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Williams et al.

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[45] **Jan. 30, 1973**

[54] IMAGE COMPARISON DEVICE AND METHOD

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[52] **U.S. Cl.**.....**250/201,** 250/213 VT, 250/219 R, 324/71 NE, 356/163

[51] **Int. Cl.**.....**G01b 7/00**

[58] **Field of Search**.....88/14 E; 250/213; 324/77 I; 343/100.7; 313/65, 65 A

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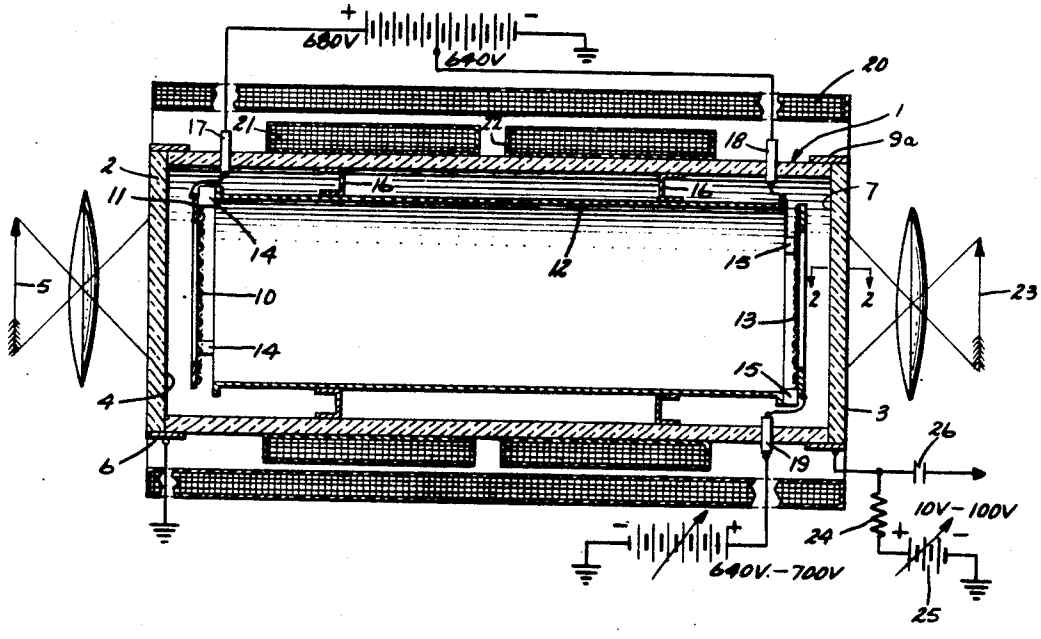
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[57] **ABSTRACT**

Separate simultaneously occurring radiation images are transformed by a storage electrode and a photoelectric cathode respectively into a charge image and an electron beam which are superimposed within an electron tube for comparison. An output signal is provided representing the coincidence of the two images.

12 Claims, 7 Drawing Figures



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SHEET 1 OF 2

Fig. 1

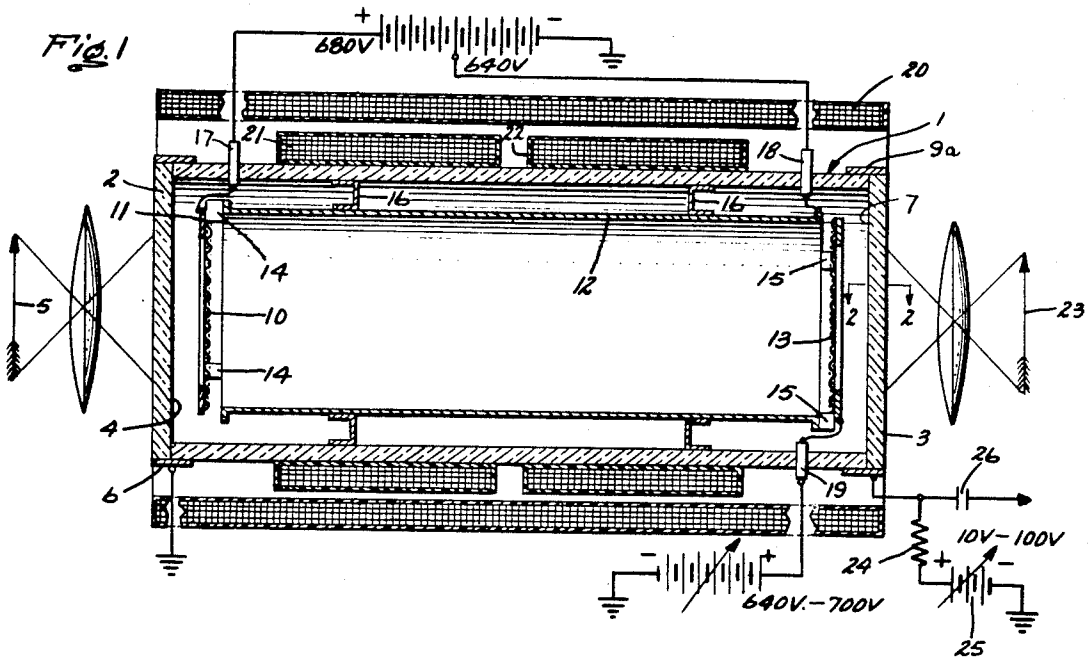


Fig. 2

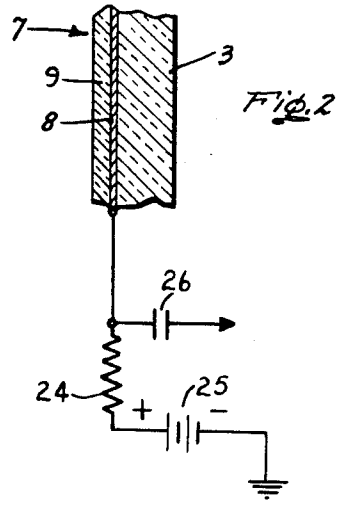


Fig. 3

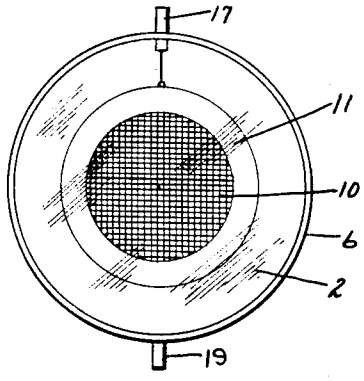
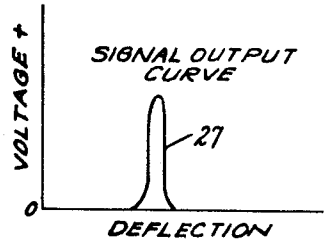


Fig. 4



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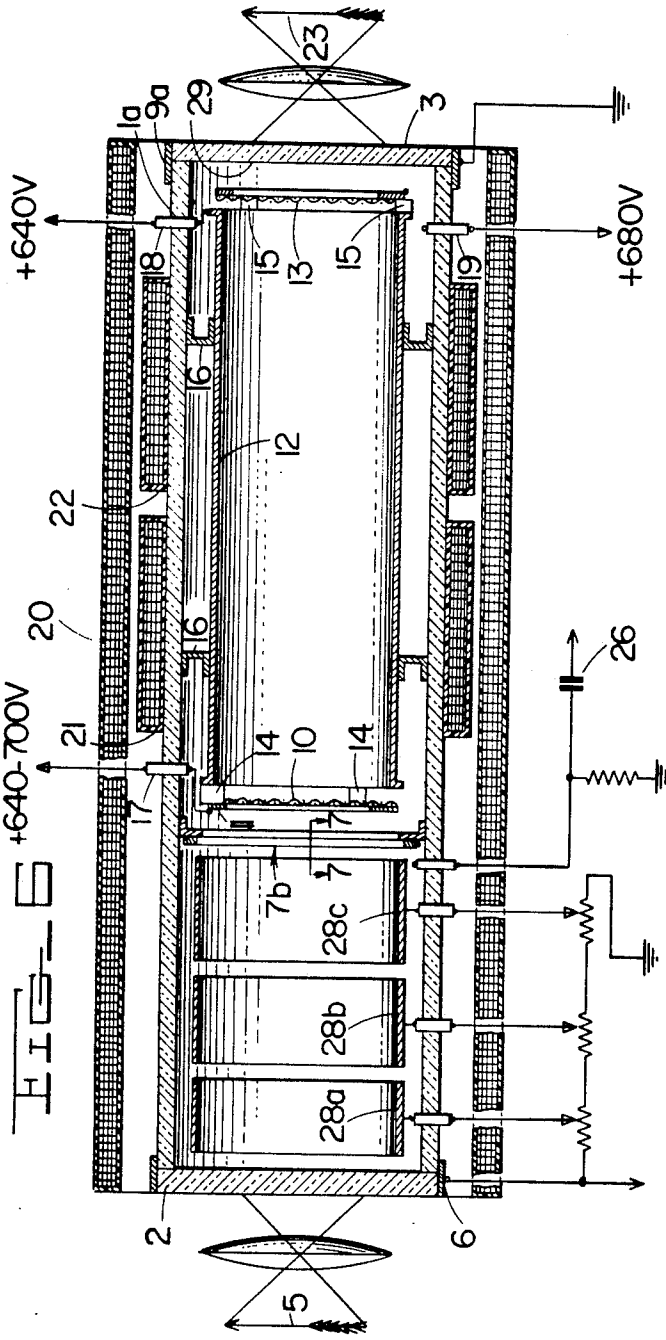


FIG. 6

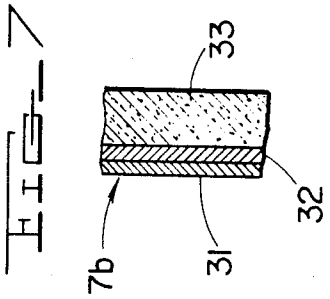


FIG. 7

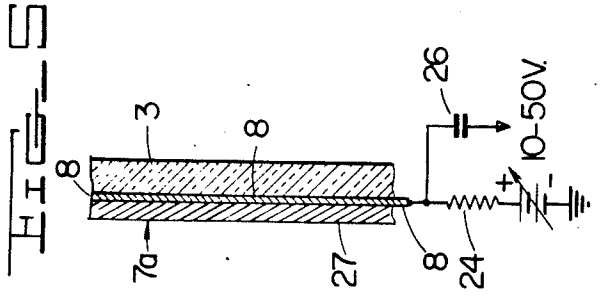


FIG. 5

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IMAGE COMPARISON DEVICE AND METHOD

The present invention relates to an image comparison device and method and more particularly to a device and method capable of determining coincidence of separately, simultaneously developed charge and electron images which correspond, respectively, to given radiation images.

Previously proposed have been image comparison or correlation devices, such as those disclosed and claimed in Nevin application Ser. No. 465,922, filed June 22, 1965, wherein electron permeable, long-term storage electrodes have been used for the storage of basic information with which a separately developed electron image may be compared. These storage and comparing steps were sequential. The present invention differs from this prior art proposal in several respects, one being simultaneous comparing and storing of images.

It is therefore an object of this invention to provide an image comparison device and method whereby comparison of a charge image with an electron image may be effected simultaneously with the creation of these images.

Another object of this invention is to provide an image comparison device wherein the destruction, erasure or read-out of a stored charge image by correlation with an electron image results in the development of an electrical signal representative of the degree of coincidence between the two images.

The invention in its broader aspects includes an electron discharge tube having a photosensitive storage electrode capable of developing and retaining a charge image in response to a given radiation image. A photoelectric cathode is operatively disposed with respect to the storage electrode for receiving either the same or a different radiation image and transforming the same into an electron image which may be focused onto the storage electrode. Means are provided for scanning or correlating the position of the electron image with the stored image such that the degree of coincidence therebetween can be determined by the development of a representative electrical signal.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a partial schematic and partial sectional view of one embodiment of this invention;

FIG. 2 is a fragmentary, enlarged sectional illustration of the storage electrode of the arrangement of FIG. 1;

FIG. 3 is a front view of the left-hand end of the device in FIG. 1;

FIG. 4 is a simple curve used in explaining the operation of this invention;

FIG. 5 is a view similar to FIG. 2 of another embodiment of this invention;

FIG. 6 is a longitudinal sectional view of yet another embodiment; and

FIG. 7 is a fragmentary cross-section of the target of the tube of FIG. 6.

Referring to FIG. 1, an elongated, evacuated, tubular envelope 1 has opposite end walls 2 and 3. A conventional photoelectric cathode 4 is deposited or otherwise

positioned on the inner surface of the end wall 2 which is transparent to the wavelength of the radiation to be viewed. More specifically, the photoelectric cathode 4 preferably is flat and disc-shaped, and at right angles to the axis of the envelope 1. An optical image projected onto the cathode 4 from a subject 5 causes the cathode 4 to emit low velocity electrons in a form which is an electron duplicate thereof. Cathode 4 is connected to a terminal 6 in the form of a metallic ring secured to envelope 1, which in turn is adapted to be connected to ground and/or to a suitable source of operating potential.

Applied to the inner face of the end wall 3, which is also selected to be transparent to radiation to be viewed, is a flat, disc-shaped storage electrode 7 (see FIG. 2) of conventional materials and construction. More specifically, the storage electrode 7 may be the same as the photoconductive targets used in common television camera tubes, such targets including a layer 8 of transparent, conductive material having thereon a layer 9 of photoconductive material which, in the absence of radiation, is a good insulator. A typical construction for such a photoconductive electrode is disclosed in Cashman U.S. Pat. No. 2,730,638. A terminal in the form of a metallic ring 9a peripherally secured to the end wall 3 is conductively connected to the metallic layer or backing 8.

In order to provide for initial acceleration of the electrons emanating from the cathode 4 and also to provide an essentially field-free space within the envelope 1 for deflection of an electron beam formed from the cathode electrons, a field electrode or mesh 10 is provided extending in parallelism with the cathode 4 in close spaced relation therewith. This mesh 10 is disc-shaped and conductively secured to a suitable metallic ring 11.

A tubular electrode 12 extends coaxially within the envelope 1 substantially the entire distance between the field mesh 10 and a collector electrode 13 disposed adjacent to the storage electrode 7. The field mesh 10 is supported on the left-hand end of the tubular electrode or drift tube 12 by means of a suitable number of ceramic or the like insulators 14 as shown. The collector 13 may also be of mesh construction identical to that of the field mesh 10 and supported on the right-hand end of the drift tube 12 by means of identical insulators 15. The collector 13 is positioned parallel to and in close spaced relationship with the electrode 7 for reasons which will be explained later on.

Securing the drift tube 12 within the envelope 1 are two metallic supporting rings 16 secured at the inner and outer peripheries thereof to the drift tube 12 and envelope 1. A terminal 17 passing through the wall of the envelope 1 is connected to the field mesh 10, another similar terminal 18 connects to the drift tube 12, and yet another terminal 19 connects to the collector 13.

For further detailed information regarding a suitable structure for the cathode 4, the mesh 10 and the drift tube 12, reference may be had to Richard H. Foote application Ser. No. 398,891, now U.S. Pat. No. 3,329,856 filed Sept. 24, 1964, and entitled "Image Dissector Tube", and also to Clayton application Ser. No. 263,321, filed Mar. 3, 1963, now abandoned.

In order to focus the electrons emanating from the cathode **4** onto the storage electrode **7**, a solenoid, focusing coil **20** extends coaxially of the tube **1** as shown. Also, suitable horizontal and vertical deflection coils **21** and **22** are mounted radially opposite the drift tube **12** and are disposed inside the focusing coil **20** as shown. Focusing coil **20**, when suitably energized, provides a magnetic field extending axially through the envelope **1** and the drift tube **12**.

Further information regarding the construction and operation of the focusing and deflection coils may be had by referring to Nevin application Ser. No. 465,922, filed June 22, 1965.

Operating potentials are applied to the various terminals as illustrated, a difference of potential being applied between the field mesh **10** and the drift tube **12**, and a variable supply voltage being applied to the collector **13**. The storage electrode **7** is operated at a voltage slightly positive with respect to ground.

With proper operating potentials applied, the left-hand face of the storage electrode **7**, in other words the surface of the photoconductive layer **9**, is charged uniformly to a potential negative with respect to the conductive backing **8**. In one mode of operation, this is accomplished by flooding the cathode **4** with light such that the latter emits a floodbeam of electrons which is focused uniformly onto the surface of photoconductive layer **9**. Electrons impacting this surface of layer **9** eject secondaries at a ratio less than unity which are collected by the electrode **13**. This leaves the surface of the layer **9** with a uniform charge which is negative with respect to the backing **8**.

By focusing a radiation image of, for example, an object **23** onto the electrode **7**, the layer **9** (FIG. **2**) is, in accordance with conventional operation, varied in conductivity at various portions the area thereof in correspondence with the intensity of the radiation image at corresponding portions thereof. This results in the total or partial discharge of the uniform area charge previously stored on the left face of the layer **9**, such that a charge image corresponding to the shape of the subject **23** is formed. More specifically, the areas on the surface layer **9** receiving highlights will discharge to the positive potential value of backing **8** such that the resulting charge image will comprise discrete adjoining areas of both positive and negative charge.

Now, assuming that the optical image of the subject **5** projected onto the cathode **4** is identical in size and shape to the charge image just developed on electrode **7**, the focusing of the resulting electron image into exact area coincidence with the charge image will result in maximum current flow through the photoconductive layer **9** and more particularly through those portions underlying the positive areas. This current passing through a load resistor **24** coupled in series between the annular terminal **9a** and a supply battery **25** results in the development of a potential drop which may be coupled to utilization circuitry (not shown) by means of a capacitor **26** also connected to the terminal **9a**. If the radiation image projected onto the storage electrode **7** is cut off and a flood electron beam directed on electrode **7** as before, the photoconductor **9** will soon charge to its original equilibrium negative value, thereby destroying the charge image. The charge on the photoconductor thereby again becomes uniformly negative across the area thereof. If the charge image created on the photoconductor results from only momentary irradiation from the object **23**, and simultaneously with the development of this charge image, the electron image previously described is superposed on the charge image, an electrical signal across resistor **24** will be produced.

Now if it is assumed that the object **5** is moved slightly to one side away from the position above assumed, and the procedure just described repeated, electrons from the cathode **4** obviously will focus onto the electrode **7** at a corresponding lateral displacement out of registry with the original charge image. The electron beam will be ineffective in changing the charge on the photoconductor inasmuch as the maximum, equilibrium negative charge has already been established, such that no signal will be produced in the output circuit **24, 26**. Now, by applying suitable deflection signals to the horizontal and vertical deflection coils **21** and **22**, the laterally displaced electron beam may be deflected or moved laterally inside the field-free region defined by the drift tube **12** so as to bring gradually (relatively speaking) the electron image into precise registry with the charge image on the electrode **7**. As this movement occurs, and as the beam moves progressively into registry with the charge image, a corresponding increase in signal current will develop through layer **9** until precise registry is reached, at which time maximum signal current will develop. This is indicated generally by the voltage signal **27** in FIG. **4** which is developed across resistor **24**, this signal increasing from about zero level (representing no image correlation) rapidly to a maximum (indicating the moment of precise correlation).

Any suitable scanning pattern may be employed for positioning the electron beam on the storage screen **7**, and in addition to this, suitable circuitry, not disclosed herein, may be coupled to the scanning coils **21** and **22** for locking the electron beam onto the charge image once coincidence has been achieved, the signal **27** being used as a control for such locking.

While magnetic focusing has been described, it will appear as obvious to a person skilled in the art that electrostatic focusing may be used instead. In the event radiation passed by the end wall **2** is of sufficient intensity and wavelength as to affect the photoconductivity of the storage electrode **7**, some kind of a barrier opaque to such radiation may be used. For example, in the event electrostatic focusing is used, a disc transversely of the tube interposed between the two end walls **2** and **3** and having a small aperture located at the beam cross-over point may be used. This disc would serve as a light shield. Additionally, the effects of such radiation can be either eliminated or minimized by using a photoconductor **9** sensitive to radiation of different wavelength than that imposed on the cathode **4**.

The mode of operation of the tube of FIG. **1** as just described is destructive, meaning that then read-out occurs, the charge image stored on the photoconductor **9** is destroyed or erased by returning the surface charge to the equilibrium negative value previously mentioned. By changing the structure of the target electrode **7** slightly and applying slightly different voltages to various of the tube electrodes, a non-destructive mode of operation can be achieved. This different tar-

get is illustrated in cross-section in FIG. 5 and is indicated generally by the numeral 7*a*. Otherwise, like numerals indicate like parts. This target 7*a* is constructed and operated the same as disclosed in Nicholson U.S. Pat. No. 3,046,431 issued July 24, 1962. Instead of using a photoconductor 9 on the conductive layer 8, a semi-conductive material in the form of layer 27 is used. The material of this layer 27 is a mixture consisting essentially of arsenic and selenium deposited on the exposed surface of the conductive layer 8 and a layer of antimony trisulfide on the exposed surface of the mixture layer. The precise composition and method of operation is disclosed in the aforesaid Nicholson patent. The layer 8 of this target 7*a* has applied thereto a positive voltage of from 10 to 50 volts.

In operation, a light signal from, for example, the arrow 23, is impressed on the target electrode 7*a* momentarily and the faceplate 3 is then capped to prevent any further illumination of the target 7*a*. A charge image is thereby impressed upon and stored by the layer 27. An electron beam from the photocathode 4 produced as already explained is projected onto the layer 27 in the same manner as previously explained in connection with the target 7. When the electron image coincides with the charge image previously focused onto the target 7*a*, an electrical signal is produced which may be coupled to external circuitry by means of capacitor 26. Multiple read-outs may be obtained without destroying the image stored on the target 7*a*, this mode of operation being characterized as non-destructive. Even though non-destructive, it will be observed that such operation possesses the simultaneity of observing and comparing two images the same as in connection with the embodiment of FIG. 1.

Yet another embodiment of this invention is illustrated in FIGS. 6 and 7, wherein two photoelectric cathodes are used instead of one. In this embodiment, like numerals will indicate like parts as before. The envelope 1, now indicated by the numeral 1*a*, is the same as that of FIG. 1 with the exception that it is made longer as shown. In the left-hand end portion are provided three axially spaced accelerating rings 28*a*, 28*b* and 28*c* interposed between the photocathode 4 and the storage target 7*b*. Between the field mesh 10 and the sleeve 28*c* is a planar target electrode indicated generally by the reference numeral 7*b*. This target electrode is suitably, fixedly supported from the inner walls of the envelope 1*a* as shown and is positioned at right angles to the tube axis. Further than this, it is of extended area of substantially the same size as the photocathode 4.

In the right-hand end of the tube, instead of a target electrode being mounted on the left-hand face of the end place 3, a photoelectric cathode 29 is provided which may be a structural duplicate of that of the photocathode 4. A connection is made between cathode 29 and the terminal 9*a*, the latter terminal being grounded as shown.

The target 7*b* is shown in fragmentary cross-section in FIG. 7 as including three layers 31, 32 and 33 of different material. The layer 31 in an operating embodiment of this invention is aluminum oxide approximately 700-Angstroms thick. The layer 32 is conductive aluminum about 500-Angstroms thick. The layer 33 is of a suitable SEC (secondary electron conductive) or EBIC (electron bombardment induced conductivity) material. Potassium-chloride as one SEC material for layer 33 would have a thickness of about 25-microns, whereas arsenic triselenide as an alternative, EBIC material would preferably be about 5-microns in thickness.

In operation, voltages are applied to the various electrodes as shown in FIGS. 6 and 7, the conductive layer 32 having a positive voltage variable between 10 and 50 volts positive with respect to ground applied thereto.

In explaining the operation of this embodiment, it is convenient to consider first the establishment of a uniform charge on the right-hand surface of the semiconductive layer 33. This is accomplished by flooding photocathode 29 uniformly with light such that a uniform emission of electrons over the entire area thereof occurs. These electrons are accelerated toward target 7*b* by reason of the potentials applied to electrodes 10, 12 and 13, and they eventually land on the surface of the semiconductor 33. The latter charges over the entire area thereof to a uniform potential corresponding to that of cathode 29 such that the right-hand surface thereof is negative with respect to backing 32.

A charge image may be stored on target 7*b* by focusing an electron image thereonto from cathode 4. This is achieved by projecting an optical image from an object 5 onto the photocathode 4 as previously explained. The electrons so emitted are focused onto the target 7*b*, but additionally they are accelerated to such high energies by reason of the accelerating electrodes 28*a*, 28*b* and 28*c* that they penetrate the two layers 31 and 32 and enter the layer 33. These electrons incident into the layer 33 cause secondary emission of electrons in SEC type targets and these secondaries flow toward and are collected by the backing 32. This results in discharging the discrete areas of the uniform charge previously established on the surface of the layer 33 opposite the points of penetration of the incident electrons such that a charge replica of the incident electron image is produced on this surface.

For read-out, an image to be compared with the stored image is indicated as being in the form of the optical equivalent of the object 23 focused onto cathode 29. By reason of the focusing field of the coil 20, the electron image off cathode 29 is focused onto the layer 33. The deflecting coils 21 and 22 are operated to move the electron image into coincidence with the stored image. Once this coincidence is achieved, the previously discharged areas will once again be charged to equilibrium value corresponding to the potential of cathode 29, this producing a signal which may be capacitively coupled from the backing 32 to external utilization circuitry. Since the charge image on target 7*b* is destroyed, the tube operates according to the destructive read-out mode.

In all of the embodiments disclosed, it will be noted that two different images can be compared simultaneously instead of on a time-sharing basis in which during one period of time a charge image is formed on a target and in a subsequent period the charge image is read-out. This is shown to be possible through the use of both non-destructive and destructive read-out modes of operation and further by different structures. In the arrangements of FIGS. 1 and 5, optical information is

used directly to produce a charge image whereas in the arrangement of FIG. 6, an electron beam is used for this purpose. Unique to all of the embodiments is the feature that instead of using a single focused pencil-like beam to read-out a single element of information at a time, the entire storage area is read-out at once by the electron image of the scene incident on a photocathode. Maximum signal amplitude is generated when the high density parts (highlight areas) of the electron beam are coincident with the highly discharged areas on the storage target, which means some bright pattern on both images match each other. While correlation of two images as explained in the preceding is possible by electronically scanning the charge pattern established on the target electrode, correlation may be achieved by the use of mechanical movement of the tube, objects being viewed, or the optical system instead of electronic scanning. In brief, it will now be appreciated that a quite complicated correlation operation can be accomplished with a minimum of complexity and with optimum signal-to-noise ratio.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. An image comparison device comprising an electron tube having a storage electrode for transforming a radiation image projected onto one end of said tube into a charge image which may be sensed by electron impingement, a photoelectric cathode at the other end for transforming a radiation image into an electron beam of corresponding configuration simultaneously with the forming of said charge image, means for imaging said electron beam into superposition on said charge image within said tube whereby the potential of the latter is sensed, and means for developing an electrical signal representative of the accuracy of the coincidence of said beam on said charge image.

2. The device of claim 1 wherein said storage electrode has an extended area impervious to electron flow therethrough and is disposed to receive said electron beam from a first direction and the first-mentioned radiation image from a second and different direction.

3. The device of claim 2 wherein said storage electrode has opposite sides and including means for projecting the first-mentioned radiation onto one of said sides and said photoelectric cathode is disposed to project said electron beam onto the other side.

4. The device of claim 2 wherein said storage electrode is of planar shape and includes a layer of photoconductive material having a surface directly exposed to said electron beam, and means for deflecting said beam over said surface.

5. The device of claim 1 including an evacuated envelope having opposite end portions, one of said end portions having said storage electrode of an extended area mounted therein; said storage electrode including a layer of photoconductive material backed by a layer of conductive material; said photoconductive layer having an exposed surface facing the other end portion of said envelope; said other end portion of said envelope having said photoelectric cathode of an extended area mounted therein facing said exposed surface and a drift tube between said exposed surface and said cathode.

6. The device of claim 5 wherein said cathode and said photoconductive layer are essentially flat and parallel, said drift tube being positioned such that the axis thereof intersects the midportions of said cathode and said photoconductive layer, a focusing coil coaxially surrounding said envelope for focusing the electron beam onto said exposed surface, and deflection coils disposed about said envelope for scanning said beam over said exposed surface.

7. The method of comparing radiation images comprising the steps of (a) developing on an electron tube storage electrode a charge image of a given radiation image, (b) developing on a photoelectric cathode of said tube an electron beam image of a radiation image which is to be compared with said charge image, (c) simultaneously with the development of said charge image focusing said electron beam image onto said storage electrode within said tube, and (d) sensing the degree of coincidence of said electron image with said charge image.

8. The method of claim 7 in which said storage electrode includes a semi-conductive extended area element, said charge image being developed on said element by establishing a charge thereover, and discharging discrete elemental areas of said element to provide said charge image.

9. The method of claim 8, including recharging said discharged areas when said electron beam image is focused onto said storage electrode.

10. The device of claim 1 including first and second photoelectric cathodes at each said end, said storage electrode disposed therebetween and including three contiguous layers, the central one of said layers being conductive and electron permeable, a second of said layers being an insulator and electron permeable, a third of said layers being a semiconductor of secondary electron induced conductivity, said second layer facing said first photoelectric cathode, electron-accelerating means disposed between said first photoelectric cathode and said second layer for imparting sufficient energy to the electrons of said electron beam to cause them to penetrate both said second and first layers and to enter said third layer, whereby said third layer becomes momentarily locally conductive, said third layer facing said second photoelectric cathode, said second photoelectric cathode emitting the electrons which form said electron beam, said imaging means including at least one accelerating electrode interposed between said second photoelectric cathode and said third layer which imparts energies to the last-mentioned electrons sufficient to charge said third layer to the potential of said second photoelectric cathode.

11. The device of claim 10 in which said third layer is one of the class of materials of potassium chloride.

12. The device of claim 3 wherein said storage electrode includes a layer of a mixture of arsenic and selenium and a layer of antimony trisulfide on the exposed surface of said mixture layer.

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