Dec. 5, 1967 R. W. CARLSON 3,356,851

IMAGE INTENSIFIER TUBE WITH SEPARABLE OPTICAL COUPLER

Filed Oct. 22, 1963

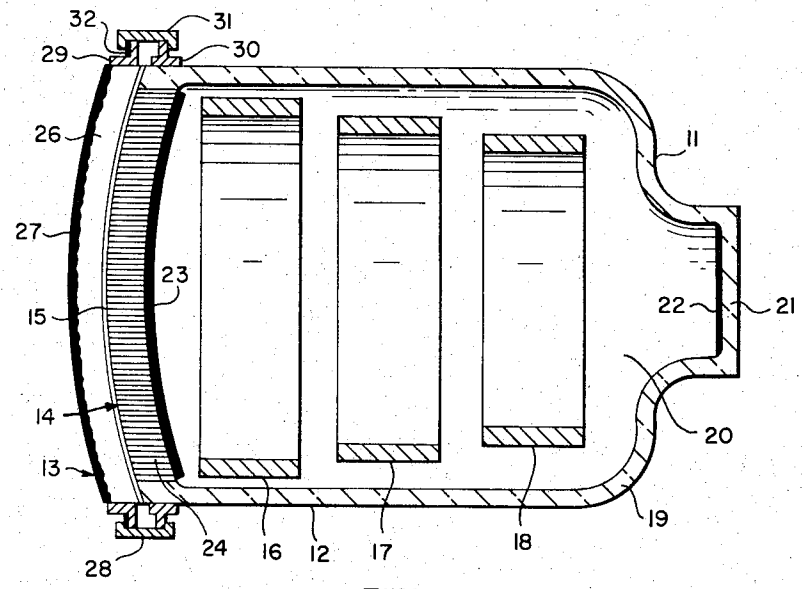


FIG.-1

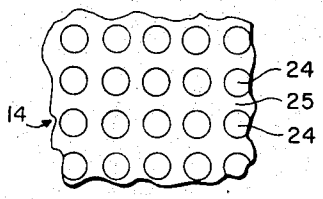


FIG.-2

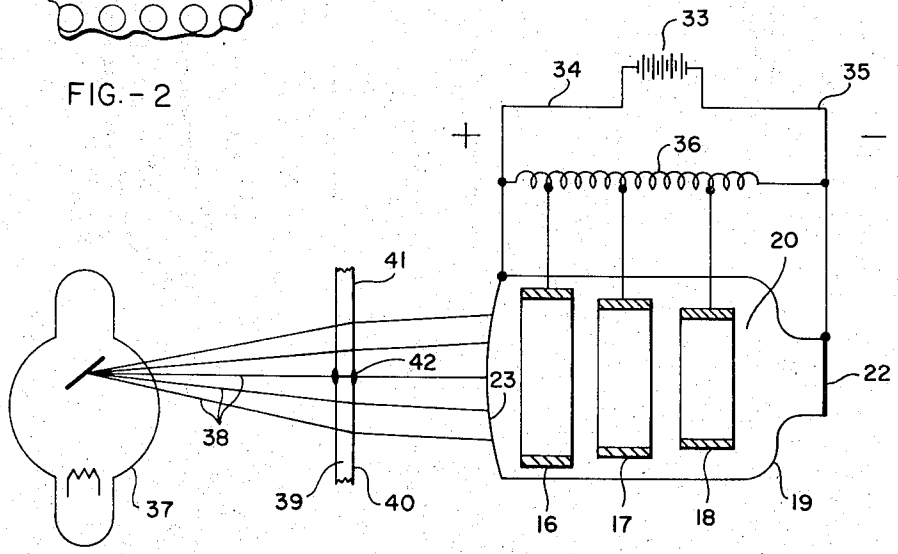


FIG.-3

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IMAGE INTENSIFIER TUBE WITH SEPARABLE OPTICAL COUPLER

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The present invention relates generally to fluoroscopy and more particularly to an image intensifier tube system for use in a fluoroscopic inspection system.

The present image intensifier tube system is especially suitable for use in fluoroscopic inspection of inanimate objects, e.g. components and materials used in air and space vehicles. Technological advances, especially in the area of missiles and spacecraft, have placed a greater need for reliability on the components and materials which make up the complex mechanism of these vehicles. This reliability is achieved mainly through more comprehensive and exceedingly rigid inspection techniques. The items to be inspected range from small electronic components having internal parts as small as .0005 inch in size to welds in metals to solid rocket fuel. In all cases, the inspection process must be rapid, inexpensive and permit 100% inspection.

In the past, radiography has been sometimes used as one means of inspection. However, if radiography is the means used, then fine-grain film radiographs must be inspected with considerable optical magnification to permit visualization of such small parts.

Other inspection methods have employed closed circuit television systems employing a vidicon camera tube which is sensitive to X-rays. Such systems employing the vidicon have at least two serious disadvantages. First, the size of the sensitive area, i.e., the raster, is quite small and approximately ⅜ by ½ inch, which limits the field of observation. Secondly, large X-ray fluxes are required to produce usuable signal strengths. In addition, since the energy which can be produced from a focal spot on an X-ray tube is limited by heat transfer problems, in practice one must use a higher kilovoltage potential to inspect a small electronic device such as a transistor with an X-ray sensitive vidicon than is required to produce a radiograph or to operate an X-ray image intensifier. This reduces the contrast of the image and increases the cost of the X-ray generator and its associated shielding. Finally, the efficiency of the X-ray sensitive vidicon is limited by the fact that its photo-cathode must be kept quite thin (approximately 30 microns) and thus, is a poor absorber for the X-ray beam.

There are many medical apparatuses for making radioactive surveys or studies of human organs. An example of one such apparatus is an image intensifier described in U.S. Patent No. 3,048,698 issued to Roland W. Carlson and entitled "Scintillation Camera." The scintillation camera described in this patent is for use in radiography for taking an instantaneous picture of the distribution of radioactive material within a human organ. This device, however, is not entirely suitable for inspecting inanimate objects by fluoroscopic techniques mainly because of the high resolution required.

In the present invention, this problem is overcome by converting the X-ray or other incident energy to visible light which is then efficiently coupled to the photo-cathode of the image intensifier tube. To accomplish the latter function, the present invention provides an image intensifier tube having a fiber optics face plate or window. The tube has a photo-cathode layer disposed on the inside surface of the face plate. An incident energy conversion unit, which is preferably a single thin crystal, is placed in contact with the outer surface of the fiber optics face

plate to convert the incident energy to light energy of a suitable wave length. A non-reflective coating preferably covers the outside surface of the conversion unit. In a preferred form of the invention, a separable optical coupling medium provides intimate optical contact between the conversion layer and the fibers optics face plate. The light from the thin crystal travels in almost straight lines to the photo-cathode with high efficiency and high resolution.

The separable coupling between the conversion unit and the face plate permits a variety of crystals or other elements capable of converting various types or levels of incident energy into light to be placed against the window of the image intensifier tube without requiring alteration of the inner tube structure in any way. This is quite advantageous over the prior arrangements wherein the means of converting the incident energy into visible light is placed inside the sealed, evacuated envelope of the image intensifier tube, and may not afterwards be changed without destroying the tube. Moreover, it also eliminates the problem in such prior arrangements wherein the crystals, screens or other conversion elements are often incompatible with the required environment inside the image intensifier tube.

Accordingly, an object of the present invention is to provide a new and improved high reslution image intensifier tube system for providing fluoroscopic images of inspected objects.

Another object of the present invention is to provide a new and improved image intensifier tube system wherein the incident energy falling on the input end of the tube system is converted to light which is intimately optically coupled to a photo-cathode layer.

Yet another object of the present invention is to provide a new and improved image intensifier tube system wherein the intensifier tube may be alternately used for amplifying various types or levels of incident energy.

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 accompanying drawing in which:

FIGURE 1 is a cross sectional view in a longitudinal plane of the image intensifier tube system of the present invention.

FIGURE 2 is an enlarged front view of a piece of the input window of the intensifier tube shown in FIGURE 1.

FIGURE 3 is a schematic diagram of an acceleration system connected to the image intensifier tube system of FIGURE 1 and shows the tube system in use.

Referring now to the drawing, a preferred form of the image intensifier tube system of the persent invention is generally designated by the reference character **11**. The tube system **11** includes an amplifier tube **12**, an incident energy conversion unit or pack **13** is disposed in front of an input image window **14** in the amplifier tube **12**, and an optical coupling medium **15** optically coupling the conversion unit **13** to the input window **14**. Electron acceleration rings **16**, **17** and **18** are provided to intensify an image received at the front window of the tube.

The image intensifier tube **12** comprises a sealed envelope **19** which defines an evacuated internal chamber **20**. The envelope **19** has the input window **14** at the front or input end of the chamber **20** and a fluorescent observation window **21** at the output end of the chamber **20**. A phosphor layer **22** covers the inner surface of the window and forms an observation screen. A photo-cathode layer **23** covers the inside surface of the input window.

The input window **14** comprises an optical fiber bundle which is a multitude of tiny light conveying transparent fibers **24** arranged in parallel relation and held together by a translucent material **25**. The input end of the input

fiber bundles **24** are shown in an enlarged, exaggerated view in FIGURE 2 for purposes of clarity. Fiber bundles .01 inch in diameter have been found suitable for use in the intensifier tube system. Fiber bundles as small as .001 inch are available and provide even better efficiency and resolution. As shown in FIGURE 1, the input fiber optics window **41** is formed integrally as a part of the tube **12** and has generally spherical front and rear surfaces.

The incident energy conversion unit **13** comprises an energy conversion layer **26** and a non-reflective coating **27**. The thicknesses of the conversion layer **26** and the non-reflective coating **27** are shown exaggerated in size in relation to the tube **12**. In a preferred form of the invention the conversion layer **26** is a single thin crystal of a material, for example, cesium iodide (CsI) for converting high energy photons (circas 1 mev. to 2 mev.) to light photons. A CsI crystal approximately ⅛ inch thick in size has been found suitable for this purpose. The non-reflective coating **27** is a light photon absorbing layer for removing light photons traveling in directions other than towards the input fiber optics window **14**. One suitable material for this latter purpose is a carbon black pigment in an epoxy resin.

The refractive index of the non-reflective coating **27** should be as close as possible to the refractive index of the conversion layer **26**. This is to assure that light photons not traveling towards the input fiber optics window **14** will pass through the interface between the coating **27** and the conversion layer **26** and will be absorbed by the coating **27** rather than reflect back into the conversion layer. As practical examples, in the preferred embodiment shown the refractive index for the conversion layer **26** is 1.8 and the refractive index for the coating **27** is 1.5. In addition, the coated surface of the conversion layer **26** is roughened to further prevent undesirable reflection from the interface between the coating **27** and the conversion layer **26**.

The optical coupling medium **15** is preferably a light photon conveying substance which provides intimate and efficient optical coupling of the conversion unit to the input window **14** and further permits the conversion unit **13** to be readily detached or separated from the input window **14** without damaging or destroying either. Examples of substances suitable for this purpose are silicone oils or greases.

A conversion unit positioning and locking apparatus **28** is provided. The positioning and locking apparatus includes a mounting flange **29** on the unit **13**, a mounting flange **30** on the tube **12**, a clamp **31** which holds the flanges **29**, **30** together, and a rubber washer **32** which provides a spring pressure to the assembly.

In FIGURE 3, an X-ray tube **37** emits a beam of X-rays **38** which impinge a specimen **39**, as for example plates **40**, **41** joined by a weld **42**. The energy in the form of X-rays passing through the welded plate impinges on the front surface of the image intensifier tube system and passes through the non-reflective coating **27** to the conversion layer **26**. The energy photons striking the conversion layer **26** cause it to isotropically emit light photons. Only those light photons traveling in a direction toward the input window **14** are received by the input end of the optical fibers **24**. All other are absorbed by the non-reflective coating **27** and are lost. Even those light photons which are at angles greater than the critical angle of reflection from the direction of the incoming photon beam will be lost. This increases the contrast sensitivity of the tube system since the light photons produced within the conversion layer **26** and absorbed by the non-reflective coating **27** are not position information carrying photons, but rather are regarded as noise.

The light photons traveling toward the input window **14** pass with little interference and high efficiency through the coupling medium **15** to the input end of the fibers in the fiber optics window **14**. The light photons travel through the transparent fibers **24** in substantially straight lines to the photo-cathode layer **23**. The light photons striking the photo-cathode layer cause it to emit electrons in an electronic image similar to the incident energy image impinging the front of the intensifier tube system. The emitted electrons are accelerated by the acceleration rings **16–18** as the electrons pass through the evacuated chamber **19** toward the output phosphor layer **22**.

The acceleration rings **16–18** are electrostatically charged and, as measured by the input window end of the tube toward the opposite end of the tube, they are of progressively decreasing diameter to focus the electrons passed through the vacuum chamber **20** into a smaller area as they are accelerated. The accelerated electrons bombard the phosphor layer **22** and produce an amplified visual image suitable for fluoroscopic purposes.

As shown in FIGURE 3, a source of direct potential **33** is connected to the photo-cathode layer **23** and to the output end phosphor layer **22** by conductors **34**, **35**. The source of electric potential **33** is so connected to prevent the photo-cathode from assuming a positive charge and thereby stopping the flow of electrons. Thus, the source of electric potential **33** and the conductors **34**, **35** can be said to provide means to neutralize the charge between the cathode and the end phosphor layer **22**. The source of electric potential **33** is also connected to the electrostatic rings **16–18** through an impedance **36** to provide and maintain proper charges in the rings. The impedance **36** is connected to the conductors **34**, **35** to place it in parallel with the tube **12**.

The present invention thus provides a light sensitive image tube with an optical multi-element front face which is capable of conducting light to a photo-cathode from a diffused source placed in intimate contact with the outer surface and this it does with high efficiency and little loss of resolution. With optical fibers as small as .001 inch, the resolution of the present image intensifier tube system will depend largely on the resolution of the external energy conversion unit. It is to be noted that the energy conversion unit is separable from the image tube without destruction of either for replacement by a conversion unit of higher resolution and/or different energy converting capabilities. Thus, a single image intensifier tube may be used with any number of conversion units to provide an X-ray image intensifier, a neutron image intensifier, an alpha particle image intensifier, as well as an intensifier for any other energy which may be used for inspection purposes.

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. An image intensifier comprising:
   (a) an image intensifier tube having an envelope with an image input end portion and an intensified image output end portion;
   (b) said image input end portion including a fiber optics input window and a photo-cathode layer adjacent the window and inside the envelope;
   (c) a thin scintillation phosphor crystal outside the envelope end disposed over the input window on the side opposite the photo-cathode layer;
   (d) a separable optical coupling medium between the scintillation phosphor crystal and the fiber optics window;
   (e) a light absorbing coating over the outer surface of the scintillation crystal; and
   (f) a separable means removably coupling the scintillation phosphor crystal and the window.

2. An image intensifier comprising:

(a) an image amplifier tube having an envelope with an input image window at one end and an output observation screen at the other end;

(b) said input window comprising a fiber optics bundle for conveying light photons in a parallel manner through the window;

(c) a photo-cathode layer within said envelope on the inside surface of said window;

(d) a fluorescent layer outside said envelope and positioned adjacent the outside surface of the window for converting incident energy photons into light photons;

(e) a separable optical coupling medium optically coupling said fluorescent layer to said input window; and

(f) separable means removably coupling said fluorescent layer to the window.

3. The device of claim 2 wherein said separable means is a locking means connected to said tube and said conversion layer and locking said conversion layer adjacent said input window.

4. An image intensifier comprising:

(a) an image intensifier tube having an envelope with an image input end portion and an intensified image output end portion;

(b) said image input end portion including an input window and a photo-cathode layer adjacent the window and inside the envelope;

(c) a fluorescent layer disposed outside the envelope and over the input window on a side opposite the photo-cathode layer; and,

(d) a separable means removably coupling the fluorescent layer and the window.

5. The device of claim 4 in which the outer surface of said fluorescent layer is rough and comprises a coat of light-opaque material having an index of refraction substantially the same as the index of refraction of said fluorescent layer.

6. The device of claim 4 wherein the window is a fiber optics bundle in which each of the fibers of said fiber optics bundle are substantially parallel.

7. The device of claim 6 in which the outer surface of said fluorescent layer is rough and comprises a coat of light-opaque material having an index of refraction substantially the same as the index of refraction of said fluorescent layer.

8. The device of claim 4 wherein said fluorescent layer is a scintillation crystal.

9. The device of claim 4 wherein an optical coupling medium is between the fluorescent layer and the input window.

10. The device of claim 4 wherein said input window is a fiber optics bundle.

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WALTER STOLWEIN, *Primary Examiner.*