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Martone et al. SUBSTITUTE FOR MISSING XR
[11] 3,769,509
[45] Oct. 30, 1973

[54] SCINTILLATION CAMERA

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[22] Filed: **Mar. 15, 1971**

[21] Appl. No.: **124,458**

Related U.S. Application Data

[62] Division of Ser. No. 833,552, June 16, 1962, Pat. No. 3,683,180.

[52] **U.S. Cl.**..... **250/71.5 S**, 250/71.5 R, 250/105
[51] **Int. Cl.**..... **G01t 1/20**
[58] **Field of Search**..... 250/71.5 R, 71.5 S, 250/105, 227

[56] **References Cited**

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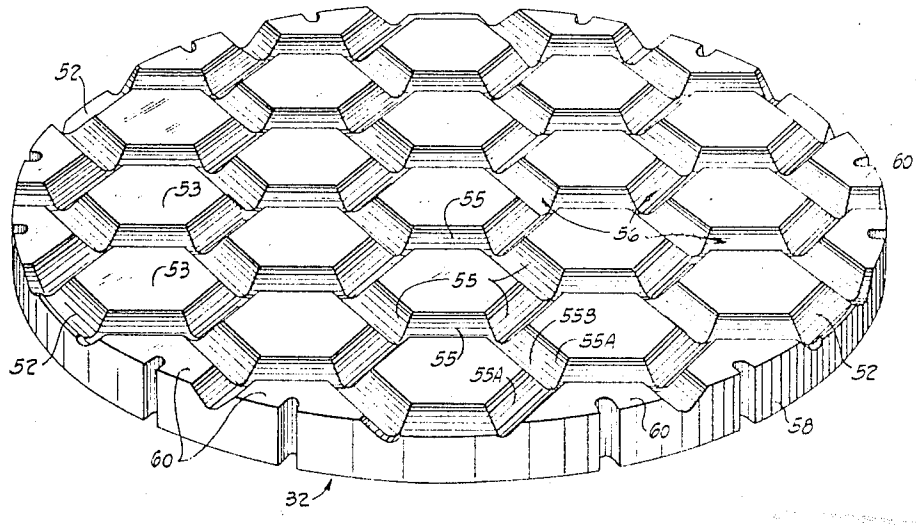
Primary Examiner—James W. Lawrence
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Attorney—Watts, Hoffmann, Fisher & Heinke

[57] **ABSTRACT**

A gamma imaging camera with a scintillation crystal and a plurality of phototubes. A light pipe optically couples the crystal and the tubes. The light pipe has, at its output end, a plurality of truncated pyramids each associated with one of the phototubes. As disclosed, the walls of the pyramids are hexagonal in cross-sectional configuration and flare outwardly to intersect adjacent walls, thus providing a continuous field of view.

The disclosure also shows a lift-out detector head subassembly construction.

24 Claims, 6 Drawing Figures



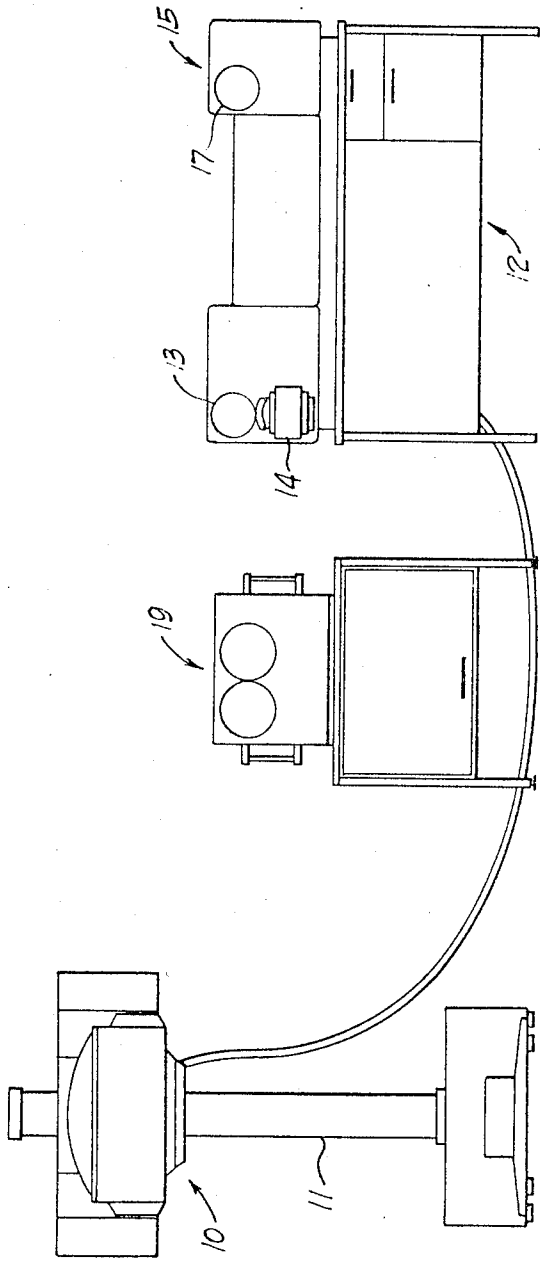


Fig. 1

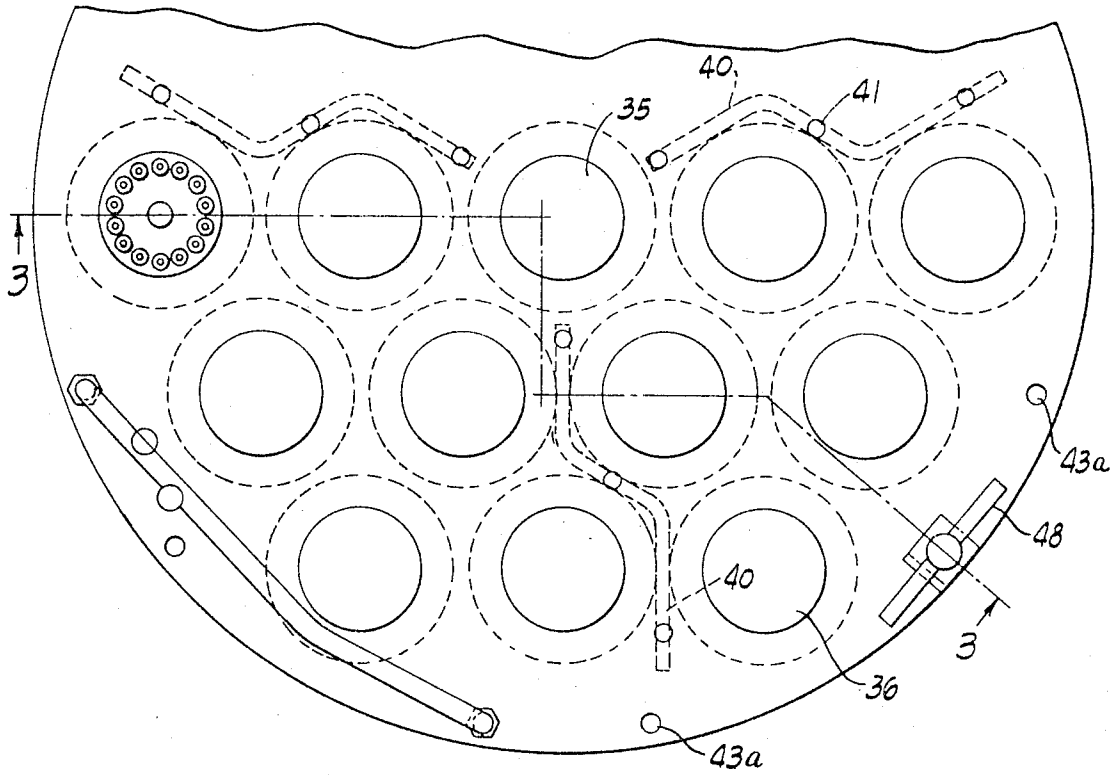

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41
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3
43a
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43a

Fig. 2

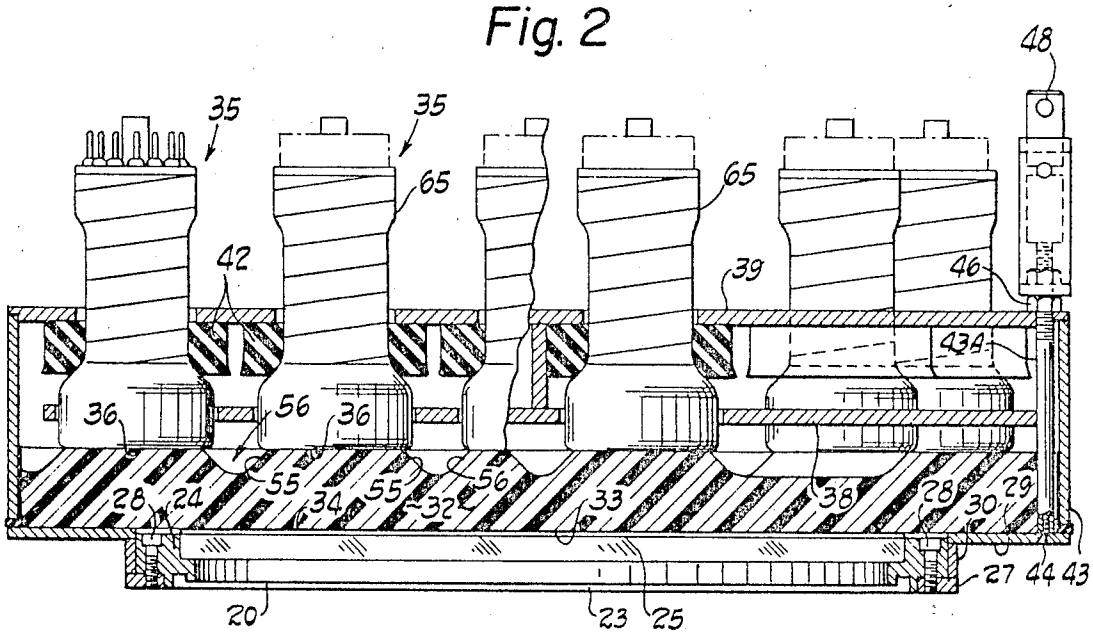

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Fig. 3

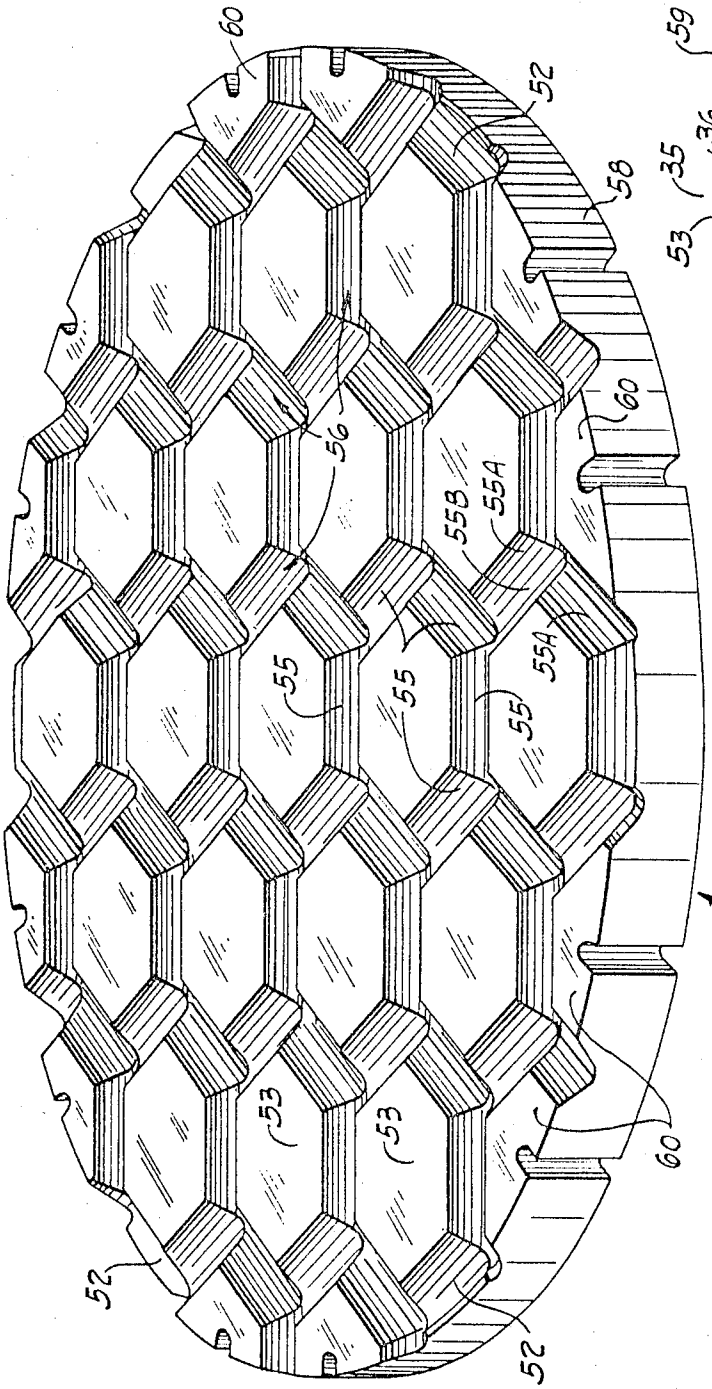

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Fig. 4

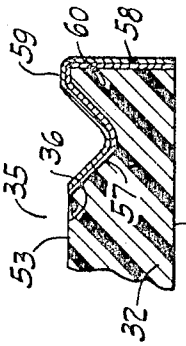

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53
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32

Fig. 5

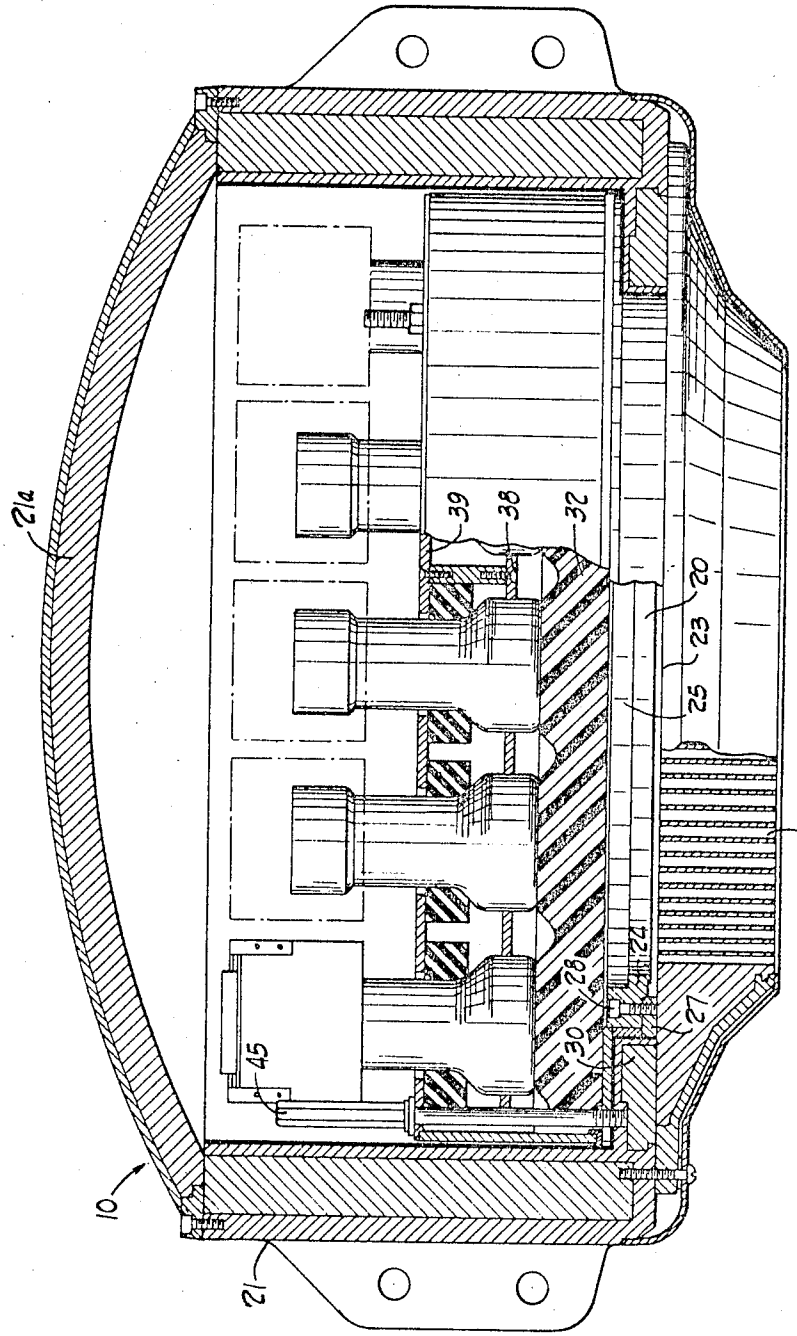


Fig. 6

SCINTILLATION CAMERA

CROSS REFERENCES TO RELATED PATENTS AND APPLICATIONS

This is a division of application Ser. No. 833,552, filed June 16, 1969, now U.S. Pat. No. 3,683,180.

1. Ser. No. 26,014 issued May, 3, 1966 to J. B. Stickney et al, reissue of U.S. Pat. No. 3,070,695 dated Dec. 25, 1962 entitled "Scintillation Scanner".

2. Copending application Ser. No. 739,793 filed June 25, 1968 by Peter G. Mueller entitled "Pulse Height Analyzer" now U.S. Pat. No. 3,683,284.

3. Copending application Ser. No. 739,889 filed June 25, 1968 by Robert Hindel entitled "Scintillation Detector Indicating System issued Oct. 6, 1970 as U.S. Pat. No. 3,532,927".

4. Application, Ser. No. 837,027, filed June 27, 1969 by Robert Hindel et al, entitled "Radiation Image Apparatus" now U.S. Pat. No. 3,560,420.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to gamma imaging devices and more particularly to that class of device known as scintillation cameras.

In the diagnosis of certain illnesses, radioactive isotopes are administered to patients. Many administered isotopes have the characteristic of concentrating in certain types of tissue and either not concentrating in or concentrating to a lesser degree in other types of tissue. For example, iodine 131 collects in thyroid glands. A graphic image produced to show the spatial distribution and concentration of this isotope in the thyroid gland provides an image of the thyroid gland itself. This image is useful in diagnosing a patient's physical condition.

2. Summary of the prior art

Generally speaking, the devices used for producing graphic images of the distribution of an isotope in a subject are known as scanners and cameras. With a scanner, a scintillation probe is moved rectilinearly along a plurality of spaced parallel paths. The energy detected is utilized to make either a photographic or a dot image reflecting the spatial distribution and concentration of the isotope in the subject. A clinically successful scanner is described in greater detail in the above-referenced U.S. No. Re. 26,014 to J. B. Stickney et al.

The devices known as cameras remain stationary with respect to the patient as the graphic image of the spatial distribution of an isotope is developed. Many cameras use an instrument where a relatively large disc-like scintillation crystal is positioned to be bombarded by gamma radiation emitted by a patient. With most cameras, a collimator is interposed between the patient and the crystal. The crystal converts the gamma ray energy impinging on it to light energy. This light energy is in the form of light flashes or scintillations. In one class of camera, a thalium-activated sodium iodide crystal is typically utilized. Since sodium iodide is highly hygroscopic, it is encapsulated within a hermetically sealed envelope. A plurality of phototubes are positioned near the crystal. When a phototube detects a scintillation, an electrical signal is emitted by the phototube. The electrical signal emitted by the phototube is of an intensity which is proportional both to the intensity of the light flash and its distance from the phototube.

Signals emitted simultaneously by the camera phototubes are amplified and then conducted to electronic circuitry. The preferred circuitry is described in greater detail in the referenced applications. This circuitry includes a pulse-height analyzer to determine whether or not the signals in question reflect the occurrence of a so-called photopeak event. Summing and ratio circuits are included which result in the signal being sent to an oscilloscope to cause a light signal to be emitted by the oscilloscope. The objective is that the oscilloscope signals be displaced relatively each at a location corresponding to the location of a corresponding scintillation in the crystal.

In a scintillation camera of the described type, a material forming an optical coupling is between the crystal and the phototubes.

In early cameras, mineral oil was used as this optical coupling. While this is an inexpensive procedure for providing a light coupling for an experimental machine, it has disadvantages. The disadvantages include: a) it obviously requires careful sealing to prevent leakage onto the patient or elsewhere; b) it presents filling problems to obtain a sufficient quantum of mineral oil in a cavity so that no matter what attitude the head is positioned in, there will be an effective light coupling between the crystal and each of the phototubes; and, c) it has other disadvantages which will become apparent.

Other cameras have been built with light pipes of solid materials. These have been configured with frustoconical shaped portions each axially aligned with a different one of the phototubes. These frustrums are difficult and relatively expensive to machine. The array of conical frustrums results in some "blank" areas of generally triangular configuration. The boundaries of these blank areas were each defined by three of the frustrums or by two frustrums and the perimeter of the light pipe.

With these prior art devices, attempts have been made to assure the conduction of as much light energy as possible to the phototubes. In fact, the attempt has been to assure that each photopeak event occurring in the crystal was delivered to the phototubes and resulted in an output signal which passed through a pulse-height analyzer or discriminator as the case might be. To assist in assuring this total reproduction of all photopeak events, prior cameras have utilized reflective surfaces in these "blank" areas and around the perimeter of the light pipe.

SUMMARY OF THE PRESENT INVENTION

With the present invention, the crystal envelope includes a polished glass window on the photomultiplier tube side of the crystal. The window is in tight, light-conducting, intimate contact with the crystal. A light pipe of thermoplastic poly(methyl methancrylate)-type polymers in cast sheet which is sold by Rohm & Haas Company, Philadelphia, Pa., under the trademark "Plexiglas" has a planar input surface which is optically coupled to the glass. The light pipe has an output surface opposite the glass and adjacent the phototubes. The output surface is machined or otherwise formed to provide a plurality of frustrums of pyramids. There is one pyramid frustrum for each phototube. Each pyramid frustrum is, in cross-sectional configuration,

hexagonal eliminating blank areas among the frustrums characteristic of prior solid light pipes.

The side walls of the pyramids are juxtaposed. Thus, a central field of view of the light pipe is continuous and uninterrupted.

It has been discovered that producing light flashes on an oscilloscope which accurately reflect the true location of a scintillation in a crystal is dependent, especially near the periphery of the crystal, on the optical coupling between the cyrstal and the phototubes. All top and side wall surfaces of the light pipe, other than the tops of the pyramids which are juxtaposed with the phototubes, are covered with a black coating for light absorption. To prevent light absorption in the pyramids, and to provide reflection, a white coating is applied to the walls of the pyramids prior to the black coating application. With this technique, scintillations perimetrally of the field of view of the light pipe are absorbed rather than reflected back into the field.

While this light absorption results in enough light energy from certain phototpeak events being absorbed that they are rejected by the circuitry, nonetheless, a very material advantage is produced. This material advantage is that distortions which have occurred in perimetral portions of prior art cameras of this type are reduced and therefore the useful field of view of the instrument is greatly enhanced. With a 13.5 inch diameter crystal, it has been found that the useful field of view of approximately 12 inches in diameter can be obtained through the use of the optical coupling of this invention as compared with useful field of view of the order of 9 to 10 inch diameter of prior art devices using crystals of 11 to 12 inch diameter.

Another advantage of the present invention is the provision of a lift-out subassembly. This subassembly includes the crystal, the light pipe and the array of phototubes. Accordingly, when service is required such as for replacing phototubes of the array, the entire subassembly can be removed from the head and a new subassembly inserted. This permits the camera to be placed back in use with nominal delay and the replacement of the phototubes to be performed at another location and at leisure.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a camera and associated consoles utilizing the novel detecting head of this invention;

FIG. 2 is a fragmentary, somewhat schematic, top plan view of the detector subassembly of this invention;

FIG. 3 is a sectional view of the detector subassembly of this invention as seen from the planes indicated by the lines 3—3 of FIG. 2;

FIG. 4 is a perspective view of the novel and improved light pipe of this invention;

FIG. 5 is an enlarged fragmentary view of a portion of the light pipe and a phototube; and,

FIG. 6 is a sectional view, on another scale, of the detector head assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a detector head is shown generally at 10. The head is adjustably mounted on a stand 11 for positioning adjacent a patient or other subject. Electrical signals from the head 10 are conducted to circitury contained within a console shown generally at 12.

The signals, after processing by the circuitry, produce a graphic image of the subject under investigation on a monitor oscilloscope 13. A duplicate image is produced on a camera osicIloscope cathode ray tube, not shown, which is viewed and photographed by a camera 14.

The circuitry in the console 12 first produces analog signals in manners more completely described in the referenced applications. Assuming the analog signals represent photopeak events, they are digitized. The digital signals may be fed to a computer for analysis and diagnosis.

The digital information is also fed to a build-in digital data processor 15. This processor utilizes the digital information to generate either a variable width profile histogram of counts versus horizontal distance of a histogram of counts versus time. such histograms are displayed on a monitor 17.

The digital information is also fed to a tape recording console shown generally at 19 for storage and subsequent utilization. The digital information is reconverted to analog to produce the images displayed on the monitor oscillscope 13 and recorded by the camera 14.

The imaging subassembly in this invention is shown in FIGS. 2, 3, and 6. The subassembly is mounted in a housing 21. The subassembly includes a large scintillation crystal 20 of thallium-activated sodium iodide. A parallel hole collimator 22 is removably secured to the housing 21, FIG. 6. Either a parallel hole or a pinhole collimator is interposed between the crystal and the patient so that the gamma rays striking the crystal are all travelling in determinable directions. The housing and the perimetral portions of the collimator are formed of shielding material such as lead so that essentially the only radiation which reaches the crystal has travelled along a determinable path through the collimator.

An input window 23 is provided. The window 23 is opaque to light but substantially transparent to gamma radiation. This input window is typically an aluminum disc fixed to and hermetically sealed to a surrounding crystal supporting ring 24. A glass output window 25 is carried by the crystal supporting ring 24. The crystal 20 and the input and output windows 23, 25 and its supporting ring 24 constitute a component which is commercially available from the Harshaw Chemical Company of Cleveland, Ohio.

The window component is secured to a supporting ring 27 by suitable fasteners 28. The supporting ring 27 is connected to a crystal assembly support ring 29 by an annular spacer 30.

A light pipe 32 is provided. The light pipe 32 has a planar input face 33 that is optically coupled to a polished, planar output face 34 of the output window 25.

A plurality of phototubes 35 are provided. The phototubes 35 are arranged in an array with a total of 19 such tubes being provided. The phototubes 35 have input windows 36 which are juxtaposed against the light pipe 32 in a manner which will be described in greater detail presently. Suitable conductors, not shown, couple the phototubes 35 to the circuitry in the console 12.

Apertured tube locator and cover plates **38, 39** are provided. The tube locator plate **38** is interposed between and spaced from the cover plate and the light pipe. Spacers **40** are interposed between the cover and tube locator plates to maintain the appropriate spacing between them. Fasteners **41**, FIG. **2**, connect the plates **38, 39** together with the spacers **40** therebetween.

Annular bushings **42** are provided. Each of the bushings **42** surrounds a corresponding one of the phototubes. The bushings **42** are interposed between the cover plate **39** and the phototubes **35**. The bushings are compressible and, on clamping of the assembly together in a manner which will be described presently, bias each of the tubes **35** into surface engagement with an appropriate portion of the light pipe **32**.

A spacer cylinder **43** and a plurality of studs **43***a* are provided. The studs **43***a* project through the cover plate **39** and are secured to the crystal assembly support ring **29** as by screws **44**, one of which is shown in FIG. **3**. The cover plate **39** and the crystal assembly support ring **29** are clamped against the spacer cylinder **43** by tightening down suitable nuts **46** on the studs **43***a*. This fixes the entire lift-out phototube assembly together with the phototubes **35** in closely juxtaposed relationship and good optical coupling with the light pipe **32** and the light pipe in turn optically coupled to the glass window **25**.

To facilitate replacement of or repair of the phototube subassembly, a pair of lift-out handles are provided. One of these lift-out handles is shown at **48** in FIGS. **2** and **3**. The lift-out handles are threaded onto selected pairs of studs **43***a* at diametrically opposite locations. When the subassembly is to be removed, housing cover **21***a* is removed. Anchor studs **45**, FIG. **6** are removed. Next the handles are raised to the position shown in FIG. **3** and the entire subassembly is lifted out of the housing **21**.

Referring now to FIGS. **4** and **5**, the light pipe **32** is machined to provide a total of **19** frustrums of pyramids **52**. The pyramids **52** each terminate at a pyramid output face **53**. Each pyramid output face is flat and designed to optically couple with an associated input window **36** of a phototube **35**. The pyramid output faces **53** are in a common plate parallel to the light pipe input face **33**.

The pyramid frustrums **52** are hexagonal in cross-sectional configuration with six planar wall surfaces **55**. These walls **55** are formed by milling grooves **56** in a surface of the light pipe **32**. While the grooves **56** can be formed such that the surfaces **55** intersect to delineate a sharp V; for convenience of manufacture and for optical reasons which appear to produce improved performance for reasons that are not fully understood, the grooves are milled such that the base of each groove is curved in configuration. Thus, each pyramid wall has a portion **55***a* which is at an obtuse angle with respect to its associated output face **53**. Each wall **55**, other than perimetral ones of said walls, parallels an adjacent wall **55** of another pyramid. The concentration of these adjacent walls is by a curved portion **55***b* which is concave in configuration as viewed from the phototube side of the light pipe. Thus, the walls of the pyramid, while they may be curved in a plane of cross section normal to the input face **33**, are straight in planes of cross section paralleling the input face. Expressed another way, each pyramid wall flares outwardly until it intersects an adjacent pyramid wall to provide total coverage in the field of view of the pyramids. The pyramids are uniformly spaced and sized.

The surfaces **55** delineating the sides of the **19** pyramids are coated with a white reflective material indicated at **57**, FIG. **5**. Side wall **58** of the light pipe and the entire top surface of the crystal **32**, other than the pyramid faces **53**, are then coated with a black coating indicated at **59**. For clarity of illustration, The white and black coatings **57, 59** are shown in greatly exaggerated thickness in FIG. **5**.

The dimension from wall to wall, diametricallyy across the top of an output face **53** of a pyramid, as measured perpendicularly to the walls, is equal to the diameter of a photocathode, not shown, of any one of the phototubes. This assures that the entire photocathode of each phototube is exposed to light transmitted through the associated pyramids.

Since each phototube is of a diameter larger than its photocathode, the phototube itself overlies the entire contiguous output face **53** of a pyramid. Thus, light passing through one of the pyramids passes only into the associated phototube. A further assurance against false signals due to stray light is provided by wrapping each phototube with black tape **65** or other light-impervious covering.

With the pyramids providing a continuous, total coverage over the field of view, and the specifically described arrangement, each scintillation occurring in the crystal **20** results in an output signal from each of the phototubes **35**. The total of all phototube signals are summed in the circuitry within the console **12**. If the sum of all signals is within a predetermined and desired energy level, as determined by a pulse-height analyzer, a signal will be reproduced on the monitor oscilloscope **13** or other output device in use.

With prior art light pipes and their surrounding reflective surfaces, attempts have been made to utilize all photopeak events. These reflections "confused" the circuitry, resulting in improperly located oscilloscope images. Also, the phototube signals of these prior devices tended on occasion to indicate that perimetral ones of the scintillations occurred more closely to the center than in fact was the case because of the lack of output signals diametrically outward from such scintillations. The resulting oscilloscope signals representative of such perimetral scintillations tended to be produced inwardly of their proper locations. The result was an excessive concentration of signals at the perimeter of an oscilloscope image.

This peripheral concentration with prior art constructions resulted in a useful field of view, in an 11 to 12 inch crystal, of the order of 10 inches in diameter or less. A 10 inch diameter field of view is about 69 percent of the total area of a 12 inch crystal. With the camera of this invention, almost 80 percent of the area of a 13.5 inch diameter crystal is utilized in producing a useful image. This outstanding advantage is obtained because some scintillations occurring near the perimeter of the crystal **20**, even when they are so-called photopeak events, will not produce signals on the monitor oscilloscope **13** or other output devices. Signals resulting from such perimetral scintillations do not occur because such a large percentage of the light energy is absorbed by the black coating on the perimetral surface **58** and on perimetral portions **60** of the light pipe.

Although the invention has been described in its preferred form with a certain degree of particularity, it is

understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. In a device for producing a display representative of the spatial distribution of incident stimuli from a subject under investigation including a light-emitting mechanism for emitting flashes of light in response to such incident stimuli and a plurality of light responsive components each of which emits electrical signals in response to light signals incident upon it with such signals each being proportional to the intensity of the light signal responded to, an improved light pipe forming at least a portion of an optical coupling between the mechanism and the components, the improvement comprising:

a. a sheet of light-transmitting material having input and output surfaces defining an input face and a plurality of separate output faces;

b. the input surface of the sheet being oriented toward the mechanism;

c. the output surface of the sheet including walls defining a plurality of truncated pyramids formed therein with each of said truncated pyramids defining a separate one of said output faces;

d. at least one of said components being optically coupled to each pyramid to receive light energy conducted through such pyramid; and,

e. the ends of the pyramids nearest said mechanism being contiguous and at least intersecting to provide a continuous field of view area.

2. The device of claim 1 wherein each pyramid is hexagonal in a plane of cross section paralleling the input surface.

3. The device of claim 1 wherein selected surfaces of said sheet perimetral of said field of view are blackened.

4. The device of claim 3 wherein th blackened surfaces comprise a perimetral surface of the sheet and portions of an output face of the sheet perimetral of the field of view and generally transverse to the perimetral surface.

5. The device of claim 1 wherein there is a white coating on the pyramid walls and a black coating over the white and on perimetral portions of the sheet.

6. A scintillation camera comprising:

a. collimation means;

b. a light emitting mechanism for providing a light output in response to incident radiation stimuli, said light output including light scintillations representative of the spatial distribution of said incident radiation stimuli;

c. light responsive means to receive the light output from said light emitting mechanism and to produce an output representative of the spatial distribution of the scintillations emitted by said light emitting mechanism and received by said light responsive means;

d. structure mounting said light emitting mechanism at a position between said collimator means and said light responsive means and shielding said light emitting mechanism from incident radiation other than that which passes through said radiation delineating means;

e. light transmitting mechanism interposed between said light emitting mechanism and said light responsive means and including a sheet of light transmitting material having an input surface oriented toward said light emitting mechanism defining an input window for receiving light scintillations and an output surface optically coupled to said light responsive means at a plurality of spaced positions, said positions defining a plurality of spaced output windows; and,

f. light absorbing means on said light transmitting material and forming at least one light absorbing ring around at least one of said output windows.

7. The scintillation camera of claim 6 wherein said light absorbing ring is of light absorbing material disposed around the perimeter of said light transmitting material and surrounding said output windows.

8. The scintillation camera of claim 6 wherein said light absorbing ring comprises a black coating.

9. The scintillation camera of claim 6 wherein said light absorbing means includes a separate light absorbing ring surrounding each of said output windows.

10. The camera of claim 9 wherein a white coating underlies said light absorbing material in regions adjacent said output windows.

11. The scintillation camera of claim 9 wherein said light absorbing means comprises a black coating.

12. The scintillation camera of claim 9 including still another light absorbing ring disposed around the perimeter of said light transmitting material surrounding all of said output windows.

13. The scintillation camera of claim 11 wherein said light absorbing rings comprise black coatings.

14. The scintillation camera of claim 6 wherein said light absorbent means comprises a layer of light absorbent material adhered to the peripheral surface of the sheet.

15. The scintillation camera of claim 14 wherein the layer of light absorbent material comprises a coating which is deposited on the peripheral surface.

16. In a gamma imaging device, the improved detector head for emitting signals that result in positioned signals on an output device comprising:

a. a housing;

b. a collimator connected to the housing;

c. a scintillation crystal carried by the housing inwardly of said collimator;

d. a plurality of phototube means within the housing and adapted to emit electric signals in response to light scintillations occurring in the crystal;

e. a crystal housing around the crystal and including an output window between the crystal and phototube means;

f. a solid light pipe optically connecting said window to the phototube means;

g. said light pipe having an input face of planar configuration in tight juxtaposed optical coupling with said window;

h. said light pipe having an output surface;

i. each of said phototube means being optically coupled to said output surface; and,

j. light-absorbing means on said light pipe and disposed perimetrally of at least certain of said phototube means for absorbing light transmitted to said light pipe such that some of the scintillations occurring in the crystal, even if photopeak events, will not produce signals on an output device.

17. The device of claim 16 wherein said light-absorbing means includes an annulus.

18. The device of claim 17 wherein said annulus is perimetral of said phototube means.

19. The device of claim 16 wherein said light-absorbing means is disposed around the perimeter of said light pipe.

20. The device of claim 16 wherein the light-absorbing means is black coating material.

21. The device of claim 16 wherein:

a. said output surface defines a plurality of spaced output windows disposed in a common plane;

b. each of said output windows is surrounded by walls defining a truncated pyramid with the walls of all such pyramids other than perimetral ones of said walls, flaring outwardly to intersect adjacent walls and provide continuous coverage over a field of view.

22. The device of claim 16 wherein the walls of each pyramid define a hexagon in a plane of cross section.

23. The device of claim 16 wherein each pyramid wall has a portion at an obtuse angle with respect to its associated output face.

24. The device of claim 23 wherein each pyramid wall other than perimetral walls is connected to an adjacent wall by a curved surface which is concave as viewed from the phototube side of the light pipe.

* * * * *