

DEVICES AND METHODS FOR DETERMINING DISTANCES

The present invention relates to devices and methods for determining distances and more particularly to active devices and methods wherein a radiation beam is transmitted to an object and reflected back to photo-electric sensor means.

Distance determining devices are employed in a variety of known apparatus. For example, such devices are useful in focus control systems, e.g. as rangefinders, in cameras, to determine the correct focus position for a lens.

Active electro-optical distance determining devices, which form one useful class within a wide variety of distance determining devices, typically employ a light emitter(s), optical means (e.g. a lens) for directing emitted light toward an object to be sensed, a photoelectric detector(s) for sensing light reflected from the object and optical means for directing the reflected light onto the detector(s). U.S. Patents 3,443,502; 3,720,148 and 4,065,778 are exemplary of triangulation techniques for active distance determination; the emitter means and detector means are spaced a known distance along a triangle base and the devices compute the object distance based on a measure of the angle between the emitted beam axis and the axis of the received beam reflected from the object.

The device disclosed in U.S. Patent 3,617,128 differs from triangulation-type distance detectors in that light is directed to the object and reflected back to the detectors along a generally common axis. The object distance is determined as being within one of a plurality of discrete range-zones based on the size of the object's

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reflected light "blur circle" (i.e., the out of focus
light spot formed at a detection plane, substantially
normal to the optical axis of the device's receiving
lens, by the object-reflected light). Blur circle
5 size is determined only approximately as extending
onto (or not extending onto) different ones of a
plurality of detectors located at different positions
in the detection plane.

In accordance with one aspect of the present
10 invention there is provided a device for determining
the distance of a radiation reflective object,
comprising means for projecting radiation onto the
object, lens means for collecting radiation reflected
by the object, at least two radiation detectors in
15 the focal plane of said lens means at different
distances from the optical axis thereof, and means
for processing the signals from the detectors to
produce an output signal indicative of the ratio of
the amplitudes of the object-reflected radiation
20 incident on the detectors, which ratio is indicative
of the distance of the object.

Such a device has the advantage that
determination of object distance within one
substantially continuous range-region can be achieved
25 as an analog output rather than being merely an
indication of within which one of several discrete
range zones the object lies. Also, the device may
have relatively low sensitivity to variations in
reflectivity among different objects whose distance
30 is to be determined.

Advantageously, the lens means serves also as
the projecting means. The projecting means may further
include a radiation emitter. The emitter has an emitter
zone in or proximate the focal plane of the lens means.

Having a single lens means for the projecting means and for collecting reflected radiation has advantages in economy, simplicity of manufacture and optical efficiency.

Advantageously, the output signal is normalised
5 by the inclusion of a magnitude adjustment based on the amplitude of object-reflected radiation on a predetermined portion of the plane in which the emitter and the detector lie.

Preferably, the detectors and the emitter
10 are formed on a common planar substrate. This has advantages in simplicity of manufacture. The detectors and emitter may be constructed as a solid state integrated circuit.

In accordance with another aspect of the
15 present invention, there is provided a method for determining the distance of a radiation reflective object, including projecting a radiation image at the object, collecting with a lens object-reflected radiation, sensing the amplitude of object-reflected
20 radiation at at least two detection zones located at different distances from the optical axis of the lens, and deriving a signal indicative of the ratio of the sensed amplitudes, which signal is indicative of the distance of said object.

25 The subsequent description of embodiments of the invention refers to the attached drawings wherein:

Figure 1 is a schematic perspective view of a camera employing a distance detection device, in accordance with the present invention, as a
30 rangefinder;

Figure 2 is an axial sectional view of a first embodiment of a distance detection device in

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accordance with the present invention;

Figure 3 is a front view of an emitter-detector portion of the distance detection device shown in Figure 2;

5 Figure 4 is a ray diagram illustrating the light emitted to and reflected from an object by a device in accordance with the present invention;

10 Figure 5 is a reflected-light-amplitude versus detector distance-from-optical axis curve for two objects at different distances;

Figure 6 is a diagram illustrating signal processing circuitry for use in an embodiment of the present invention;

15 Figures 7 and 8 are views similar to Figure 3 but showing second and third forms of emitter-detectors; and

20 Figure 9 is a cross-sectional view of one preferred integrated circuit form of emitter-detector panel useful in a device in accordance with the present invention.

25 Figure 1 illustrates schematically an embodiment of the present invention employed in a still camera 10 of a kind known in the art and including a housing 11, aperture 12, taking lens 13, viewfinder 14, shutter release 15 and other conventional still camera mechanisms (not shown). In the illustrated still camera the distance detector, in accordance with the present invention and denoted generally 20, is embodied as a rangefinder for
30 controlling the position of the camera's taking lens 13.

35 The distance detector 20 comprises lens means 21 mounted in predetermined spaced relation to an emitter and detector panel 22 by support means 23. The details of the distance detector 20 can be seen more clearly in Figures 2 and 3. The

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emitter and detector panel 22 comprises a light emitter 24 located in the optical axis of the lens 21 and two concentric annular photodetectors 25 and 26 respectively located at different distances, i.e. radii, from emitter 24. In that the detectors are at different distances from the emitter, they are also at different distances from the optical axis of the lens means. The emitter 24 and detectors 25 and 26 have emitter and detector zones, respectively, which lie substantially in a common emitter-detector plane 19 and are mounted generally coaxially with the optical axis 28 of lens means 21, with the common emitter-detector plane 19 substantially normal to axis 28. In the present embodiment the emitter 24 is a light emitting diode (LED) adapted to emit visible or other radiation. The emitter and the lens means constitute means for projecting radiation onto the object whose distance is to be measured. The term "light" as used herein includes visible as well as other radiation outside the normal visible range of the electromagnetic spectrum. The detectors 25 and 26 can be any of a variety of photoelectric transducers such as photocells or semiconductor light sensors. Lens means 21 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. In this embodiment the lens of the projecting means and the lens through which light returns to the detectors are one and the same. However, embodiments could be constructed in which the lenses are different.

35 The distance between the lens means 21 and the common emitter-detector plane 19 of panel 22 is

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important. This can be explained more easily with reference to Figure 4, where the plane of a reflective object O_1 , the lens means 21 and the emitter-detector plane 19 are illustrated in one exemplary interrelation. As shown, the emitter-detector plane 19 is preferably located at or proximate the focal plane of lens means 21. With this arrangement the light emitted from emitter 24 is directed (solid lines) by the lens means 21 substantially parallel to the optical axis 28, which extends along the "detection region" of the detector 20, to the object O_1 . The light reflected from the object O_1 (dotted and dash lines) passes back through lens means 21 to plane 19 in a manner dependent on the distance of the object from the detection device. Specifically, the extent of the out-of-focus condition of the reflected light e.g. a spot, at plane 19 is inversely proportional to the distance of the object O_1 from lens means 21. When the plane 19 is precisely at the focal plane of lens means 21, the diameter D of the "blur circle" at plane 19 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 19 positions proximate the focal point of lens means 21, 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 24 varies

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in a way indicative of the distance Z of the object (generally linearly with respect to distance from the emitter). The present invention uses this characteristic that the ratio of light amplitudes measured
5 by the detectors at different distances from the emitter varies predictably with object distance, to derive outputs respectively representative of the distance to different objects.

Figure 5 illustrates graphically the principles
10 underlying a particular distance detection device in accordance with the present invention by means of a plot of the amplitude of reflected light at plane 19 versus the distance from the emitter 24. In Figure 5 the curve S₁, representing the amplitude versus
15 distance-from-emitter for light reflected from object O₁, is significantly different from the similarly-plotted curve S₂, which represents amplitude versus distance-from-emitter for light reflected from a similarly reflective closer object O₂.

20 At least two detectors 25, 26 are located at different distances l₁ and l₂ from the emitter 24 and each detector provides an electrical signal having an amplitude which is proportional to the light amplitude incident on it. A normalized slope value
25 "s" for the curve therefore can be determined by simple analog signal processing circuitry by the relation

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

where A₁ and A₂ are the amplitudes of the electrical signals from detectors 25 and 26 respectively. In the above relation, the slope value is normalized
35 by the factor $\frac{1}{A_1}$ because the amount of light reflected

back from a given object (and collected by lens means 21) varies inversely with the distance of the object. Normalization also is important because different objects have different reflectivities. It will be appreciated that a 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 19 that is as close to the emitter 24 as practical.

It will be recognized that 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 desired slope of the curve is taken as the ratio of the light amplitudes. Reference is now made to the signal processing circuit 30 shown in Figure 6. As shown, the output currents from photodetectors 25 and 26 are applied to respective current to voltage converter circuits 61, 62 (e.g. operational amplifiers), whose outputs are applied to a difference amplifier circuit 63. The difference amplifier circuit 63 performs the operation $A_1 - A_2$ of the above equation and applies the resultant analog difference signal to analog divider circuit 64 which can be one of various types known in the art (e.g. having matched MOS transistors or operational amplifiers). The circuit 64 performs the normalization dividing $A_1 - A_2$ by the quantity A_1 provided by converter circuit 61. The resultant analog signal is uniquely indicative of a particular object distance.

In the camera shown in Figure 1, the output (control voltages of varying magnitude dependent on object distance) of the signal processing circuit 30 controls the flexure of bimorph bender elements 37, 38, which control the position of taking lens 13 along the picture taking optical axis 18 of the camera. In

the rangefinder shown in Figure 1 it is preferred that the optical axis 28 of the distance detector 20 be substantially parallel to the picture taking optical axis 18. Further detailed description of suitable
5 bimorph bender constructions and electrical control for lens positioning is set forth in text No. 20340 in the March 1981 edition of the journal Research Disclosure. For larger displacements for focussing a lens the output of processing circuit can control a
10 lens drive motor (e.g. by means of a read only memory or potentiometer circuit) to move the lens 13 to the position proper for photographing a detected object.

As noted above, the emitter-detector plane preferably is located at or proximate the focal plane
15 19 of the lens means 21. 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 length $f = 50$ mm, a spacing of the
20 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 19 is positioned precisely at the focal plane of the lens). In some
25 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. An example of such an application is one in which a device in accordance with the invention has
30 been designed to operate optimally within a particular range of distances and it is desired, subsequently to manufacture, to operate optimally in a lesser range. It has been found that in such circumstances superior results may be achieved if the emitter is slightly

displaced from the focal plane.

Preferably, the emitter and detectors are centered generally on the optical axis 28 of the lens means 21. However, the device is quite forgiving with respect to such centering. For example, with the lens, emitter and detectors 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 the optical axis of the lens).

Figures 7 and 8 illustrate alternative configurations for emitter-detector panels. In Figure 7 the panel 70 comprises an emitter bar 71 which is optically isolated by elements 72 (e.g. a carbon-filled plastic chip) from detector bars 73, 73', 74, 74' and 75, 75'. In this configuration, additional detectors 75, 75' are spaced further from the emitter bar 71 to provide added accuracy for close-in distances (for which the slopes of the curves S are more gradual). In the Figure 8 embodiment, the emitter-detector configuration is such that the emitter 81 is radially outside and concentric with concentric annular detectors 83 and 84.

Figure 9 illustrates an emitter-detector panel 22' in which the emitter and detectors are formed as a monolithic, integrated array of solid state devices. The panel 22' shown in Figure 9 comprises a gallium arsenide substrate 91 (n-Ga As) material overlying a metal layer 92 (e.g. a gold-germanium alloy) and having formed thereon as gallium arsenide phosphide layers 93 (graded epitaxial layer of n-Ga As_{1-y}Py) and 94 (epitaxial layer n-Ga As_{1-x}Px). The emitter and detector p regions 95 and 96 respectively are formed by standard photolithographic techniques and zinc diffusions to comprise p-Ga As_{1-x}Px material. A silicon nitride dielectric layer 97 isolates the

emitter and detector regions electrically and an optically dense material, e.g. carbon-filled plastic is formed in a cut groove 98 to optically separate the regions 95 and 96. Electrodes 99 are formed of
5 aluminum and configured by standard metallization techniques, and an antireflection coating 100 is formed on the emitter and detector regions as shown.

Embodiments of the present invention may be simple optically (because a single lens element can be used)
10 and electrically (because analog signal can be used). It will be appreciated, however, that digital processing circuitry (e.g a microprocessor circuit on a read only memory circuit) can be used if desired. Structures in accordance with the present invention
15 facilitate alignment because the emitter and detectors can be fabricated together and because the single lens causes the reflected radiation to always be centered on the emitter.

Further, the number of ranges of distance
20 detectable is not a function of the number of detectors utilized. That is, the distance sensitivity of devices and methods in accordance with the present invention is, generally, limited by signal-to-noise considerations rather than by the number of
25 detectors. Additionally, devices and methods in accordance with the present invention can be not highly sensitive to variance in reflectivity of the object whose distance is being detected because the sensor outputs are compared to each other rather than
30 to predetermined thresholds. In certain applications it may be desirable to employ devices in accordance with the present invention in conjunction with signal processing circuitry which subtracts background noise such as that due to ambient light.

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CLAIMS

1 A device for determining the distance of a radiation reflective object, comprising means for projecting radiation onto the object, lens means for collecting radiation
5 reflected by the object, at least two radiation detectors in the focal plane of said lens means at different distances from the optical axis thereof, and means for processing the signals from the detectors to produce an output signal indicative of the ratio of the amplitudes of the object-
10 reflected radiation incident on the detectors, which ratio is indicative of the distance of the object.

2 A device as claimed in claim 1, wherein the lens means serves also as the projecting means, and the projecting means further includes a radiation emitter, the emitter
15 having an emitter zone in or proximate the focal plane of the lens means.

3 A device as claimed in claim 1 or 2, wherein output signal is normalised by the inclusion of a magnitude adjustment based on the amplitude of object-reflected
20 radiation at a predetermined position on the plane in which the detectors lie.

4 A device as claimed in claim 2 or 3, wherein the detectors and the emitter are formed on a common planar substrate.

25 5 A device as claimed in claim 4, wherein the detectors and the emitter are constructed as a solid state integrated circuit.

6 A device for determining the distance of a radiation reflective object substantially as hereinbefore described
30 with reference to and as illustrated in Figs. 1 to 6 or Figs. 1 to 6 as modified by Fig. 7 or Fig. 8 or Fig. 9 of the accompanying drawings.



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- 7 A method for determining the distance of a radiation-reflective object, including projecting radiation at the object, collecting with a lens object-reflected radiation, sensing the amplitude of object-reflected
- 5 radiation at at least two detection zones located at different distances from the optical axis of the lens, and deriving a signal indicative of the ratio of the sensed amplitudes, which signal is indicative of the distance of said object.
- 10 8 A method of determining the distance of a radiation-reflective object as claimed in claim 7 and substantially as hereinbefore described.
- 9 A photographic camera incorporating a device as claimed in any of claims 1 to 6.
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