. The emitter 124 can be a light emitting diode (LED) adapted to emit visible or other radiation. The term "light" as used herein includes visible as well as other radiation outside the normal visible range of the electromagnetic spectrum. The detectors 125 and 126 can be any of a variety of photoelectric transducers such as photocells or semiconductor light sensors. The single lens 121 can comprise a single convex lens element, as illustrated, or more complex multi-element structures. The lens desirably is optimized for operation at the wavelength of the light emitted by the emitter (e.g. in regard to antireflection coatings) but need not be corrected for chromatic aberration.

The distance between the lens 121 and the common emitter and detector plane of panel 122 is important. This can be explained more easily with reference to Figure 10, where the plane of a reflective object O_1 , the lens 121 and the emitter and detector plane 122 are illustrated in one exemplary interrelation. As shown, the emitter and detector plane is located at or proximate the focal plane of lens 121. With this arrangement the light emitted from emitter 124 is directed forwardly (solid lines), by the lens, substantially parallel to the optical axis 128, which extends along the detection region of the device 120, to the object O_1 . The light reflected from the object O_1

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(dotted and dash lines) passes back through lens 121 and is directed backwardly to the vicinity of the detector means, i.e. to plane 122, in a manner dependent on the distance of the object from the rangefinder. Specifically, the extent of the out-of-focus condition of the reflected light, e.g. a spot, at plane 122 is inversely proportional to the distance of the object O_1 from lens 121. When the plane 122 is precisely at the focal plane of lens 121, the diameter D of the "blur circle" at plane 122 is defined by the relation:

$$D = \frac{2fd}{Z}$$

where f is the focal length of the lens, d is the lens diameter and Z is the object distance. For other plane 122 positions proximate the focal point of lens 121, the size of the blur circle also is a monotonically decreasing function of the distance of the light-reflecting object.

Because of the above-described relationship of the size of the blur circle to the distance of the object, the relative light intensity within the blur circle at different distances from the light emitter 124 varies in a way indicative of the distance Z of the object (generally linearly with respect to distance from the emitter). Figure 11 illustrates graphically the underlying principles by means of a plot of the amplitude of reflected light at plane 122 versus the distance from the emitter 124. In Figure 11 it can be noted that the curve S_1 , representing the amplitude versus distance-from-emitter characteristic for light reflected from the object O_1 , is significantly different from the similarly-plotted curve S_2 .

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which represents amplitude versus distance-from-emitter for light reflected from a closer, similarly reflective object O_2 . The distance to a particular object is determined by identifying its relative-light-amplitude versus distance-from-emitter characteristic at plane 122.

One advantageous way to identify the different object-reflected light characteristics representing different object distances (e.g. curves S_1 and S_2) is by means of a slope value for the curve. For this purpose, at least two detectors 125, 126 are located at different distances l_1 and l_2 from the emitter 124 and each detector provides an electrical signal having an amplitude which is proportional to the light amplitude incident on it. A normalized slope value "s" for the curve therefore can be determined by simple analog signal processing circuitry by the relation

$$s = \frac{A_1 - A_2}{l_1 - l_2} \cdot \frac{1}{A_1}$$

where A_1 and A_2 are the amplitudes of the electrical signals from detectors 125 and 126 respectively. In the above relation, the slope value is normalized by the factor $1/A_1$ because the amount of light reflected back from a given object (and collected by lens 121) varies inversely with the distance of the object. Normalization also is important because different objects have different reflectivities. It will be appreciated that sensed value other than A_1 can be used for normalization, it being preferred to obtain a value for the amplitude of the reflected light from a location on plane 122 that is as close to the emitter as practical.

The slope of the curve is indicative of the ratio of the light amplitudes at the two detectors. If more than two detectors are used, the derived slope of the curve is taken as the ratio of the light amplitudes.

5 Fig. 12 shows a signal processing circuit 130 in which the output currents from photodetectors 125 and 126 are applied to respective current to voltage converter circuits 161, 162 (e.g. operational amplifiers), whose
10 outputs are applied to a difference amplifier circuit 163. The difference amplifier circuit 163 performs the operation $A_1 - A_2$ of the above equation and applies the resultant analog difference signal to analog divider
15 circuit 164 which can be one of various types known in the art (e.g. having matched MOS transistors or operational amplifiers). The circuit 164 performs the normalization
 dividing $A_1 - A_2$ by the quantity A_1 provided by converter circuit 161. The resultant analog signal is
 uniquely indicative of a particular object distance.

 In the camera illustrated in Figure 7, such
20 signal processing circuit 130 provides its outputs (control voltages of varying magnitude dependent on object distance) to control the flexure of bimorph bender
 elements 137, 138, and thus the position of taking lens 113 along the picture taking optical axis 118 of the
25 camera. In the rangefinder shown in Figure 7 it is preferred that the optical axis 128 of the device 120 be
 substantially parallel to the picture taking optical axis 118. Further detailed description of suitable bimorph
 bender constructions and electrical control for lens
30 positioning is set forth in text No. 20340 in the March 1981 edition of the journal Research Disclosure. For
 larger lens focus displacements the output of processing circuit can

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control a lens drive motor (e.g. by means of a read only memory or potentiometer circuit) to move the lens 113 to the correct position for photographing a detected object.

As noted above, the emitter and detector plane
5 is located at or proximate the focal plane of the lens means 121. The desired precision of such placement depends upon the focal length of the lens and upon the accuracy of distance detection needed for a particular application. For example with a lens having focal
10 length $f = 50$ mm, a spacing of the emitter plane 0.08 mm behind the lens focal plane causes less than 10% difference in the output signal at an object distance of 3 m or less (compared to the signal created when the plane is positioned precisely at the lens focal plane).
15 In some applications it is preferred to position the emitter slightly behind the lens focal plane to focus the emitted light toward a point beyond the object ranges of interest. This may be so if the rangefinder has been designed to operate within a certain range of
20 distances and after manufacture it is desired to operate in a lesser range.

The emitter and detector configuration preferably is generally centered with respect to the optical axis of the lens 121. However, this device is
25 quite forgiving with respect to such centering. For example, with the lens, emitter and detector described above, a centering deviation of 7mm from the optical axis produces only about 1% signal change (compared to the signal from a configuration precisely centered on
30 the lens optical axis).

Figures 13 and 14 illustrate configurations for emitter and detector panels alternative to that illustrated in Figs. 8 and 9. In Figure 13 the panel 170 comprises an emitter bar 171 which is optically

isolated by elements 172 (e.g. a carbon-filled plastic chip) from detector bars 173, 173', 174, 174' and 175, 175'. The additional detectors 175, 175' are spaced further from the emitter bar 171 to provide added accuracy for close-in distances (where the slopes of the curves S are more gradual). In Figure 14, the emitter and detector configuration provides the emitter 181 at an outer concentric location to inner concentric detectors 183 and 184.

Figure 15 illustrates a particularly preferred construction for emitter and detector panel 122. In this configuration the emitter and detectors are formed as a monolithic, integrated array of solid state devices. The panel 122 shown in Figure 15 comprises a gallium arsenide substrate 191 (n-Ga As) material overlying a metal layer 192 (e.g. a gold-germanium alloy) and having formed thereon as gallium arsenide phosphide layers 193 (graded epitaxial layer of n-Ga As_{1-y} Py) and 194 (epitaxial layer n-Ga As_{1-x} Px). The emitter and detector p regions 195 and 196 respectively are formed by standard photolithographic techniques and zinc diffusions to comprise p-Ga As_{1-x} Px material. A silicon nitride dielectric layer 197 isolates the emitter and detector regions electrically and an optically dense material, e.g. carbon-filled plastic is formed in a cut groove 198 to optically separate the regions 195 and 196. Electrodes 199 are formed of aluminum and configured by standard metallization techniques, and an antireflection coating 200 is formed on the emitter and detector regions as shown.

The examples illustrated in Figs. 7 to 15 are simple optically (because a single lens element is used) and electrically (because analog signal is used) and alignment is facilitated because the emitter and detectors can be fabricated together and because the single lens causes the reflected radiation to always be centred on the emitter, where the emitter is located on the optical axis.

By having a single lens for directing radiation from the emitter forwardly, and for directing reflected radiation backwardly to the vicinity of the detector means, with the effective aperture provided by the lens for the emitter and the detector means being substantially coincident, the frontal surface area, for example, of a camera, occupied by the rangefinder is kept to a minimum, and conversely the area taken up by the rangefinder is put to maximum use because the aperture of the lens is used for both directing and collecting. Also, the rangefinder is relatively simple to manufacture.

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Claims:

1. A rangefinder, for determining the range of an object, comprising a radiation emitter and detector means for detecting radiation generated by the emitter and reflected by the object, a single lens for directing radiation from the emitter forwardly, and for collecting reflected radiation and directing it backwardly to the vicinity of the detector means, the radiation emitter and detector means being located in or proximate the focal plane of the lens, and the effective aperture provided by the lens for the emitter and for the detector means being substantially coincident.
2. A rangefinder as claimed in claim 1, wherein the radiation is arranged to be directed forwardly by the single lens through a first generally cylindrical volume of space, and the detector means is arranged to receive, through the lens, radiation from a second generally cylindrical volume of space, a third volume of space being common to said first and second volumes and extending a predetermined distance from said lens, the rangefinder further including means responsive to the detector means for detecting whether a reflecting object lies in the third volume of space.
3. A rangefinder as claimed in claim 1 or 2, wherein the emitter and detector means include solid state devices integrated on a common substrate.
4. A rangefinder as claimed in claim 3, wherein the emitter and the detector means are sealed in a container of which the lens forms one end.
5. A rangefinder as claimed in claim 1, wherein the detector means includes two detectors located at different distances from the emitter, the two detectors signalling the amplitude of light incident on them which is directed backwardly by the lens, having been reflected by the object, the



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rangefinder further including means for processing the signals from the detectors to produce an output signal indicative of the object's distance.

6 A rangefinder substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 6 of the accompanying drawings.

7 A camera including a rangefinder as claimed in any preceding claim.

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