United States Patent [19]

Sharpe et al.

[11] **3,801,821**

[45] **Apr. 2, 1974**

[54] **LARGE FIELD FLASH SENSOR**

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[73] Assignee: **Sun Chemical Corporation**, New York, N.Y.

[22] Filed: **June 14, 1973**

[21] Appl. No.: **369,823**

[52] **U.S. Cl.** ..... **250/209**, 250/220 M

[51] **Int. Cl.** **H01j 39/12**

[58] **Field of Search** ..... 250/209, 220 M, 208; 340/25, 27

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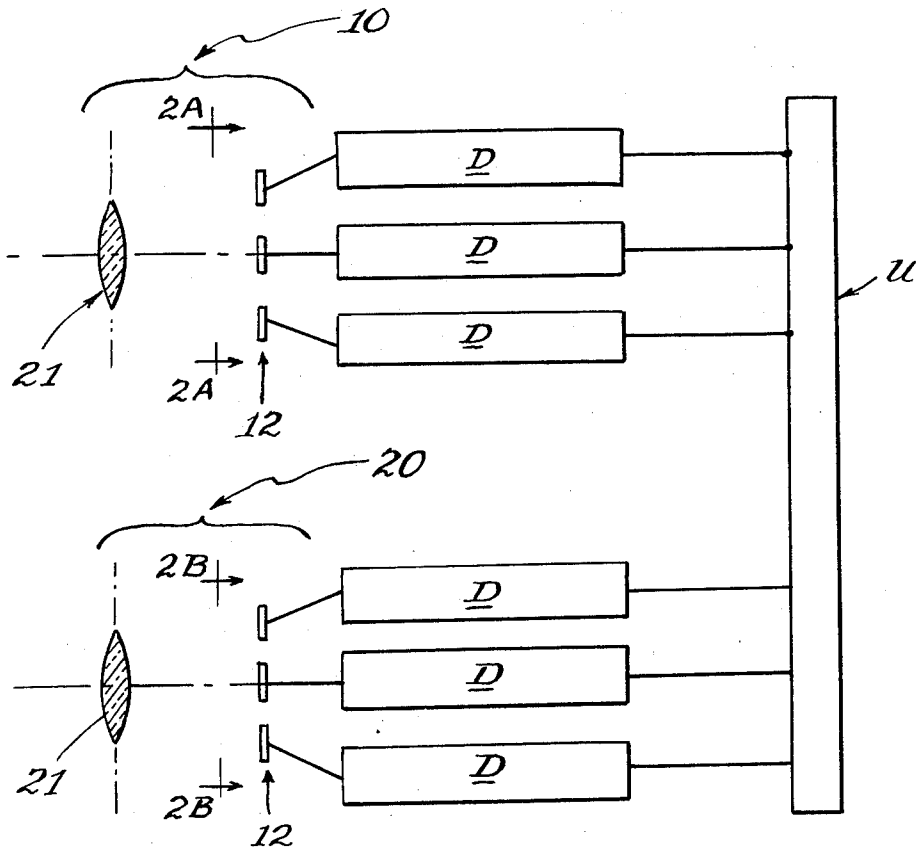
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Assistant Examiner—T. N. Grigsby
Attorney, Agent, or Firm—J. Patrick Cagney

[57] **ABSTRACT**

A large field flash sensor includes a plurality of optical sensing means each boresighted to a common wide field of view and signal detection means responsive to each optical sensing means.

4 Claims, 14 Drawing Figures



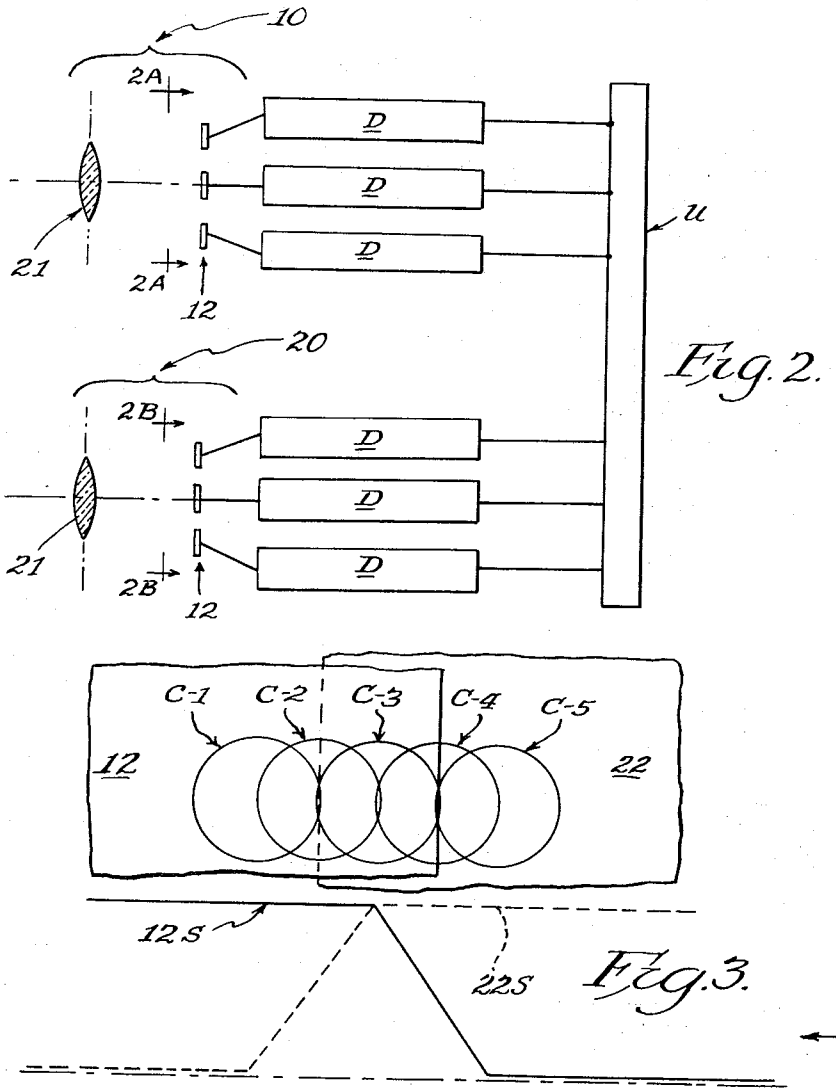


Fig. 2.

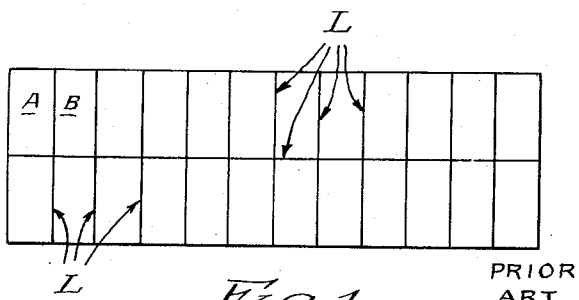


Fig. 1.

Fig. 1A.

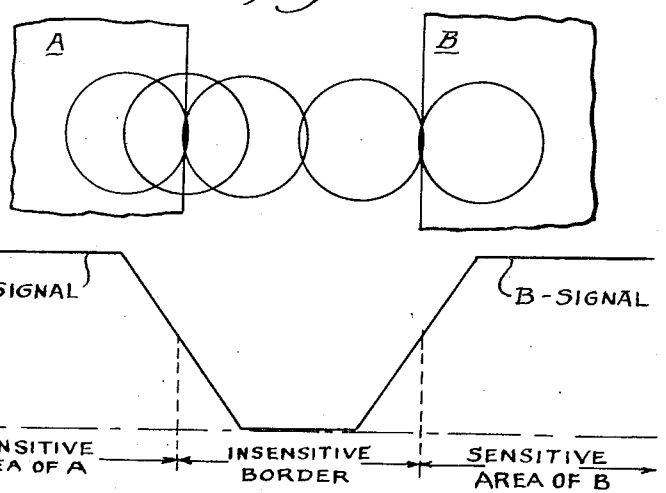


Fig. 3.

Fig. 4B.

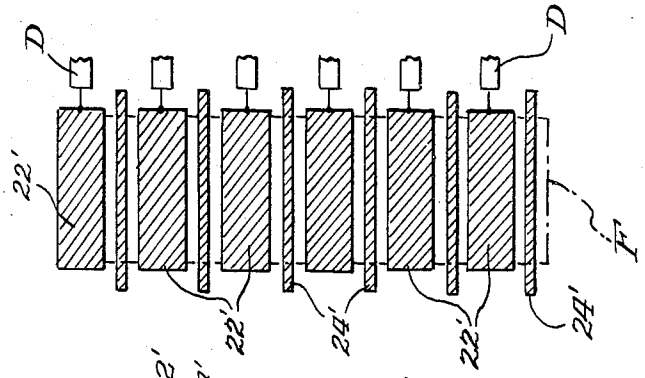


Fig. 4A.

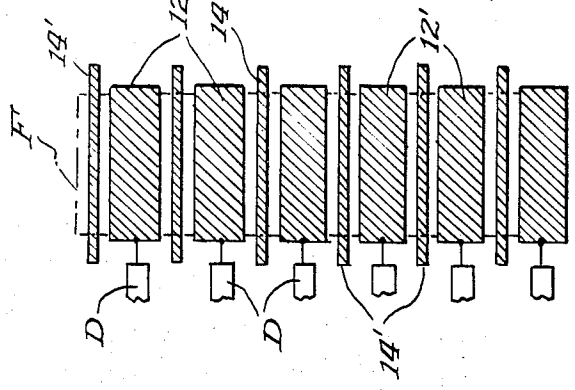


Fig. 2B.

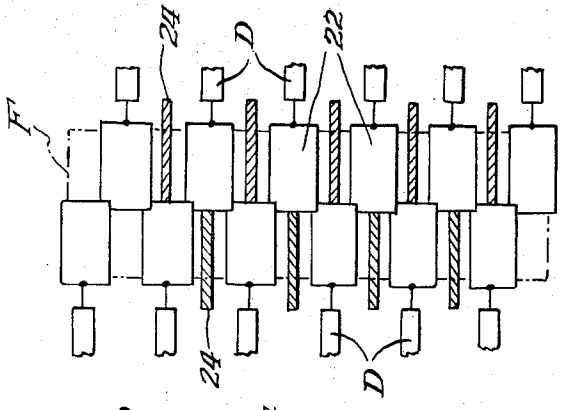
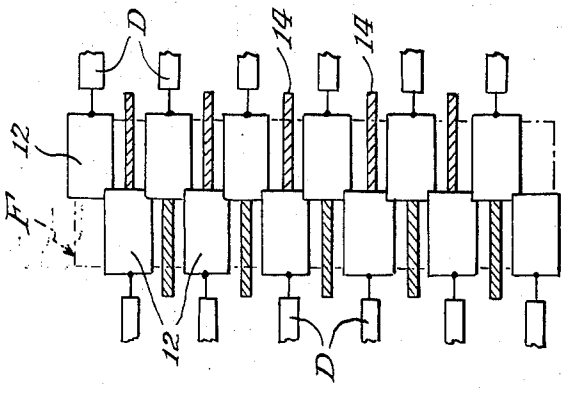


Fig. 2A.



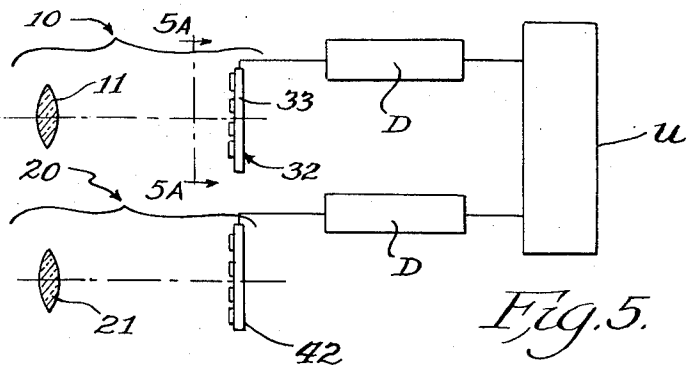


Fig. 5.

Fig. 5A.

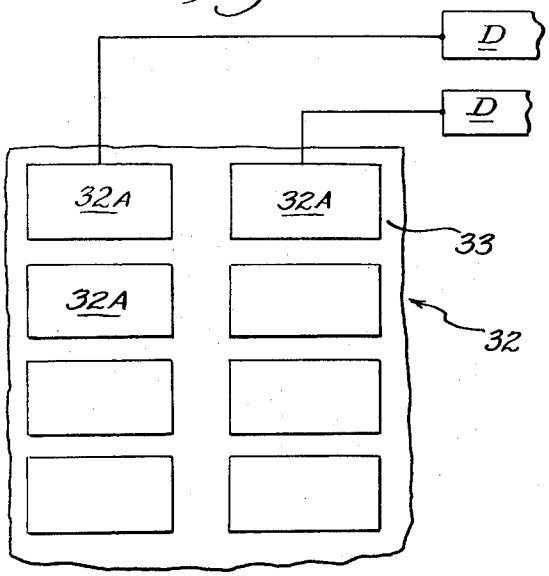


Fig. 6.

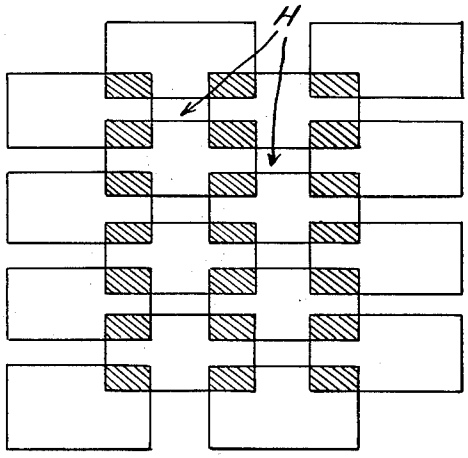


Fig. 9.

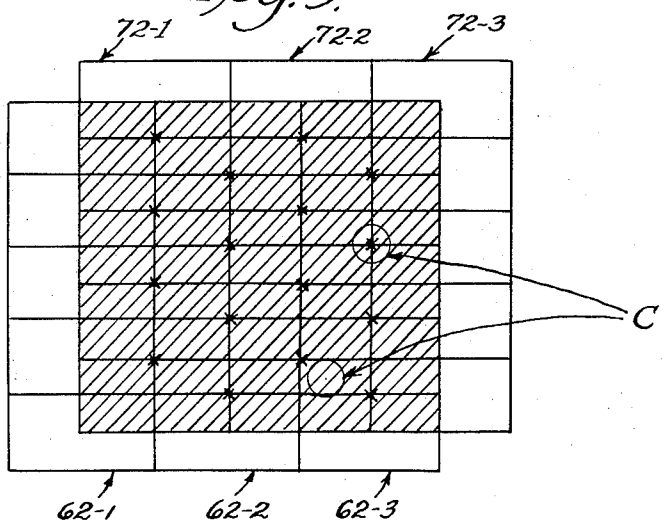


Fig. 7.

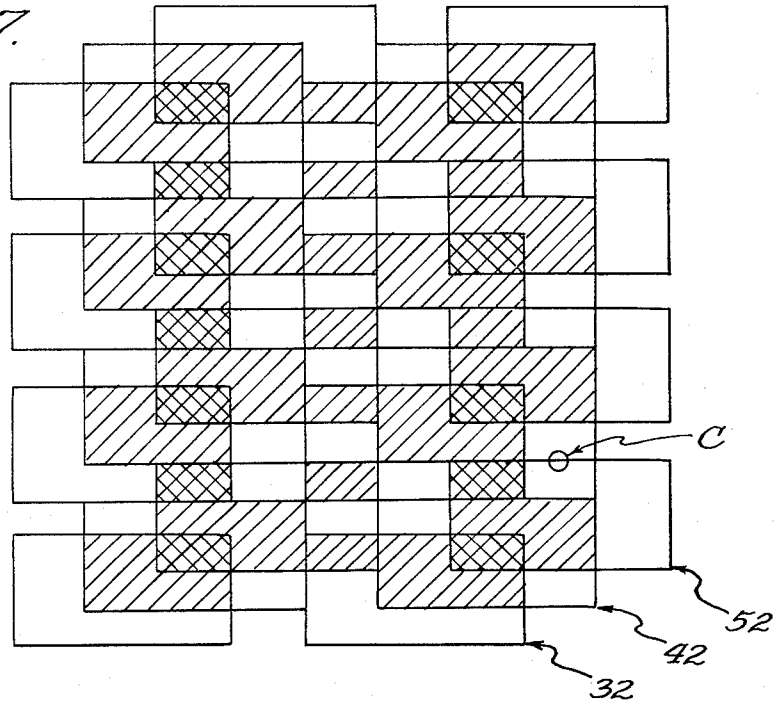
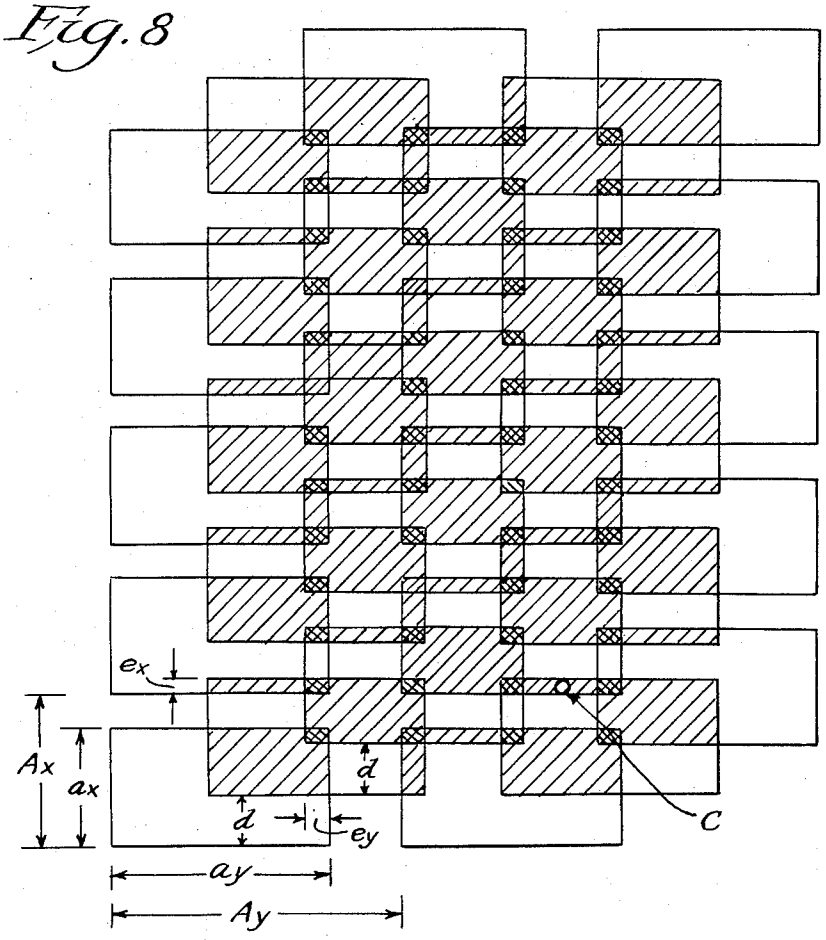


Fig. 8



LARGE FIELD FLASH SENSOR

BACKGROUND OF THE INVENTION

The invention relates to devices for sensing the presence and direction of one or more small flashing targets within a large field of view. A target may flash once, or repeatedly with a regular or random time spacing. The flash energy is primarily within the optical portion of the electromagnetic spectrum. The target may appear anywhere in the field of view, typically in a field of π steradian.

In order to guarantee the sensing of a distant target in the presence of normal background energy, a certain minimum optical collecting area must be provided. Moreover, the viewing of a large field must be shared by a plurality of photosensitive detector elements in order to distinguish the angular locality of a given target flash. The use of time-sharing to reduce the number of elements is not feasible because a target may flash anywhere at any time.

If the foregoing requirements are met by providing each element with a separate lens, the size of the lens group becomes impracticable. This problem has been solved in the prior art by employing a common collecting lens with many detector elements arranged in a contiguous fashion as shown in FIG. 1. A disadvantage accruing to this arrangement is evident when the blur circle C of the target image overlaps the insensitive border of two adjacent elements A,B, in which case no signal is detected when less than half of the energy is focused on either element. A series of blur circle positions are illustrated in FIG. 1A to show the A and B detector element signal responses. Neither detector element sees full signal level unless the entire blur circle comprising the target image falls thereon.

The range for detection of such targets is therefore reduced until the square-law effect restores the signal to the original detectable value. The locus of targets so affected is the pattern of lines L formed by the intersections of the array elements as shown in FIG. 1.

The width of the lines describing the regions of weakened response is directly proportional to the diameter of the blur circle. The width is further increased by the presence of any gaps or regions of insensitivity such as normally exists at the periphery of the individual photosensitive areas comprising the elements of the array.

SUMMARY OF THE INVENTION

The present invention provides unique large field flash sensing arrangements that minimize the regions of weakened response.

This invention may be usefully applied as the sensor for a pilot warning indicator (PWI) of the type which utilizes the flash of a Xenon strobe light on one aircraft to actuate a sensor on another aircraft. Sensors for this type of PWI typically employ an array of silicon photodiode detectors behind a collecting lens to develop an electrical pulse corresponding to the Xenon flash. The pulse is separated from noise by filtering or discriminating circuitry and amplified to actuate a warning light or audio tone for alerting the pilot of the aircraft carrying the PWI sensor.

In accordance with this invention large field flash sensing arrangements comprise a plurality of optical sensing means each comprised of a lens and an array of photosensitive elements, each lens being boresighted to a common wide field of view to collect and focus target energy upon the corresponding array in accordance with the location of such energy, signal detection means separately responsive to each array of elements and utilization means responsive to the signal detection means to indicate the location of flashing target energy in the field.

Complementary sensor arrays are utilized to minimize the lines of weakened response that characterize the prior art. The complementary arrays are slightly oversize so that an image falling just within the edge of an element in one array is also within the edge of an element in the complementary array which commands the neighboring field of view. The overlap in field coverage at the border of adjacent element edges thus results in redundant detection of a target at such regions.

In a typical embodiment each of the complementary two-dimensional arrays has overlapping corner intersections where its adjacent elements overlap. The only regions of the array where energy from a target image is not fully collected are at these corner overlaps. These corner overlap regions constitute a set of points in the common total field of view which typically is less than one-half of 1 percent.

In another embodiment, three complementary two-dimensional arrays are appropriately overlapped and proportioned to achieve full and uniform field coverage.

An additional feature of the invention resides in the provision of light traps in the spaces between the elements of the same array so that when energy from a concentrated source is focused upon one element, it will be confined to such element and will not scatter to other elements of the same array.

Other features and advantages of the invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which show structure embodying preferred features of the present invention and the principles thereof, and what is now considered to be the best mode in which to apply these principles.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings forming a part of the specification, and in which like numerals are employed to designate like parts throughout the same:

FIG. 1 illustrates a prior art detector array and the pattern of its lines of weakened response;

FIG. 1A diagrammatically shows the signal response characteristics at the region of the pattern lines of FIG. 1;

FIG. 2 is a schematic diagram of a large field flash sensing system using a pair of optical sensors boresighted on a common wide angle field;

FIGS. 2A and 2B are diagrammatic view taken at the lines 2A—2A and 2B—2B, respectively, of FIG. 2 and showing the lay-out of geometrically complementary arrays of detectors utilized in the system of FIG. 2;

FIG. 3 is a diagram illustrating the signal response characteristics for the arrays of FIGS. 2A and 2B when an image falls on edges of elements in both arrays;

FIGS. 4A and 4B are diagrammatic views showing the lay-out of an alternative embodiment of geometrically complementary arrays of detectors for use in the system of FIG. 1;

FIG. 5 is a schematic diagram of another embodiment of a large field flash sensing system using a pair of optical sensors boresighted on a common wide angle field;

FIG. 5A is taken on the line 5A—5A of FIG. 5 and illustrates a linear strip array in the form of a solid state device having a pair of linear strips of photosensitive areas arranged in rows on a common substrate that contains integrated circuitry for self-scanning each row;

FIG. 6 diagrammatically represents the effective overlapping response relationship between a pair of geometrically complementary arrays of the type shown in FIG. 5;

FIGS. 7 and 8 are diagrammatic representations similar to FIG. 6 but representing the effective overlapping response relationship for alternative embodiments of geometrically complementary arrays; and

FIG. 9 is a view similar to FIG. 6 but representing the effective overlapping response relationship for complementary arrays of closely spaced self scanning charge transfer types that may be utilized in the system of FIG. 5.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings and particularly to FIG. 2, a large field flash sensing system in accordance with this invention is shown as comprising essentially a pair of optical sensors **10, 20** boresighted to cover a common field of view and connected in one-to-one correspondence to continuous type flashing signal detection electronics D that supply output to a utilization means U.

The optical sensor **10** is comprised of a lens **11** and an array of photosensitive elements **12,** the array having an arrangement as shown in FIG. 2A. The optical sensor **20** is comprised of a lens **21** and an array of photosensitive elements **22,** the array having an arrangement as shown in FIG. 2B to be geometrically complementary to the array of elements **12.**

Each lens is capable of collecting and focusing target energy coming from anywhere in a wide field of view (for example, a 90° × 30° field) onto its respective array. The outline of the effective common field of view F as imaged on each array is shown in phantom in FIGS. 2A and 2B. Since the lenses **11, 21** are boresighted to the same field, the entire field of view is covered by some photosensitive element of either the array **12** or the array **22.**

Each photosensitive element of each array is connected to a separate signal detection means D, each signal detection means including circuitry suitable for amplifying and enhancing flash signals to discriminate against system and background noise by means of techniques similar to those established in radar technology for producing an output whenever target energy of sufficient flash magnitude is received at the corresponding photosensitive element. The signal detection circuits D are connected to utilization means U to indicate the location of any flashing target energy in the field of view.

A major advantage of the system of FIG. 2 over the prior art is that it eliminates the lines of weakened range. The photosensitive detecting elements pictured in FIGS. 2A and 2B are oversized so that an image falling just within the edge of an element in the array of elements **12** is also within the edge of an element in the array of elements **22** which commands the neighboring field of view. The overlap in field coverage at the border of adjacent complementary elements thus results in redundant detection of a target at such borders.

A target blur circle is represented at various positions C–1 to C–5 in FIG. 3 to illustrate the signal response of the elements of the separate arrays when the target circle is at a field position where there is overlap between the arrays. Thus, the detector element **12** produces a signal **12S** which, as shown in full lines, is a maximum at target circle positions **C–1, C–2** and **C–3,** half strength at position **C–4** and zero at position **C–5.** Correspondingly, the detector element **22** produces a signal **22S** which, as shown in dotted lines, is a maximum at positions **C–5, C–4** and **C–3,** half strength at position **C–2** and zero at position **C–1.**

The only regions of each array where energy from a target image is not fully collected are the corner intersections of the photosensitive elements in either the array **12** or the array **22.** In the embodiment represented in FIGS. 2A and 2B the physical overlap at the corners of the elements are achieved by slightly tilting each element out of the plane containing the array. It should be apparent from FIGS. 2A and 2B that the corners so defined coincide and constitute only one set of weak points in the common total field of view. The percentage of the field affected by such points in a typical embodiment of the subject invention is less than one-half of 1 percent.

A further advantage of the invention is obtained by utilizing the physical spacing between the elements of the array **12** and likewise between the elements of the array **22** for the suppression of stray light. Spurious light sources of high intensity such as the sun and parts of the sunlit sky readily affect more than one element because of local reflection and scattering of such light off the element surfaces and off the nearby mechanical and optical parts. The complementary geometrical pattern between the arrays **12, 22** provides a spacing between elements of each array. Light traps in the form of simple black baffles **14, 24** or separators are shown mounted between adjacent elements in FIGS. 2A and 2B. Thus, the sun or other energy from a concentrated source when focused upon an element of either array will be confined by the adjacent baffles and will not scatter to the photosensitive elements of the same array lying between the baffles.

A special form of this invention shown in FIGS. 4A and 4B consists of photosensitive detector elements having one dimension which spans the whole field of view, the image of which is again shown in phantom and identified as F. The absence of any corner intersections permits this arrangement to cover the entire sensor field without any weak lines and without any points of weakened field. The elements **12'** shown in FIG. 4A are wider than the field F and are isolated by baffles **14'.** The elements **22'** shown in FIG. 4B are wider than the field F and are isolated by baffles **24'.**

It is contemplated that other patterns or arrays using squares, hexagons, etc. for the photosensitive elements may be utilized in the practice of this invention. In addition, it is possible to utilize three or more lenses with complementing arrays each individually boresighted to a common field to achieve the same advantages.

Another large field flash sensing system in accordance with this invention is shown in FIG. 5 as comprising a pair of optical sensors **10, 20** boresighted to cover

a common field of view and connected to scanning type flashing signal detection electronics D that supply output to a utilization means U.

The optical sensor **10** is comprised of a lens **11** and an array of photosensitive elements **32,** the array **32** being of a strip type as shown in FIG. **5A.** Similarly, the optical sensor **20** is comprised of a lens **21** and an array of photosensitive elements **42** which is also of the strip type like that shown in FIG. **5A.**

The strip array **32** shown in FIG. **5A** is made in the form of a solid state charge transfer device. These solid state devices have photosensitive areas **32A** arranged in a row on a common substrate **33** which contains integrated circuits for enabling a self-scan of the row for detecting any charges developed by exposure of the photosensitive elements **32A** to an optical image. These two-dimensional arrays of photosensitive elements are fabricated so that the spacing between elements in a row and between rows is much smaller than the dimensions of each element.

A separate scanning type flash signal detection circuit D is shown connected to monitor each row of elements. Thus, in the embodiment of FIG. **5** the strip array **32** comprised of two rows is connected to a pair of detection circuits D. Correspondingly, the strip array **42** has two rows connected to a pair of detection circuits. The overlapping of the complementary arrays of the type shown in FIG. **5A** and their consequent field coverage is shown in FIG. **6** where the parts of the field covered redundantly by an element of each array are shown with crosshatching. Enclosed areas without crosshatching (clear) are covered by only one element of one of the arrays. Areas such as are denoted by H are not covered at all and constitute blind holes in the field sensitivity pattern. These blind holes are shown exaggerated in size for purposes of illustration but the actual size of such holes can be minimized by reducing the spacing between adjacent photosensitive areas.

The embodiment of FIG. **2** also may use photosensitive arrays of the type shown in FIG. **5A** wherein the sensitive elements are aligned in a row on a common substrate so as to form a sectionalized photosensitive strip. A simple array of two linear strips is shown in FIG. **5A.** One such array is used with lens **11** to serve as the detecting array **12** of FIG. **1** and another complementary array is used with the lens **21** to serve as the array **22.** The individual elements of each strip are separately connected to individual detection circuits as described in connection with FIGS. **2, 2A** and **2B.**

The existence of holes can be overcome for such strip arrays by the use of three instead of two sets of lens-array optical sensor assemblies. For example, three lenses each equipped with a corresponding strip array **32, 42, 52** and each boresighted on a common field to cooperate in a complementary field coverage as represented in FIG. **7.** In this figure, double crosshatching denotes field regions covered by three elements (one of each array), single crosshatching by two elements and enclosed clear areas by only one element. It can be noted that all of the target image energy is collected by at least one sensitive element for all image positions except at the borderline of two clear areas, as indicated by the circular image C in the figure. In this case each bordering element receives half the target, constituting a weakened line of field sensitivity. There are nine such lines in the working region of the figure.

By using a properly proportioned and fully balanced arrangement of three sensors, the field covered by their arrays may be made free of holes and lines of weakened field sensitivity. Such an arrangement is shown in FIG. **8** where crosshatching is used as in FIG. **7.** Within the working area of overlap, an image C equal to or less than the size indicated (i.e., will be seen completely by at least one element, providing the indicated dimensions satisfy the following governing relationships.

$A = 0.3d$

$a = 2d + e$

If $K \equiv a/A$, then $e = A\,(3K-2)/3$

By design limitation, $e>0$ and $K<1$

Thus, $\frac{2}{3} < K < 1$

For the specific pattern shown in FIG. **8,**

$Kx = Ky = \frac{3}{4}$

It should be noted that the use of the non-selfscanning two-dimensional mosaic structures as shown in FIGS. **6, 7** and **8** in the system of FIG. **2** requires that each detection element be connected to a separate detection circuit to provide parallel operation of all elements and insure detection of a randomly timed target flash. On the other hand the use of self scanning charge transfer structures of the types shown in FIGS. **6, 7** and **8** requires only one detection circuit for each strip as shown in the system of FIG. **5.**

A similar type of self scanning strip array for use in the system of FIG. **5** is shown in FIG. **9** wherein a large number of photosensitive areas are arranged in extremely closely spaced charge transfer coupled relationship. For example, the array of FIG. **9** may have as many as 10,000 detection elements whereas the arrays of FIGS. **2A, 2B, 4A** and **4B** typically consist of **50** elements. The closely spaced element arrays as shown in FIG. **9** are advantageous when employed as complementary sensors in accordance with this invention.

Furthermore, the scan rate may be fast enough to sample parts of the target flash in time. This feature is important when using a self-scan mosaic for flash sensing because it enhances the ratio of flash energy to background energy collected during the sampling period.

The complementary relationship of such arrays is shown in FIG. **9** wherein the self-scanned strips **62–1, 62–2, 62–3** comprise the array of one sensor and the self-scanned strips **72–1, 72–2, 72–3** comprise the array of the other sensor. The gaps between elements are assumed to be very small compared with the image size C. Within the working area denoted by crosshatching, an image may appear anywhere and be fully collected by at least one photosensitive element, except when it is located on one of the intersections of four elements, as denoted by X marks in the diagram. The division of energy at these points results in weak points or regions in the field sensitivity pattern, similar to those previously identified with the pattern of FIG. **2.**

If the two-dimensional array is expanded to allow non-zero spacing between the separate strips or rows, the pattern holes expand into lines of reduced sensitivity. However, the arrangement can be used where the small percentage of field so affected can be tolerated.

Thus, while preferred constructional features of the invention are embodied in the structure illustrated herein, it is to be understood that changes and variations may be made by those skilled in the art without

departing from the spirit and scope of the appended claims.

What is claimed is:

1. A large field flash sensing device comprising a plurality of optical sensing means, each sensing means comprised of lens means and a two-dimensional array of photosensitive elements and having said lens means boresighted to a common wide field of view to collect and focus target energy upon a region of the corresponding array in accordance with the location of such target energy in said field, signal detection means separately responsive to each of said arrays to produce a signal representative of the location of the array region that receives target energy, and utilization means responsive to said signal detection means to indicate the location of flashing target energy in said field.

2. A large field flash sensing device as defined in claim 1 and wherein said arrays have the photosensitive elements thereof disposed in a complementary relationship to said common field of view wherein portions of elements of one of said arrays have the same location relative to said common field of view as portions of elements of another of said arrays.

3. A large field flash sensing device as defined in claim 1 and wherein said photosensitive elements and said signal detection means are connected in one-to-one correspondence.

4. A large field flash sensing device as defined in claim 1 and wherein said arrays have rows of charge coupled photosensitive elements and each row is connected to a separate scanning type signal detection means.

* * * * *