

METHOD AND DETECTOR DEVICE FOR ELECTRONIC POSITION-REFERRED
DETECTION OF RADIATION

The invention relates to a method for image
signal decoupling in position-transmitting high-vacuum
detector devices for quanta or particle radiation in
5 accordance with the preamble of Patent Claim 1, as well
as to a detector device which operates according to the
method and is based on the features in accordance with
the preamble of Patent Claim 2.

In order to detect individual UV or other
10 electromagnetic radiation quanta, particles or the like,
position-transmitting, electronically operating detector
systems are required for various applications. In order
to be able to detect individual radiation quanta with
high efficiency using such detector systems, multi-
15 channel electron multipliers are used which have to be
installed in special high-vacuum glass bodies, depending
on the application. In order to achieve two-dimensional
locating or positioning of the photon detection, it is
also necessary to install in the conventional systems
20 (compare Figure 5) complex, resistive anode structures 1
which have, for example, four contacts in high vacuum 7
which are led to the outside and render possible digital
spatially resolving determination of the radiation
detection. For the production of the detector, assembling
25 and mounting the complex anode structure 1 in the
evacuated glass body 6 together with the wire bushings
for high-frequency signals required for this purpose not
only signify great technical difficulties, but also
exclude the possibility of being able later to adapt the
30 anode structure 1 to a changed measurement task in an
individually optimized fashion. The individual detector
components form a unit which can no longer be separated
or changed in the conventional methods and detector
devices.

35 In addition to the evacuated glass body 6,
already mentioned, and the layer-shaped, resistive anode
structure 1 having a downstream electronic system with
connections 13 for in each case four preamplifiers, for
example, there are present in the known detector system

in accordance with Figure 5 an electron converter layer 4 (UV quanta electron converter layer), applied to the inner side of a radiation-transparent cover substrate 10, a chevron plate system 3 as charge multiplier having high-voltage led wires 9, which are led out, as well as the resistive anode structure 1 which is applied to the vacuum-side inner surface of the counter-substrate 11. A local charge avalanche generated by an UV quantum on the anode structure 1 is specified by reference 8.

10 It is the object of the invention in the case of detector devices of the type described for quanta or particle radiation to provide technically substantially simpler and more reliable electronic positioning, that is to say position-referred image signal decoupling without
15 direct electrical contacts through the vacuum partition wall, together with the possibility of adaptation to changed measurement tasks.

 In the case of a method for image signal decoupling in the case of position-transmitting high-
20 vacuum detector devices for quanta or particle radiation which impinge on a spatially resolving anode structure via an electron multiplier device as an electron avalanche, the invention is characterized in that the electron avalanche remains spatially collected for a
25 short time inside the vacuum on the anode side of the detector device by means of a high-resistance, conducting thin film, and the collected charge is read out capacitively, coupled through a vacuum wall, as an image charge by means of a low-resistance anode layer which is
30 arranged opposite the high-resistance thin film outside the vacuum and is structured in a fashion suitable for locating.

 Whereas in the case of prior-art radiation quanta detector devices the spatially resolving anode structure
35 is arranged in the interior of the high vacuum with a plurality of vacuum-tight bushings for high-frequency signals for the downstream electronic system without a subsequent possibility of adjustment or adaptation to different measurement tasks, the invention is based on

the concept of collecting the charge avalanches, induced by the radiation quanta, in a short-term spatially bound fashion on the inner surface, opposite the radiation entrance, of the counter-substrate through a continuously uniform high-resistance conducting layer and then of coupling them capacitively through the vacuum wall (substrate layer) on to a low-resistance, structured anode layer outside the vacuum.

A position-transmitting detector device for electromagnetic radiation or particle radiation, in which inside a high-vacuum space which is bounded by a planar, radiation-transparent cover substrate and a counter-substrate held at a distance therefrom there are present following one another in a layer-like fashion on the radiation incidence side a plate-type electron multiplier arrangement and, opposite the latter at a distance, a planar anode, is characterized according to the invention in that for the purpose of capacitive, position-referred image signal readout the anode is designed as a layer arrangement in such a way that there are present on the vacuum-side inner surface of the counter-substrate a high-resistance charge collecting layer and, opposite the latter on the outer surface of the counter-substrate, that is to say outside the vacuum, a low-resistance anode layer structured in a fashion suitable for locating.

By contrast with conventional detector devices for electromagnetic radiation quanta or particle radiation, the invention chiefly provides the advantage that comparatively simple, uniform detector elements or modules can be used whose electronic position readout can be matched individually and in an optimized fashion to different measurement tasks by means of different structuring of the low-resistance anode layer situated outside the vacuum. A further essential advantage resides in that no electrical bushings are required into the vacuum for high-frequency current pulses. Furthermore, there is the possibility of producing the electronic system for amplification and digitization in conjunction with the low-resistance anode structure as a highly

integrated circuit (for example using SMD technology, as a hybrid or as ASIC).

It is advantageous for the low-resistance, structured anode layer to be designed, for example, in the form of a so-called wedge and strip anode, the charge-collecting regions or busbars for reading out in a manner proportional to the image charge being arranged at least two, preferably at three edge sides of the anode layer respectively at right angles to one another. However, it is also possible to employ other, arbitrary, suitable structures such as, for example, a Vernier anode, a spiral structure, a delay line layer or a pixel system which is read out digitally by means of a CCD. Furthermore, it is necessary or at least expedient to select the internal resistances of the charge-collecting layer, on the one hand, and the capacitively coupled outer anode layer and downstream electronic system, on the other hand, with regard to optimizing the spatial resolution, while simultaneously taking account of the dielectric provided by the counter-substrate layer.

In order to avoid image errors in the edge region of the detector device, it is expedient to permit the sensitive area of the outer, low-resistance anode layer to project over the image edges of the vacuum-side charge collecting layer.

The invention and advantageous details are explained more closely below, with reference to the drawings, by means of an exemplary embodiment.

In the drawings,

Figure 1 shows a sectional representation of the principle of a detector device having position-transmitting readout for electromagnetic radiation quanta or particle radiation in accordance with the invention; Figure 2 shows the partial representation of a section of the counter-substrate of the detector device according to Figure 1;

Figure 3 shows a representation of a diagrammatic top view of a portion of a wedge and strip anode such as can advantageously be used for position-transmitting image

signal decoupling in accordance with the invention;

Figure 4 shows an example of a measurement result (bottom) with the use of an experimental setup (top) having a detector according to the invention with a capacitively coupled, position-transmitting anode structure; and

Figure 5 shows the diagrammatic representation of a section of a conventional, position-transmitting detector device for electromagnetic radiation quanta or particle radiation.

In the detector system according to Figure 1, the image-intensifier system, specifically the photoelectron converter layer 4, the chevron plate system 3, situated therebelow, of a multichannel electron multiplier, and the high-resistance anode layer 1 according to the invention, is installed as previously in a high vacuum 7. In a manner differing from the prior art, however, for the purpose of electronic position readout the complex anode structure 2 is applied or arranged outside the vacuum 7 on the rear of the detector, that is to say, for example, on the rear of the counter-substrate 6. The transmission of the precise positional information for the position of an incident radiation quantum (UV quantum) or particle is performed capacitively after appropriate charge multiplication by the counter-substrate 6, preferably consisting of glass, of the image intensifier system on to the low-resistance anode structure 2, which is located outside the vacuum. This capacitive transmission is possible because the charge collecting layer which is formed on the inner side of the base- or counter-substrate 6, that is to say in the vacuum, is applied as a high-resistance (anode) layer on which the electron avalanche 8 induced by a single radiation quantum or particle is collected and remains there a few 10ns because of the assumed high layer resistance (megaohm range), as illustrated in Figure 2. This local charge avalanche 8 couples capacitively through the glass layer of the counter-substrate 6 and generates an image charge on or in the opposite,

low-resistance anode structure 2. The low-resistance anode structure 2 can, for example, be designed as a wedge and strip anode having three contact regions a, b and c. The structure of this anode can be adapted in a comparatively simple way to the positional resolution respectively required. The anode structure 2 is located in this case on the outer side of the counter-substrate 6, that is to say in the normal air atmosphere. The precise position of the image charge can then be determined via correspondingly adapted, quick charge-sensitive preamplifiers and an evaluation logic system (not represented) known in principle. The capacitive decoupling renders a high spatial resolution possible when the internal resistances of the two anode layers 1, 2 are optimally adapted to one another and the anode structure 2 is geometrically structured in a correspondingly highly resolving fashion. Apart from a wedge and strip anode as described, for example, in the publications Lit [1] and [2], other spatially resolving anode structures also come into consideration within the scope of the invention, for example a Vernier anode, an anode of spiral structure, a delay-line layer or a pixel system which is read out digitally by means of a CCD.

The principle of the capacitive, position-referred signal decoupling for digital position read-out can be described briefly as follows with reference to Figure 2: the local charge cloud 8 generated in the chevron plate 3 in the vacuum impinges on the high-resistance anode layer 1 which, for example, can be a Ge layer with a thickness of a few 100 nm, and remains there for a few 10 ns. During this time, an image charge is built up by capacitive coupling on the other side, situated outside the vacuum, of the counter-substrate 6 on the low-resistance anode structure 2. Depending on the geometry of this low-resistance anode structure 2, for example as a three-part wedge strip anode (compare Figure 3), each position is uniquely determined by a specific image charge ratio. For a low-resistance anode structure, this image charge distribution can be determined by quick

electronic components. It is possible, in turn, to use the ratios of the image charges Q1, Q2 and Q3 to determine precisely the position X, Y in the image plane, in accordance with the following relationships:

$$\begin{aligned} \frac{X}{X_0} &= \frac{Q_1}{Q_1 + Q_2 + Q_3} \\ \frac{Y}{Y_0} &= \frac{Q_2}{Q_1 + Q_2 + Q_3} \end{aligned}$$

An image charge cloud 20 which forms on the anode structure 2 is indicated in Figure 3 by a shaded region.

A detector device according to the invention can be used to detect individual events with a very high position-referred temporal resolution. In the case of the detectors currently being tested, the spatial resolution is approximately 1/250 of the detector width or, given the use of suitable lens systems, 0.5°.

Figure 4 shows a measurement setup (top) and results (bottom) relating to the positional determination of incident radiation. A radioactive preparation radiating alpha particles was used as radiation source 22. The radiation-transparent cover substrate and the photoelectron converter layer are eliminated in the case of this arrangement, since the alpha particles can release electrons directly at the entrance into the chevron plate 3. A shadow mask 21 which is made from wires 0.2 mm thick and whose image is to be electronically detected is mounted between the radiation source 22 and the chevron plate 3.

The lower image of Figure 4 shows the shadow image, picked up by the wedge and strip structure of the low-resistance anode 2 and the downstream electronic system, of the wires of the shadow mask 2, which are tensioned at right angles to one another. The resolving power determined in the case of these measurements was below 0.2 mm, as a function of the selection of the anode structure.

The particular advantages of the invention can be summarized as follows:

1. The type of image signal decoupling according to the invention requires in the vacuum only a simple
5 high-resistance monolayer having a single penetrating voltage contact. No bushings are required for high-frequency current pulses. This leads to a substantial simplification of the production of the vacuum component.
2. By comparison with conventional detectors of
10 this type, all that is required between the channel or chevron plate 3 and the high-resistance anode layer 1 is a moderate voltage of typically 200 volts, which permits the detector to be operated in a simpler and more reliable manner. Consequently, the dark discharge rate of
15 the detector system is markedly reduced and destruction of the anode structure by voltage flashovers in the detector is virtually excluded.
3. The spatially resolving, low-resistance anode structure 2 is arranged outside the vacuum 7 and can, in
20 accordance with the user's wishes, be virtually arbitrarily adapted and exchanged, with the result that adaptation to the precision of the locating is possible individually in a wide range to each user problem, for example a relative spatial resolution of 1 to 0.1%.
- 25 4. The electronic system 5 for amplification and digitization can be mounted, using modern SMD or hybrid technology, directly on the anode structure 2 outside the vacuum in an integrated fashion, thus producing a substantially better resolution and a clear simplifi-
30 cation of the electronic system with corresponding savings in costs. The spatially resolving, low-resistance anode structure 2 can be applied either on a separate plate or directly on to the outer side of the vacuum partition walls of the counter-substrate 6.
- 35 5. The anode structure 2 outside the vacuum 7 can be mounted with a larger sensitive area than corresponds to the chevron or channel plate 3. Image errors at the image edge can thereby be avoided.



Patent claims

1. Method for electronic, contactless image signal decoupling in the case of position-transmitting high-vacuum detector devices for electromagnetic radiation quanta or particle radiation which impinge on a spatially resolving anode structure via an electron multiplier device (3) as an electron avalanche (8), characterized in that the electron avalanche (8) is collected for a short time inside the vacuum (7) on the anode side of the detector device by means of a high-resistance, conducting thin film (1), and the collected charge is read out capacitively as an image charge by means of a low-resistance anode layer (2) which is arranged opposite the high-resistance thin film (1) outside the vacuum (7) and is structured in a fashion suitable for locating.
2. Position-transmitting detector device for electromagnetic radiation or particle radiation, in which inside a high-vacuum space (7) which is bounded by a planar, radiation-transparent cover substrate (12) and a counter-substrate (6) held at a distance therefrom there are present following one another in a layer-like fashion on the radiation incidence side a plate-type electron multiplier arrangement (3) and, opposite the latter at a distance, a planar anode (1), characterized in that for the purpose of capacitive, position-referred image signal readout the anode is designed as a layer arrangement in such a way that there are present on the vacuum-side inner surface of the counter-substrate (6) a high-resistance charge collecting layer (1) and, opposite the latter on the outer surface of the counter-substrate (6), a low-resistance anode layer (2) structured in a fashion suitable for locating.
3. Detector device according to Claim 2, characterized in that the vacuum-side, high-resistance charge collecting layer (1) is designed as a uniformly planar monolayer on the counter-substrate (6) and a high-voltage potential can be applied to it from outside via a vacuum-tight bushing (11).
4. Detector device according to Claim 3,



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characterized in that the charge collecting layer (1) is a high-resistance semiconductor layer.

5. Detector device according to Claim 4, characterized in that the charge collecting layer (1) is a germanium (Ge) layer.

6. Detector device according to one of the preceding Claims 2 to 5, characterized in that the structured, low-resistance anode layer (2) is designed in the form of a wedge and strip anode having busbars (a, b, c) for reading out charges, in a manner proportional to the image charge, at at least two edge sides of the anode layer (2) which are at right angles to one another.

7. Detector device according to one of the preceding Claims 2 to 5, characterized in that the structured, low-resistance anode layer (2) is designed in the form of a Vernier anode.

8. Detector device according to one of Claims 2 to 5, characterized in that the structured, low-resistance anode layer (2) has a spiral structure.

9. Detector device according to one of Claims 2 to 5, characterized in that the structured, low-resistance anode layer (2) is designed as a delay line layer.

10. Detector device according to one of Claims 2 to 5, characterized in that the structured, low-resistance anode layer (2) is designed in the form of a pixel system which is read out digitally by means of a CCD.

11. Detector device according to one of the preceding Claims 6 to 10, characterized in that the structured anode layer (2) is applied to a separate plate (10) which is mechanically adapted to the outer surface of the counter-substrate (6).

12. Detector device according to one of Claims 6 to 10, characterized in that the structured anode layer (2) is applied directly to the outer surface of the counter-substrate (6).

13. Detector device according to one of the preceding Claims 2 to 12, characterized in that the internal resistances of the charge collecting layer (1) and the capacitively coupled outer anode layer (2) are selected



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with regard to optimizing the spatial resolution.

14. Detector device according to one of the preceding
Claims 2 to 12, characterized in that the outer, low-
resistance anode layer (2) has a sensitive area
5 projecting over the image edges of the vacuum-side charge
collecting layer (1), such that image errors are avoided
in the edge region.