

BISPECTRAL ELECTROMAGNETIC WAVE DETECTOR**5 BACKGROUND OF THE INVENTION**

The invention relates to an electromagnetic wave detector, notably a bispectral photoconductor-based detector.

- 10 The invention is advantageously applicable in the fabrication of a bispectral detection matrix.

DESCRIPTION OF THE PRIOR ART

- 15 Detection systems that detect radiation in two spectral bands are used in applications such as the identification or recognition of objects. Measurement of the thermal emission of an object in two spectral bands enables its temperature or its distance from the observer to be deduced, which represent additional information compared with that provided by a
- 20 monospectral image. An example of a quantum-well detector that can detect two wavelengths is described in the French patent application n°92 08384.

- Integrated two-band detectors provide information from both bands for each pixel in a focal plane, thus reducing the weight, electrical power and cost of
- 25 the complete system. Moreover, the integration of such detectors in the same focal plane requires no optical alignment.

SUMMARY OF THE INVENTION

- 30 According to the invention, an integrated two-band detector is composed of two active layers and three layers for the electrical contacts (figure 1) superimposed on a substrate. The signal of the active layer D1 is collected between the contacts C1 and Cc and the signal of the active layer D2 is collected between C2 and Cc. However, hybridization techniques do not
- 35 enable two independent contacts for each active layer on small pixels. The invention proposes a connection configuration for such detectors that

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provides for two sequential signals with a single contact for addressing the pixels.

The invention therefore relates to a photoconductor-based electromagnetic
5 wave detector including:

- at least one first and one second overlaid plane active detector elements separated by a common layer, said first and second detector elements being sensitive to the different wavelengths;
- a first means of connection connected in common to said first and
10 second detector elements, a second means of connection connected to said first detector element, and a third means of connection connected to said second detector element;
- means for applying control voltages successively to each means of connection;
- 15 - means connected to said first means of connection to detect a photoconduction current each time a control voltage is applied.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Other characteristics and advantages of the present invention will become apparent on read the following description of a preferred embodiment, with reference to the attached drawings:

- figure 1 shows two superimposed detectors;
- figures 2a to 2d show a set of two detectors with associated
25 electrical connection elements;
- figures 3a and 3b show a plan view and a sectional view of a matrix of bispectral detectors;
- figures 4a to 4c show example of a method of fabrication of the device according to the invention;
- 30 - figures 5 to 9 illustrate variants of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the simplified diagram in figure 1, the detector according to the
35 invention includes, overlaid on a substrate:

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- a contact layer C2.
- an active photoconducting layer D2,
- a common contact layer Cc,
- an active photoconducting layer D1,
- 5 - a contact layer C1.

The active photoconducting layers D1, D2 can be layers of photoconducting material. They can also be made in the form of stacks of layers constituting quantum-well detectors. The two active layers D1, D2 have different
 10 characteristics such that they become photoconducting when irradiated with electromagnetic waves of different wavelength (or bands of wavelength). The active layers D1, D2 becomes photoconducting when subjected to radiation of respective wavelengths λ_1 and λ_2 . The detector receiving radiation RZ as shown in figure 1, the active layer D2 is transparent at
 15 wavelength λ_1 .

The contact layers C1 and C2 enable control voltages to be applied. The contact layer Cc is common to the two detector elements comprised of active photoconducting layers. It is held at a reference voltage and enables
 20 detection of the photocurrents generated by the detectors D1, D2.

Figure 2a shows a more detailed embodiment of the detector according to the invention in which the detector is encapsulated in an insulating material IG. The connection terminals P1, P2, Pc traverse this insulator and enable
 25 contacts to be made on the contact layers C1, C2, Cc respectively.

The substrate is transparent to the wavelengths to be measured, so the detector receives the radiation RZ to be detected through the substrate.

30 When the radiation RZ is received by the detector, to detect two wavelengths λ_1 , λ_2 or bands of wavelengths, a reference voltage Vref is applied to the connection terminal Pc, in other words to the common contact layer Cc (see figure 2b). This reference voltage can be a ground, for example. Next, we first apply a voltage V1 to the contact layer C1 (terminal
 35 P1) and the reference voltage Vref to the contact layer C2 (terminal P2).



The detector element D2 is rendered inactive, the detector element D1 is active and generates a photocurrent i_1 . If the radiation RZ contains a wavelength λ_1 , the device A detects this current i_1 . This operation corresponds to the position of the switches K1 and K2 in figure 2b.

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Secondly, the switches K1, K2 are set to the positions shown in figure 2c. A voltage V2 is applied to the contact layer C2. The reference voltage Vref is applied to the contact layer C1. The detector element D1 is then inactive, whereas the detector element D2 is made active and generates a photocurrent i_2 on reception of a wavelength λ_2 . The device A measures this photocurrent.

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The device according to the invention thereby enables the successive detection of wavelengths λ_1 and λ_2 .

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Figure 2d represents the operation of the device when both detector elements D1 and D2 are active. The switches K1 and K2 respectively apply the voltage V1 and V2 to them. These potentials have the same sign relative to the reference voltage Vref such that, in the presence of wavelengths λ_1 and λ_2 , the two detector elements D1 and D2 generate photocurrents in the same direction in the device A which therefore measures the sum of the generated photocurrents. The signal measured therefore corresponds to the sum of the signals in the two spectral bands.

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As an example, the control voltage could be 2 Volts for V1 and 4 Volts for V2.

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Figures 3a and 3b show a plan view and a sectional view of a matricial embodiment of a bispectral detector according to the invention.

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The detectors of the matrix are made on a control contact layer C2 common to all the detectors. The connection terminal P2 is therefore common to the whole matrix. Each detector includes a detector element D1, a detector element D2, the contact layers C1 and Cc and the connection terminals P1 and Pc. The connection terminals P1 are all connected together to apply a

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voltage V_1 or V_{ref} (see earlier) to all the detector elements D_1 of the matrix. The contact layer C_2 and the connection terminal P_2 being common to the whole matrix, the potential applied to the terminal P_2 is applied to all the detector elements D_2 of the matrix.

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To enable reading of the detectors of the matrix, each detector is located at the intersection of a network of line and column conductors. In figure 3c, we have shown only the connection terminal P_c of each detector. Each intersection is equipped with, for example, a transistor Tr whose base is
10 connected to the line wire. The emitter and the collector are connected respectively to a terminal P_c and a column wire. By applying a suitable potential to a line wire we can control all the transistors of the line and connect all the terminals P_c of a line to column wires. It is therefore possible to read on each column wire the photocurrent generated by the detector
15 connected to this column wire.

In this embodiment, all the terminals P_1 are interconnected and set to the same potential. The same applies to the contact layer C_2 that is common to all the detectors and connected to the terminal P_2 .

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In a variant of the embodiment, the control contact layer C_2 is cut into strips such that each strip is common to a line of detectors. We then have one terminal P_2 per contact strip C_2 , i.e. per line of detectors.

25 In a similar manner, instead of interconnecting all the terminals P_1 , we can interconnect them in lines of detectors, in which case we have one terminal P_1 per line of detectors.

The terminals P_c of the detectors are interconnected by column wires of the
30 matrix. The operation of the matrix of detectors is then sequential by line. During each detection operation of a line, we apply the voltage V_1 to the terminal P_1 of this line and the voltage V_{ref} to the terminal P_2 , then the voltage V_2 to the terminal P_2 and the voltage V_{ref} to the terminal P_1 . The reading is taken on the column wires; each column wire enables reading of
35 one detector of the controlled line.



During each control of a line, the operation of the detectors of the other lines can be inhibited by applying a voltage V_{ref} to the terminals P1 and P2 of these lines.

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Owing to the bispectral operation of the detectors (see the description relating to figures 2b and 2c) during each detection operation on a line, we will have a reading time of the detector elements D1 (operation corresponding to figure 2b) followed by a reading time of the detector
10 elements D2 (operation corresponding to figure 2c).

We shall now describe a method of fabrication of a detector according to the invention, with reference to figures 4a to 4c.

15 On a substrate of material transparent to the wavelengths to be detected, we successively make a contact layer C2, one or more photoconducting layers D2 constituting the photodetector element D2, a common contact layer Cc, one or more photoconducting layers D1 constituting the photodetector element D1, and a contact layer C1 (figure 4a).

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The upper detector element D1 is formed by engraving or ionic implantation of the layers C1 and D1; the engraving (or implantation) stops at the contact layer Cc (figure 4b).

25 The lower detector element D2 is then formed by engraving or ionic implantation of the layers Cc and D2; the engraving (or implantation) stops at the contact layer C2 (figure 4c).

The whole structure is then covered with a layer of insulator IS (figure 2).

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Next, three holes are made in the layer of insulator to access the three contact layers: metal deposits are made in these holes to form the contact terminals P1, P2 and Pc.



For the fabrication of a matrix of detectors, the various detectors are made collectively as described previously. We then obtain a structure such that shown in figure 3b. As we have seen, the terminal P2 is common to the whole matrix. All that remains is therefore to make on the surface of the
5 matrix the interconnecting conductors of the terminals P1, then the matrix of terminals Pc.

We have described above the invention making use of vertical transport detectors such as multi-quantum well detectors. We shall now describe the
10 invention with horizontal transport detectors.

The detector is composed of two active layers separated by an insulating layer Cc (see figure 5).

15 Ohmic contacts are made at the two ends of each active layer D1, D2. At one of the ends of the detector, the ohmic contacts are made common to define the reading contact Pc. This contact Pc (one contact per pixel) will assure the connection with the input stage of the reading circuit. The lower contact P2 is connected to the active layer D2; the upper contact P1 is
20 connected to the active layer D1. We therefore see that when the active layers are suitably polarized the detector operates in a similar manner to the one described previously, with the difference that the current circulates in the plane of the active layers instead of perpendicularly to the plane of the active layers.

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In figure 5, an insulating layer IS1 is inserted between the active layer D2 and the substrate.

Figure 6 shows a matrix organization of detectors such as those in figure 5.
30 In this organization all the contacts P1 are connected to each other by column wires. The same applies for the contacts P2 and Pc. One central test terminal Pt per detector can be used to perform a current test.



Figure 7 shows a variant of the embodiment in figure 5 including a conducting layer C3 placed on the substrate and on which the structure in figure 5 is formed.

- 5 Figure 8 shows a matrix organization of detectors of figure 7. In this matrix organization, the layer C3 enables a single terminal connection P2 to be used that is common to all the detector pixels.

It will be clear to professionals of the art that there are additional possibilities
10 of improvement while remaining within the framework of the invention:

- inclusion of diffraction networks engraved on the top of the detector to minimize the thickness of the active layer and increase the detection sensitivity of the device; they also enable the responses of the two stages to be desymmetrized;
- 15 - use of a "serpentine" geometry (see figure 9) which increases the resistance of the pixel (by increasing the developed length and decreasing the equivalent electric surface without substantially changing the optical area); this geometry also provides some flexibility as regards metallurgical defects, since these then cause
20 only local short-circuits.



**WHAT IS CLAIMED IS**

1. Photoconductor-based electromagnetic wave detector including:
 - 5 - at least one first and one second overlaid plane active detector elements separated by a common layer, said first and second detector elements being sensitive to the different wavelengths;
 - a first means of connection connected in common to said first and second detector elements, a second means of connection connected to said first detector element, and a third means of connection connected to said second detector element;
 - 10 - means for applying control voltages successively to each means of connection;
 - means connected to said first means of connection to detect a photoconduction current each time a control voltage is applied.
 - 15
2. Detector according to claim 1, wherein said common layer is an electrical contact layer to which said first means of connection is connected, and said first and second detector elements are enclosed between two electric control contact layers, said second and third means of connection each being connected to one of said control contact layers.
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3. Detector according to claim 1, wherein said common layer is an insulating layer, said first means of connection is connected to a first end of each detector element, and said second and third means of connection are each connected to a second end of a detector element, said first and second ends of each detector element being opposite ends of the detector element.
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4. Detector according to claim 1, wherein said means for applying a control voltage can be used to apply:
 - 30 - a reference voltage to said first means of connection;
 - this same reference voltage to said second means of connection;
 - 35 - a control voltage to said third means of connection.





5. Detector according to claim 4, wherein said means for applying a control voltage include switching means that enable, first, a control voltage to be applied to the first of said control contact layers and said reference voltage to be applied to the second of said control contact layers, then secondly, a control voltage to be applied to the second of said control contact layers and said reference voltage to be applied to the first of said control contact layers.
6. Detector including a matrix of detectors according to claim 2, made on a substrate, a first control contact layer being made on the face of the substrate and being common to a set of detectors, each detector including, on this first control contact layer, a first detector element of photoconducting material, a contact layer for reading, a second detector element of photoconducting material, and a second control contact layer which is connected to this same respective second control contact layer of all the other detectors of the matrix.
7. Detector according to claim 6, including a matrix of line conductors and column conductors superposed on said matrix of detectors, each detector being located substantially at an intersection of the matrix of line conductors and column conductors and being connectable to the column wire at the intersection via a switching device that can be controlled by a voltage applied to the line wire at the intersection.
8. Detector according to claim 6, wherein:
- said first control contact layer is made in the form of strips, a row of detectors being made on each strip;
 - said second contact layers of the detectors of each row of detectors are also interconnected;
 - said reading contact layers of a detector of each row of detectors are interconnected to form columns of detectors.
9. Method of fabrication of a detector according to claim 2, including the following stages:
- fabrication on a substrate of:





- a first contact layer,
- at least one first layer of photoconducting material,
- a second contact layer,
- at least one second layer of photoconducting material,
- 5 • a third contact layer;
- engraving of the third contact layer and the second layer of photoconducting material to define a first detector element;
- engraving of the second contact layer and the first layer of photoconducting material to define a second detector element;
- 10 - encapsulation of said layers in an insulating material;
- engraving of holes in the insulating layer to access the contact layers, and metallization of these holes.

10. Method of fabrication of a matrix of detectors according to claim 9,
15 wherein several detectors are collectively made on the same substrate, the first contact layer being common to all or some of the detectors, the process also including the engraving of the first layer of photoconducting material before encapsulation by the insulator, and the interconnection of holes connected to the third contact layer in the
20 different detectors.

11. Detector including a matrix of detectors according to claim 3, made on a substrate, a conducting layer common to all the detectors being made on the face of the substrate, this layer being covered by an insulating layer, each detector including, on this insulating layer, a first detector
25 element of photoconducting material, a common insulating layer, a second detector element of photoconducting material, said second means of connection all being interconnected and said third means of connection all being interconnected.

