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Coaxial unfocused optical sensor for dual mode seekers
Coaxialer ungebündelter optischer Sensor für einen Doppelsuchkopf
Capteur coaxial optique non-focalisé pour un autodirecteur à deux modes

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Description

Background of the Invention

[0001] The present invention is directed to an optical sensor which may be used in conjunction with a radio frequency (rf) sensor as part of a dual mode sensor. More particularly, this invention relates to a dual mode millimeter wave and optical sensor system for use with a guidance system of a projectile.

[0002] Dual mode sensors are increasingly employed in conjunction with the guidance systems of munitions to improve operational flexibility and resistance to countermeasures. A number of approaches have been taken in designing such dual mode sensors.

[0003] In one approach called 'common aperture' and often seen in aperture-limited applications such as munitions and covert sensors, a common aperture is shared by the radio frequency (rf) sensor and the optical sensor so as to allow each sensor to collect the maximum incoming energy. To that end, US 5,214,438 discloses a millimeter wavelength (mmw) and infrared sensor having a common receiving aperture. US 4,866,454 similarly discloses a multi-spectral imaging system having a common aperture. Other representative patents include US 4,652,885 and US 4,636,797 which both disclose a dual mode antenna in which mmw and infrared energy enter a common aperture and propagate through a common transmission device to a point where the energies of respective wavelengths are divided for subsequent processing. "Common Aperture Dual Mode Semi-Active Laser/Millimeter Wave Sensor" a US Patent application serial number 08/959,602 filed October 28, 1997 describes yet another approach to a dual mode single aperture sensor which uses a pyramid with surfaces selectively coated to reflect semi-active laser energy and selectively passes mmw energy.

[0004] Unfortunately, common aperture dual mode sensors typically result in decreased sensitivity and decreased accuracy for both modes. Elements that are used by both the mmw and optical sensors must either be broadband to encompass both operating wavelengths thereby decreasing sensitivity or have selective coatings to selectively pass one wavelength while reflecting the other. Where it is desired to use such dual mode sensors on high speed munitions, the design problems are exacerbated as many of the coatings and other materials useful for single aperture constructions are not robust enough to operate at high speeds where frictional heating becomes significant.

[0005] In another approach to the dual mode sensor called 'separate aperture', separate apertures are employed for each wavelength band. US 5,182,564 to Burkett et al. discloses one such device in which a mmw rf microstrip array is embedded within an infrared reflector assembly. US 4,264,907 to Durand, Jr. et al. discloses a seeker system on a missile comprising an infrared sensor and an rf sensor. The dual mode seeker employs two rf antennae emanating from the missile. US 4,108,400 to Groutage et al. also discloses a dual mode guidance system having two separate apertures for detecting energy. The rf sensors are disposed on the skin of a missile about an alternate sensor. US 4,698,638 to Branigan et al. discloses a dual mode target seeking system comprising an rf antenna and an electro-optical processing system extending through the rf antenna.

[0006] Where wavelengths in excess of mmw are detected, an optical sensor may be placed in front of the rf sensor without significantly interfering in the operation. In the case of mmw, however, the blockage of the center of the rf sensor by the electro-optical sensor can degrade the resolution of the rf sensor. While this problem can be minimized by reducing the size of the optical sensor, this in turn reduces the sensitivity and range of the optical sensor.

[0007] US 5 319 188 discloses an optical detection system which is primarily useful in detecting incident laser illumination, permitting simple signal processing to determine the direction of the illumination. The detection system comprises an annular or circular entrance opening in an opaque plate and a circular optical detector spaced from and axisymmetric with the opening. Laser or other collimated light energy passing through the opening illuminates all, or particular portions of the detector depending on the direction and angle of incidence of the energy, thereby providing all of the information necessary to determine the elevation and azimuth of the source of the energy.

[0008] It is a goal of the present invention to provide an unfocused optical sensor which may be used in conjunction with an rf sensor as part of a dual mode sensor that overcomes the problems of the prior art devices. The inventive dual mode sensors have an inner mmw rf sensor surrounded by an unfocused optical sensor and can be used in conjunction with the guidance system of a munition.

[0009] For the purposes of this disclosure, the term 'munition' is to be understood in its generic sense which includes projectiles, and ammunition including bullets, missiles and rockets. Also, for the purposes of this application, the term 'target source of optical energy' shall refer to any source of reflected optical energy, i.e. any optical energy reflected off of a target.

Summary of the Invention

[0010] The goal mentioned above has been achieved according to the present invention by a sensor for use with a guidance system of a munition, as defined in claim 1. Advantageous embodiments are claimed in dependent claims 2 to 7.
Brief Description of the Figures

[0011]

Figure 1 is a perspective view of one embodiment of the inventive optical sensor.

Figure 2 shows a side cross-sectional view of an inventive dual mode sensor.

Figure 3 shows a front elevation view of an optical sensor for use in the present invention.

Figure 4 is a cross-sectional view of an optical sensor for use in the present invention showing a ray trace of optical beams of a given angle impinging on the inventive dual mode sensor.

Figure 5 is a block diagram of the inventive dual mode sensor in use.

Detailed Description of the Invention

[0012] While this invention may be embodied in many different forms, there are described in detail herein specific preferred embodiments of the invention. This description is an exemplification of the principles of the invention and is not intended to limit the invention to the particular embodiments illustrated.

[0013] The sensor system of the present invention is intended for use as a target measurement device mounted on a munition or other suitable support system. As seen in Fig. 1, an optical sensor, shown generally at 100, comprises a plurality of optical detector units 104. Each of the optical detector units 104, when illuminated with optical energy of the appropriate frequency, produce an optical detector output signal. Optical detector units 104 are disposed, preferably symmetrically disposed in an annulus 114, about a common point 108. One or more light blocking devices 112 are arranged in a substantially circular shape around common point 108.

Light blocking device, shown as cylinder 112 are constructed and arranged so as to block at least a portion of any incoming optical energy propagating in a direction oblique to the longitudinal axis of the munition from one or more of the optical detector units 104. The sensor system further comprises a signal processor 248 (shown in Fig. 2) operably associated with the optical detector units to receive the optical detector output signals and provide a guidance signal to the guidance system.

[0014] Although not essential, the sensor desirably comprises an even number of optical detector units. It is more desirable that the system comprise at least four optical detector units. The accuracy of the sensor increases with the number of optical detector units. In a preferred embodiment, the sensor contains eight optical detector units. Optionally, each optical detector unit may be formed of two or more smaller optical detectors slaved together to produce one optical detector output signal. Each optical detector unit, whether consisting of a single optical detector or several optical detectors slaved together, is operably associated with the signal processor. As such, the signal processor has ‘n’ channels, where ‘n’ corresponds to the number of optical detector units.

[0015] While it is preferable that the light blocking device(s) have a substantially circular cross-section, other cross-sectional shapes may be used as well, such as an ellipse or a square. In the preferred embodiment of Fig. 1, the light blocking device is cylindrical.

[0016] The light blocking device is desirably reflecting, made of aluminum or aluminized Mylar, so as to reflect impinging optical energy outward onto one or more optical detector units and thereby increase the signal reaching the illuminated optical detector units. Where the light blocking device is reflecting, it is desirable, although not necessary that it be uniformly reflecting. Other possibilities for a reflective light blocker include a light blocker with evenly spaced reflective strips.

[0017] Further, it is desirable that the light blocking device be oriented normal or nearly normal to the plane of the optical detector units, as shown in Fig. 1. In the former case, a cylindrical reflector is preferred. Where the light blocking device is reflecting, this angular relationship becomes more important as less light will be reflected onto the detectors as the angle between the plane of the optical detector units and the reflecting surface of the light blocking device becomes obtuse. Of course, the exact angle of the light blocking device relative to the detectors will depend on the geometrical constraints imposed by the frame on which the sensor is mounted. Where, for example, the sensor is mounted on a bullet, aerodynamic or other considerations may dictate an obtuse angle between the detectors and the reflecting surface of the light blocking device.

[0018] In a preferred embodiment, the optical detector units will be arc shaped and arranged in an annulus around a cylindrical, reflecting light blocking device as shown in Fig. 1. With reference to Fig.1, the length of light blocking device 112, as designated by reference numeral 113, is from about 1 to about 50 times the width of the optical detector units 104, designated by reference numeral 105 and defined to be the distance between inner arc 107 and outer arc 109 of a detector 104. It is desirable that the ratio of length 113 to width 105 be from about 1:1 to about 10:1 and more desirable that the ratio be from about 2:1 to about 4:1. It is even more desirable that the ratio be from about 2:1 to about 3:1.

[0019] The ratio of the length of the reflector to the width of the optical detector units will determine the angular field of view of the optical sensor. In the case where the optical sensor comprises an annulus of optical detector units and a cylindrical reflector disposed interior to and abutting the annulus, the field of view will be given by the inverse tangent of the ratio of the length of the reflector to the width (that is, the difference between the length of the outer radius of an optical detector unit and the inner radius of an optical detector unit.

[0020] In one embodiment, as shown in Figs. 2 and
the sensor system operates as a dual mode sensor, further comprising an rf sensor. The dual mode sensor shown generally at 210, comprises an inventive optical sensor comprising optical detector units 234 arranged in a substantially annular shape, shown generally at 214, mounted coaxially about an rf sensor, shown generally at 218. The dual mode sensor further comprises a light blocking device 222 constructed and arranged for blocking optical energy from one or more of the optical detector units 234 comprising the substantially annular optical detector units 214. As depicted, light blocking device 222 is mounted coaxially with rf sensor 218. In a preferred embodiment, light blocking device 222 is reflecting and reflects impinging optical energy onto one or more of the optical detector units forming substantially annular optical detector 214.

[0021] Each optical detector unit 234, in addition to the detector, further comprises a circuit board 242 for conditioning the signal output by the detector and preamps 246 for amplifying the optical detector output signal.

[0022] A signal processor 248 operably associated with the optical detector units 234 (including circuit boards 242 and preamps 246) receives the optical detector output signals from the optical detector units as well as from rf sensor 218 and provides a guidance signal to the guidance system of the munition.

[0023] The inventive sensor optionally further comprises optional optical filters 250, as are known in the art, mounted over the optical detector units 234 forming substantially annular optical detector 214. Optical filter 240 is a narrow band-pass filter designed to pass optical energy within a narrow range about the desired optical frequency (i.e. the frequency of the illuminator used to illuminate the target). Desirably, the optical filter will pass optical energy within an approximately 15-20 nm range about the optical wavelength to be detected and filter out optical energy of other wavelengths. Optical filter 240 may be bonded directly to the detectors or otherwise mounted in front of the optical detector units.

[0024] The optical sensor may further comprise an optionally transparent radome 222, mounted over substantially annular optical detector units 214 as well as an rf transparent radome 230 mounted forward of the rf sensor.

[0025] Substantially annular optical detector units 214, as shown in front elevational view in Fig. 3, is formed of a plurality of optical detector units 234 arranged in a segmented ring coaxially about the rf sensor as seen best in Figure 3. An even number of such detectors is desirable and four or more optical detector units are preferred. With additional detectors, higher accuracy measurements may be obtained. The detectors are symmetrically disposed in the segmented ring and are arranged such that for every detector, there is a paired detector situated across the ring from it. In the optical sensor shown in Fig. 3, eight detectors are present.

[0026] Although it is preferred that the optical detector units be arranged in an annulus, other shapes approaching an annulus are contemplated as well including a hexagon and other polygonal arrangements.

[0027] The operation of the inventive optical sensor including substantially annular optical detector units 214 is shown in Fig. 4. A target is illuminated with beams of optical energy by a remote illumination device such as a laser. The beams are scattered by the target, and some of the scattered optical energy is detected by the optical sensor. A portion of the scattered optical energy arrives at substantially annular optical detector units 214 as substantially parallel beams of optical energy 262a-e and disposed at a given angle relative to the longitudinal axis of the munition extending through the center of substantially annular optical detector 214. Although the optical energy is actually scattered by the target, the beams that are seen by the optical detector units when the detectors are at any significant distance from the target (i.e. where the distance between the sensor and the target is greater than several multiples of the diameter of the annulus of detectors) are substantially parallel. Beams 262 are then detected by pairs of oppositely disposed optical detector units 234. Considering one such pair of oppositely disposed optical detector units 234a and 234b, incoming parallel beams 262a,b are detected directly by optical detector unit 234a. Incoming beam 262c, although reflected by reflector 222 is also detected by optical detector unit 234a. Parallel beams 262d,e are not, however, detected by oppositely disposed optical detector unit 234b being blocked by light blocking device 222. As such, if a target is at a positive angle relative to the optical detector units, more optical radiation will be detected by optical detector unit 234a than by optical detector unit 234b. Of course, as the magnitude of the angle of the incoming optical radiation approaches 0°, optical detector unit 234b will begin to detect optical radiation. If the target is head-on, that is, at a 0° angle relative to the longitudinal axis extending through the center of substantially annular detectors 214, optical detector units 234a,b will detect equal amounts of optical radiation resulting in a null difference signal and a positive sum signal. This combination of a positive sum signal and zero difference signal helps distinguish between a target that is head-on and the absence of a target. Finally, if the target is at a negative angle relative to the longitudinal axis extending through the center of substantially annular detectors 214, optical detector unit 234b will detect more optical radiation than optical detector unit 234a. The difference in optical radiation detected by each pair of oppositely disposed optical detector units may then be analyzed to yield the location of the target.

[0028] Rf sensor 218 as shown in Fig. 2, comprises transceiver 314, transreflector 318, twist reflector 322 and optionally, rf radome 230. Transceiver 314 serves as a combination of an rf transmitter for transmitting rf signals to a target and rf receiver for receiving signals.
reflected off of the target. In use, transceiver 314 forms linearly polarized rf energy in a well-known manner. Because of the polarization of the rf energy relative to transreflector 318, the rf energy is collimated by transreflector 318 and reflected toward twist reflector 322. Transreflector 318 comprises a grid of parallel wires shaped so as to be able to collimate impinging rf energy of the appropriate polarization. Twist reflector 322 then shifts the phase of the reflected rf energy by ninety degrees and reflects the rf energy back towards transreflector 318. With the polarization shift, the collimated rf energy is transmitted through transreflector 318 and toward a target.

[0029] At least a portion of the polarized rf energy impinging the target is reflected back from the target, traversing transreflector 318 and impinging on twist reflector 322 where its polarization is again shifted by ninety degrees. The rf energy is reflected onto transreflector 318 which in turn focuses and reflects the rf energy on transceiver 314. Transceiver 314 includes a receiver for analyzing the return signal.

[0030] Although in a preferred embodiment, the rf sensor is configured to work in a conical scanning (con-scan), monopulse mode as is known in the art, the present invention is not intended to be limited to such an rf sensor. Other rf sensors, as are known in the art, may be used in conjunction with an optical detector in the practice of the present invention.

[0031] In general, the rf sensor, or more specifically, twist reflector 322 and transreflector 318 are mounted forward of substantially annular optical detector 214. Although in most applications, and as depicted in Fig. 2, substantially annular optical detector 214 is adjacent to and behind twist reflector 322 in the tip of the munition, substantially annular optical detector units 214 may be set further back in the body of the munition, depending on the shape of the munition and aerodynamic and other considerations.

[0032] In use, as shown in Fig. 5, a target 410 is illuminated with a beam of optical radiation 414 such as from remote illuminator 418. At least a portion 422 of optical radiation 414 reflected by target 410 is received by optical sensor 430. Similarly, rf sensor 434 transmits polarized rf energy 438 toward target 410. At least a portion 442 of rf energy 438 is reflected back to rf sensor 434. The detected rf and optical signals are processed in a signal processor 446 which outputs a guidance signal 450 to a guidance system 454 which guides the munition.

[0033] While the reflector is coaxial with the rf sensor, at least a portion of the reflector may be mounted concentrically about at least a portion of the rf sensor. Similarly, at least a portion of the optical sensor may be mounted concentrically about at least a portion of the rf sensor.

[0034] The preferred optical detector units for use with the present invention are silicon based detectors such as those manufactured by EG&G and Centronics which detect optical radiation between the wavelengths of about 200 nm to about 1100 nm. Of course, suitable optical detector units made from other materials, operating at other frequencies may also be used in conjunction with target illuminating devices operating at other wavelengths.

[0035] The target illuminator used in conjunction with the optical sensor produces optical radiation in a wavelength range detectable by the optical sensor. Where silicon detectors are used, the preferred target illuminator operates at a wavelength of 200 nm to 1100 nm. More desirably, the target illuminator will output energy of wavelength of about 1000 nm.

[0036] Although arc shaped optical detector units are preferred, as shown in Fig. 3, other shaped optical detectors units may be used as well including rectangular optical detector units. In general, as the number of optical detectors units decreases, it is more desirable to have arc segment optical detector units. In a preferred embodiment, eight silicon arc shaped optical detector units are employed. Each optical detector unit consists of two silicon arc shaped optical detector units slaved together to form one unit with one output signal.

[0037] The preferred rf detectors for use with the present invention operate in the mmw range and more specifically, in a frequency range of from about 30 GHz to about 150 GHz.

[0038] The signal processor and guidance system may be any suitable device as known in the art.

[0039] From the foregoing, it should be appreciated that the invention combines 1) an active mmw sensor that transmits energy toward a target and receives the reflected energy and 2) an unfocused optical sensor that receives electromagnetic radiation in the optical range reflected from the target such as by a remote illuminator.

[0040] The above Examples and disclosure are intended to be illustrative and not exhaustive. These examples and description will suggest many variations and alternatives to one of ordinary skill in this art. All these alternatives and variations are intended to be included within the scope of the attached claims. Those familiar with the art may recognize other equivalents to the specific embodiments described herein which equivalents are also intended to be encompassed by the claims attached hereto.

Claims

1. A sensor (100) for use with a guidance system of a munition, the munition having a front end and a rear end, and a longitudinal axis therethrough, the sensor mounted on the munition and comprising:

   a plurality of optical detector units (104; 234) disposed about a common point (108) on the longitudinal axis, each optical detector unit (104; 234) being situated substantially equidis-
tantly from the common point (108) to receive incoming optical energy from a target source (410) of optical energy, each optical detector unit (104; 234) on receiving incoming optical energy producing an optical detector output signal;

a light blocking device (112; 222) with a substantially circular shape arranged around the longitudinal axis, whereby at least a portion of the light blocking device (112; 222) is situated forward of the optical detector units (104; 234), wherein the light blocking device (112; 222) is situated closer to the longitudinal axis than the optical detector units (104; 234) are;

whereby the light blocking device (112; 222) is constructed and arranged so as to block at least a portion of any incoming optical energy propagating in a direction oblique to the longitudinal axis, from one or more of the optical detector units (104; 234); and

a signal processor (248) operably associated with the optical detector units (104; 234) to receive the optical detector output signals and provide a guidance signal to the guidance system.

2. The sensor of claim 1 wherein the light blocking device (112; 222) is reflecting and is arranged so as to reflect impinging optical energy onto at least one or more of the optical detector units (104; 234).

3. The sensor of claim 1 wherein the optical detector units (104; 234) are symmetrically disposed about the common point (108).

4. The sensor of claim 1 comprising an even number of optical detector units (104; 234), each optical detector unit (104; 234) oppositely disposed about the common point (108) from a second optical detector unit (104; 234).

5. The sensor of claim 1 further comprising an rf sensor (218) to receive rf energy and produce an rf sensor output signal, the signal processor (248) operably associated with the rf sensor (218) to receive the rf sensor output signal and provide a guidance signal to the guidance system.

6. The sensor of claim 5, the rf sensor further comprising a transreflector (318) and a twist reflector (322), wherein the plurality of optical detector units (104; 234) are mounted on the munition coaxially with and exterior to the transreflector (318) and a twist reflector (322), about the longitudinal axis of the munition.

7. The sensor of claim 5 wherein the rf sensor (218) detects rf in the frequency range of about 30 GHz to about 150 GHz.

Patentansprüche

1. Sensor (100) zur Verwendung mit einem Lenksystem einer Munition, wobei die Munition ein vorderes Ende und ein hinteres Ende und eine Längsachse dadurch aufweist, wobei der Sensor auf der Munition angeordnet ist und umfasst:

- eine Vielzahl von optischen Detektoreinheiten (104; 234), welche um einen gemeinsamen Punkt (108) auf der Längsachse angeordnet sind, wobei jede optische Detektoreinheit (104; 234) sich im Wesentlichen äquidistant von dem gemeinsamen Punkt (108) befindet, um eingegehende optische Energie von einer Zielquelle (410) optischer Energie zu empfangen, und jede optische Detektoreinheit (104; 234) beim Empfangen der eingehenden optischen Energie ein optisches Detektorausgangssignal produziert;

- ein Licht-Blockierelement (112; 222) mit einer im Wesentlichen Kreisform, welches um die Längsachse angeordnet ist, wodurch mindestens ein Teil des Licht-Blockierelementes (112; 222) sich vor den optischen Detektoreinheiten (104; 234) befindet, wobei das Licht-Blockierelement (112; 222) sich näher zu der Längsachse als zu den optischen Detektoreinheiten (104; 234) befindet; und

- wodurch das Licht-Blockierelement (112; 222) gebaut und angeordnet ist, um mindestens ein Teil jeder eingehenden optischen Energie, welche sich in einer zu der Längsachse schrägen Richtung verbreitet, von einer oder mehreren der optischen Detektoreinheiten (104; 234) zu blockieren; und

- einen Signalprozessor (248), welcher betätigbar mit den optischen Detektoreinheiten (104; 234) verbunden ist, um die optische Detektorausgangssignale zu empfangen und dem Lenksystem ein Lenksignal bereitzustellen.

2. Sensor nach Anspruch 1, wobei das Licht-Blockierelement (112; 222) reflektierend ist und so angeordnet ist, um einfallende optische Energie auf mindestens eine oder mehrere der optischen Detektoreinheiten (104; 234) zu reflektieren.

3. Sensor nach Anspruch 1, wobei die optische Detektoreinheiten (104; 234) symmetrisch um den gemeinsamen Punkt (108) angeordnet sind.

4. Sensor nach Anspruch 1, umfassend eine gerade
Anzahl von optischen Detektoreinheiten (104; 234), wobei jede optische Detektoreinheit (104; 234) um den gemeinsamen Punkt (108) gegenüber einer zweiten optischen Detektoreinheit (104; 234) angeordnet ist.


6. Sensor nach Anspruch 5, wobei der HF-Sensor einen Transreflektor (318) und einen Verdrehreflektor (322) weiter umfasst, wobei die Mehrzahl von optischen Detektoreinheiten (104; 234) auf der Munition angebracht ist, außerhalb des Transreflektors (318) und des Verdrehreflektors (322) und gleichachsig damit um die Längsachse der Munition.

7. Sensor nach Anspruch 5, wobei der HF-Sensor (218) HF in dem Frequenzbereich von ungefähr 30 GHz zu ungefähr 150 GHz detektiert.
Fig. 1
Fig. 4