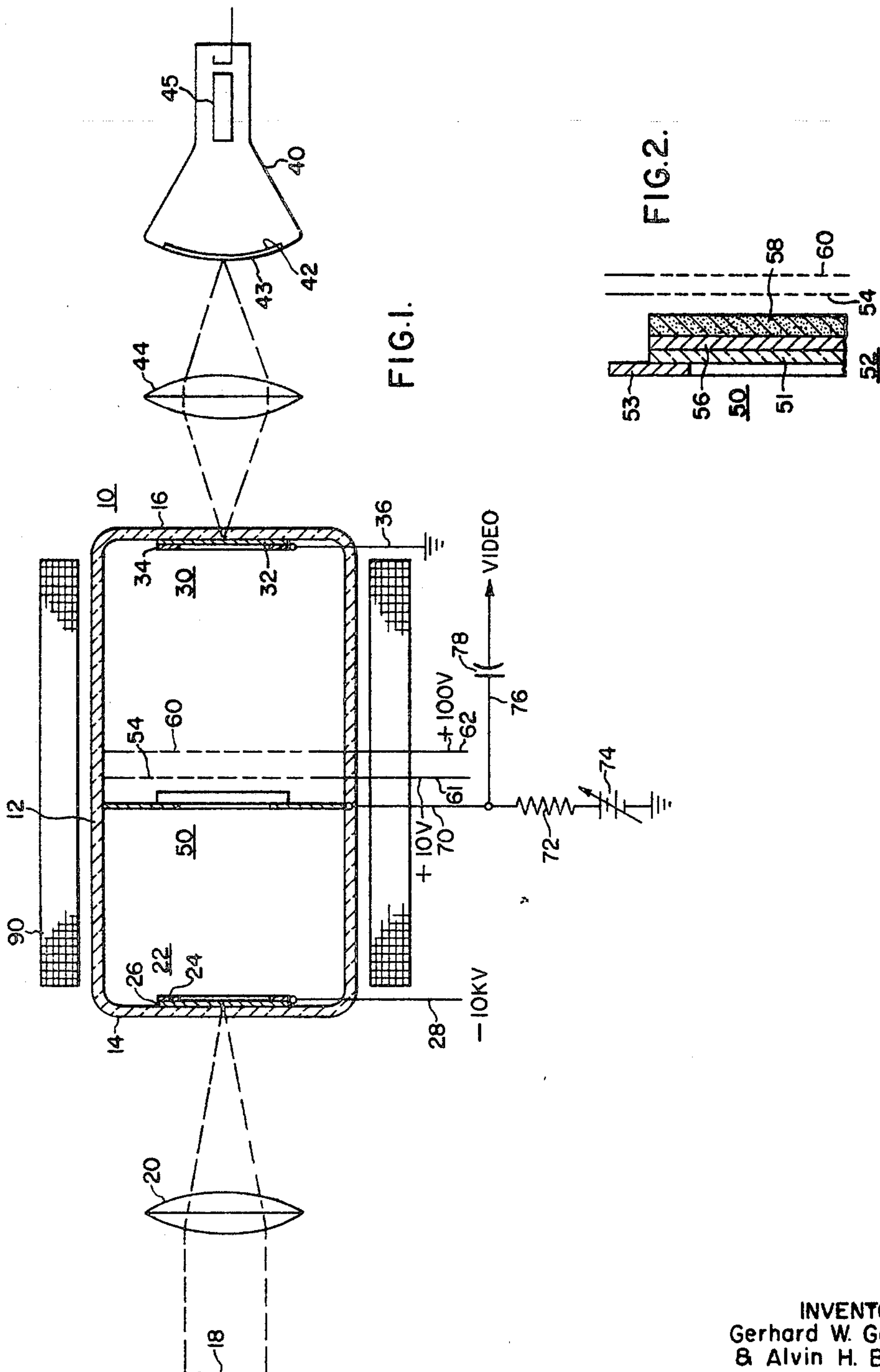
Oct. 8, 1968 G. W. GOETZE ET AL 3,405,309

RADIATION DETECTION SYSTEM

Filed Jan. 12, 1965



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United States Patent Office
3,405,309
Patented Oct. 8, 1968

3,405,309

RADIATION DETECTION SYSTEM

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Continuation-in-part of application Ser. No. 241,641, Dec. 3, 1962. This application Jan. 12, 1965, Ser. No. 425,020
6 Claims. (Cl. 315—11)

ABSTRACT OF THE DISCLOSURE

A radiation detection system which utilizes a first photoemissive input screen onto which an input scene is directed. The electrons generated therefrom are accelerated by high voltages into a transmission secondary electron conduction type of target and establish a charge pattern on the opposite surface of said secondary electron conduction target corresponding to the input scene. Read out of the charge pattern on the secondary electron conduction target is provided by means of a second photosensitive image screen spaced from the secondary electron induction target and excited by a flying spot scanning device. A high magnetic focusing field is provided for focusing the electrons directed onto the secondary electron conduction target from both photoemissive screens to provide a high resolution image device. The deflection portion of the reading system is completely isolated from the high magnetic field provided in the envelope and the conductive backing on the secondary electron conduction target facing the first screen prevents charge build up or redistribution of electrons on the input side of the target.

The present application is a continuation-in-part of our copending patent application, Ser. No. 241,641, filed Dec. 3, 1962 and now issued as U.S. Patent 3,213,316.

This invention relates to a radiation detection system and more particularly to those in which information is stored on a target member and the information then read out by means of an electron beam.

This invention is directed to the solution of the problem found in astronomy, spectrography and many other scientific and military applications where image recording under conditions of extremely low photonfluxes is required. A photoelectric surface (one which emits electrons in response to radiation) has an efficiency for responding to light photons which is about 100 times higher than that of a photographic emulsion. The minimum contrast that can be detected (for a given line number and exposure time) is theoretically 10 times lower for an ideal photoelectric device than for the photographic emulsion. The photoelectric surface also does not exhibit reciprocity failure. Unfortunately, the photoelectric surface cannot store of record photons as does the photographic emulsion. As a consequence, numerous devices have been built and proposed to circumvent this shortcoming in order to make use of the better quantum efficiency of the photoelectric surface. Most of these devices employ means for amplifying the energy of the photoelectrons prior to recording. This amplification may be obtained by acceleration in electric field, by charge multiplication or by a combination of these methods. The ultimate recording and signal integration is almost exclusively done on a photographic emulsion using the light emitted by an output phosphor (responsive to electron bombardment) or by exposing the emulsion directly to the electron bombardment.

This particular invention is directed to a separate class

of devices like an image orthicon pick-up tube in which the signal is integrated in the form of an electrical charge pattern on a storage target and this electrostatic charge pattern is subsequently read out by a scanning electron beam resulting in an electrical video signal which may be in turn displayed on a suitable television monitor system. This latter class of devices suffers from insufficient resolution, poor contrast and lack of adequate electrical charge storage.

It is accordingly an object of this invention to provide an improved radiation detection system.

It is another object to provide an improved radiation detection system with high resolution.

It is another object of this invention to provide an improved radiation detection system of extremely high storage capabilities and integration characteristics.

Still a further object of this invention is to provide a radiation detection system with high quantum efficiency.

It is still another object of this invention to provide a radiation detection system in which complete readout of the detected scene in the form of a charge image may be had in one scan by an electron beam.

Briefly, the objects of this invention are accomplished by providing a radiation detection system which utilizes a photoemissive input screen onto which an input scene is directed. The electrons generated therefrom are accelerated by high voltages into a transmissive secondary electron conduction type of target and establish a charge pattern on the opposite surface of said secondary electron conduction target corresponding to the input scene. Readout of the charge pattern on the secondary electron conduction target is provided by means of a secondary photoemissive screen or surface spaced from the secondary electron conduction target and excited by a flying spot scanning device. A very high magnetic focusing field is provided for focusing the electrons directed onto the secondary electron conduction target from both photoemissive screens to provide high resolution images. The deflection portion of the reading system is completely isolated from the strong magnetic field provided within the envelope.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this description.

For a better understanding of the invention, reference may be had to the accompanying drawings in which:

FIGURE 1 is a cross-sectional view, partly schematic, of a radiation detecting system incorporating the teachings of this invention; and

FIG. 2 is a cross-sectional view of the storage electrode system employed in the device of FIG. 1.

Referring in detail to FIG. 1, there is illustrated a radiation detecting system. The system includes an evacuated envelope **10**. The envelope **10** consists of a cylindrical wall portion **12** closed at each end by face plates or windows **14** and **16**. The face plate **14** is transmissive to radiations directed onto the envelope **10** from a scene **18**. A suitable lens system **20** is provided between the scene **18** and the face plate **14** for focusing the radiations onto a photocathode surface **22** provided on the inner surface of the face plate **14**. The face plate **14** may be of a suitable material such as glass in the case of a visible light input. The photocathode **22** consists of a suitable photoemissive coating **24** sensitive to the input radiation such as cesium-antimony for a visible light input and is evaporated onto the inner surface of the face plate **14**. A suitable electrically conductive contact, which may be in the form of a conductive ring 26, is provided on the photoemissive layer 24 and is connected by a lead-in member 28 to a suitable potential source of about 10,000 volts negative with respect to ground.

The light from the scene 18 is directed onto the photoemissive material 24 and excites the photoemissive material. It is obvious that conversion systems could be utilized for converting the scene radiation such as infrared and X-ray into radiations to which the photoemissive material would be more sensitive and efficient. For example, in the case of X-rays, an X-ray responsive phosphor could be utilized within the envelope 10 which in turn emits radiation to which the photoemissive surface is responsive.

A photocathode 30 is provided at the output end of the envelope 10 and consists of a photoemissive layer 32 of a suitable material such as cesium antimony deposited on the inner surface of the face plate 16 with a suitable electrically conductive contact in the form of a ring member 34 also provided on the face plate 16. The lead-in 36 provides means of connecting the photocathode 30 to a suitable potential source illustrated in the figure as ground potential.

A cathode ray tube 40 is provided external of the envelope 10 of any suitable design and utilizes a suitable phosphor layer 42 on the inner surface of the face plate 43. The ouput radiation of the phosphor layer 42 of the cathode ray tube should be matched to the response of the photocathode 30. The cathode ray tube 40 is provided with an electron gun 45 for generating an electron beam which is directed onto the phosphor layer 42 and the light generated by the electron beam scanning over the phosphor layer 42 is focused onto the cathode 30 by means of a suitable lens system 44. Fiber optics may be utilized within the face plates 14, 16 and 43.

Positioned between the photcathodes 22 and 30 is a target assembly 50. The target assembly 50 consists of a target member 52 and a grid member 54. The target member 52 includes a support ring 53 of a suitable material such as kovar alloy (Westinghouse Electric Corporation trademark for an alloy of nickel, iron and cobalt). A support layer 51 of a suitable material such as aluminum oxide is supported on the ring 53 with a suitable electrically conductive film 56 such as aluminum deposited on the support layer 51. A porous coating 58 of a suitable insulating or semiconducting material which exhibits the property of generation of secondary electrons in response to electron bombardment and has the further property that the secondary electrons are conducted through the voids of said material to the conductive back plate 56 which faces the photocathode 22. Secondary electrons may also be emitted from the exposed surface of the layer 58. The coating 58 may be of any suitable material such as an alkaline earth metal compound, such as potassium chloride, magnesium chloride, or magnesium oxide.

The mesh or screen electrode 54 serves as a collector for the secondary electrons emitted from the exit or exposed surface of the coating 58. The mesh 54 is positioned at a distance of about 10 mils or less from the exposed surface of the layer 58 and held at a potential of about 10–100 volts positive with respect to ground by a suitable potential source connected to a lead-in member 61 exterior of the envelope. The mesh 54 also contributes in maintaining a uniform electric field between a collector electrode 60 and the target member 52. The collector electrode 60 is held at a potential of about 1,000 volts positive with respect to ground by a suitable potential source connected to a lead-in member 62 exterior of the envelope.

A specific description of a suitable storage target 52 illustrated in FIG. 2 includes an aluminum oxide film 51 of 1000 A. in thickness supported on a 5/8 inch diameter ring 52. The layer 56 of 500 A. in thickness of aluminum is deposited on the film 51 by vacuum evaporation. The aluminum layer 56 is covered by the layer 58 of potassium chloride which is formed by evaporating the potassium chloride in an inert gas atmosphere at a pressure of a few millimeters of mercury. The density of the layer 58 is only about two percent (2%) of the bulk density of potassium chloride. A typical thickness is 25 microns which corresponds to a mass per unit area of 100μ gm. cm.^{2} (bulk KCL density=1.984 gm. cm.^{3}). Other suitable structures are available, such as omitting the layer 51 and providing support by the layer 56.

The target assembly 50 is mounted within the tube by well known techniques prior to exhausting of the tube and a lead-in member 70, connected to the conductive layer 56 is connected to the upper terminal of a resistor 72. The lower terminal of the resistor 72 is connected to a positive terminal of a suitable potential source such as battery 74 with the negative terminal of the battery 74 connected to ground. The video signal may be derived from the assembly by means of a lead 76 connected to the upper terminal of the resistor 72 and through a capacitor 78. The potential of the source 74 is variable and normally operates at about 15 volts positive with respect to ground. The mesh 54 operates at a potential of about 50 volts positive and the collector mesh 60 operates at a potential of about 1,000 volts positive.

Positioned about the envelope 10 is a suitable magnetic field producing means which may be an electromagnetic coil or a permanent magnet assembly. The permanent magnet assembly may be of the type described in the copending application Ser. No. 61,289, now U.S. Patent 3,155,860, filed Oct. 7, 1960, entitled "Continuously Permanent Magnet for Imaging Purposes" by G. W. Goetze, and assigned to the present assignee. In the specific embodiment a magnetic assembly 90 is illustrated as an electromagnetic coil and provides a uniform magnetic field perpendicular to the target assembly 50 and the cathodes 22 and 30. A high magnetic field is utilized in this application which is at least greater than 1,000 gauss in order to provide a high resolution. The cathode ray tube 40 is positioned or suitably isolated from the magnetic system 90 in order to insure that the magnetic field has substantially no effect on the movement of the electron beam within the cathode ray tube 40.

In the operation of the device shown in FIG. 1, an optical image of the scene 18 is projected and focused onto the cathode 22 and as a result generates an electron image corresponding to the scene 18. This electron image is accelerated by the 10,000 volts between the photocathode 22 and the target assembly 50 to a high velocity and penetrates through the support layer 51, the conductive layer 56 of the target assembly 50. The electron image penetrates through the electron permeable layers 51 and 56 and enters into the layer 58 and induces secondary electron conduction within the layer 58. The acceleration voltage between the photocathode 22 and the target 50 should be adjusted such that substantially all of the primary electrons from the photocathode 22 almost completely penetrate the entire storage electrode 50 but do not completely pass through to the layer 58.

For example, in the case of the target having a support layer 51 of 1000 A., a conductive layer 56 of aluminum of thickness about 500 A. and a porous insulator layer 58 of a thickness of about 25 microns, the acceleration voltage would be about 10,000 volts. The primary electrons on passing through the layers 51 and 56 lose about 25% of their initial energy and the remaining 75%, about 7,500 electron volts, is dissipated within the low density layer 58. The primary electrons from the photocathode 22 create a certain number of low energy electrons in the layer 58 which is about two orders of magnitude higher than the number of incident or primary electrons. The number of secondary electrons generated within the layer 58 may be about 200 per primary.

If the target assembly 50 has been polarized prior to the impact of the signal or writing electrons from the cathode **22**, which is done by applying a positive potential of about 15 volts to the back plate **56** and stabilizing the exposed surface or exit surface of the layer **58** at ground potential (the potential of cathode **30**), the low energy secondary electrons generated within the layer **58** cause the exit surface to change its potential to more positive values due to the conduction of the low energy electrons across the layer **58** through the vacuum spaces or voids in the layer **58** and between the particles of the very porous layer **58** to the positive back plate **56**.

The secondary emissive electrons emitted from the surface **58** are collected by the electrode **54**. The field impressed on the layer **58** is limited to less than 10^4 volts per centimeter so that the back plate **56** collects electrons conducted through the voids of the layer **58** and does not operate in the conventional electron bombardment induced conductivity range where high fields are utilized. A more thorough description and discussion of the target assembly **52** may be found in the copending application Ser. No. 241,641, now U.S. Patent 3,213,316, filed Dec. 3, 1962, entitled "Image Storage System" by G. W. Goetze et al., assigned to the same assignees as the present invention.

It should be noted with regard to this image section that additional multipliers may be utilized if so desired and the important features here with regard to the high resolution of the device is accomplished by the high magnetic field utilized within the image section and the scan section which insures that the electrons are focused correctly onto the target assembly **50**. In addition, due to the conductive backing layer **56** on which the electrons strike, the problem of charge build-up and redistribution of electrons such as found in the image orthicon type of tube is not found in this device.

As pointed out above the electron image directed onto the target assembly **50** establishes an electrostatic charge image positive in nature on the exposed surface of the layer **58**. This electrostatic charge image established on the surface of layer **58** is read out by means of electrons emitted from the photocathode **30**. The phosphor screen **42** of the cathode ray tube **40** is scanned by the electron beam in any suitable manner to scan a raster thereon. An optical image of the raster or pattern scanned on the cathode ray **40** is projected onto the scanning cathode **30** by the lens system **44** and forms in effect a scanning light spot on the scanning cathode **30**. Photoelectrons are liberated from the photocathode **30** under the influence of the scanning light spot and are directed as a low velocity electron stream toward the target assembly **50**. The electrons emitted from the photocathode **30** are accelerated by means of the 1000 volts potential applied between the accelerator grid **60** and the photocathode **30**. The electrons on passing through the accelerator **60** are decelerated by means of the mesh **54** and the surface potential of the layer **58** which is at ground prior to the write operation. Sufficient current must be supplied from the photocathode **30** to return the exit surface of the layer **58** to substantially ground potential. In those areas where no electrons from the photocathode **22** strike the target assembly **50**, there will be no current produced in the output circuit of the signal plate **56**. Elemental areas of the layer **58** which are positive by reason of impingement of electrons from the photocathode **22** will be neutralized by the low velocity electron beam from the cathode **30** and as a result a signal will be obtained in the video output circuit. The elemental area will also be returned to ground potential, so that after scanning the target assembly **50** with the scanning cathode **30** the surface of the layer **58** will be at ground potential and primed to receive the next scene information. The electrical signal which is derived from the target assembly **50** in response to the scanning operation can then be displayed on a suitable cathode ray tube monitor and a picture taken thereof or viewed directly as desired. It should also be noted here that because of the utilization of the low velocity electron beam there is no problem of electron distribution across the surface as is the case in high velocity scan. The high efficiency of low velocity readout is utilized with accurate focusing provided by the high magnetic field of the magnetic system **90**.

The resulting structure provides a radiation detecting system which has high intrinsic resolution due to the high lateral resistivity of the layer **58**. In addition, the layer **58** also provides extremely good storage and integration characteristics. The resistivity of the film is equal to or greater than 10^{17} ohm-centimeters. It should be emphasized that in this type of tube one may view a scene for several minutes and the target would integrate this information over this period of time and then readout could be accomplished in a period of time of less than $\frac{1}{30}$ of a second. This feature is particularly desirable in those applications where the light level is extremely low, but movement is relatively nil. The device also provides a large storage capacity of about 10^{10} events per square centimeter as compared to 10^7 events per square centimeter for Kodak film 103 *a*–O. Another desirable feature of the invention is that complete destructive readout of the image is accomplished in one scan by the reading electron beam.

While there has been shown and described what is considered to be the preferred embodiment of the invention, modification thereto will readily occur to those skilled in the art. It is not desired, therefore, that the invention be limited to the specific arrangements shown and described, and it is intended to cover in the appended claims all such modifications which fall within the true spirit and scope of the invention.

We claim as our invention:

1. An electrical device comprising a target electrode sensitive to electron bombardment including a continuous layer of an electrically conductive material, a porous layer of material exhibiting the property of generation of low energy secondary electrons and conduction thereof in response to electron bombardment deposited on one surface of said conductive layer, a first photoelectrically sensitive cathode positioned and spaced from one side of said target electrode, a second photoelectrically sensitive cathode spaced from and disposed on the opposite side of said target electrode with respect to said first photoelectrically sensitive cathode, means for scanning said first photoelectrically sensitive cathode with a flying spot of light to deliver a stream of electrons, means for projecting said stream of electrons onto the surface of said porous layer at a first velocity, means for projecting an image of input radiations onto said second photoelectrically sensitive cathode to liberate an electron pattern therefrom corresponding to said input radiations, means for projecting said electron pattern onto said target to penetrate through said conductive layer and enter into said porous layer and generate secondary electrons within said layer and establish a charge pattern upon the exposed surface of said porous layer, means for establishing a field across said porous layer of less than 10^4 volts per centimeter and means for providing a uniform magnetic field having its lines of force perpendicular to said first and second cathodes and said target to focus the electrons liberated from areas on each of said first and second cathodes onto correspondingly positioned areas of said target.

2. A radiation detection system comprising an evacuated envelope including an input photocathode onto which radiation of a scene to be detected is directed, a storage target electrode spaced from said input photocathode, said storage electrode including a continuous layer of an electrically conductive material, a porous layer of secondary electron conduction material deposited on one surface of said conductive layer remote with respect to said input photocathode, means for accelerating electrons emitted by said input photocathode for penerating said conductive layer and inducing secondary electron generation and conduction within said porous layer, means for establishing a field across said porous layer of less than 10^4 volts per centimeter to permit secondary electron conduction between the exposed surface of said porous layer and said electrically conductive layer to establish a positive charge on the exposed surface of said porous layer in response to electron bombardment of said storage target by electrons emitted from said input photocathode, means for directing an electron scanning reading beam onto said exposed surface of said porous layer to derive an electrical signal from said electrically conductive layer corresponding to the light scene directed onto said input photocathode, said electron scanning reading means comprising a reading photocathode operating at given potential positioned on the side of said target facing said exposed surface of said porous layer and spaced therefrom, magnetic field producing means surrounding said envelope for focusing the electrons emitted from said input photocathode and said reading photocathode, said magnetic field producing means providing a field of greater than 1000 gauss perpendicular to said storage target and said photocathodes and means positioned exterior of said magnetic field for generating and directing a light beam onto said reading photocathode for exciting said reading photocathode and means for directing said light beam over said reading photocathode for re-establishing the charge on said exposed layer of said porous layer to substantially the potential of said reading photocathode.

3. An electrical device comprising an evacuated envelope having therein a target electrode sensitive to electron bombardment including a continuous layer of insulating material exhibiting the property of producing secondary electrons in response to electron bombardment and conduction of said secondary electrons, a first photoelectrically sensitive cathode positioned and spaced from said target electrode, a second photoelectrically sensitive cathode spaced from and disposed on the opposite side of said target electrode with respect to said first photoelectrically sensitive cathode, means exterior of said envelope for scanning said first photoelectrically sensitive cathode with a flying spot of light to deliver a stream of electrons, means for projecting said stream of electrons onto one surface of said insulating layer at a first velocity, means for directing an input radiation scene onto said second photoelectrically emissive cathode to liberate an electron image therefrom corresponding to said input scene, means for projecting said electron image onto said target at a velocity higher than said first velocity to penetrate into said insulating layer to generate secondary electrons therein, means for establishing an electric field across said secondary electron emissive layer of less than 10^4 volts per centimeter and means for providing a magnetic field having its lines of force perpendicular to said cathodes and said target to focus the electrons liberated from areas on each of said cathodes onto correspondingly positioned areas of said target.

4. A radiation detection system comprising an evacuated envelope having therein an input photocathode therein to receive radiation from a scene, said envelope having a storage target electrode spaced from said input photocathode, said storage electrode including a continuous layer of an electrically conductive material, a porous layer of material exhibiting the property of conduction of secondary electrons generated therein deposited on one surface of said conductive layer remote with respect to said input photocathode, means for accelerating electrons emitted by said input photocathode through said conductive layer and into said porous layer to generate secondary electrons therein, collecting means spaced from the exposed surface of said porous layer for collection of secondary electrons emitted from said porous layer, means for establishing an electric field across said porous layer to permit secondary electron conduction between the exposed surface of said porous layer and said electrically conductive layer to establish a positive charge on the exposed surface of said porous layer in response to electron bombardment from said input photocathode, means for directing a reading electron scanning beam onto said exposed surface of said porous layer to derive an electrical signal from said conductive layer corresponding to the light image directed onto said input photocathode, said electron scanning means comprising a reading photocathode positioned on the side of said target facing said exposed porous layer and spaced therefrom, means for generating and directing a light beam onto said reading photocathode for exciting said reading photocathode and means for scanning said light beam over said reading photocathode to scan said reading beam over said target for re-establishing the charge on said exposed layer of said porous layer to substantially the potential of said reading photocathode.

5. An electrical system comprising an evacuated envelope having therein a target electrode sensitive to electron bombardment including a continuous porous layer of secondary electron emissive material, an electrically conductive means provided on one surface of said layer, a first photoelectrically sensitive cathode within said envelope and spaced from one side of said target electrode, a second photoelectrically sensitive cathode spaced from and disposed on the opposite side of said target electrode with respect to said first photoelectrically sensitive cathode, means exterior of said envelope for scanning said first photoelectrically sensitive cathode with a spot of light to deliver a stream of electrons, means for projecting said stream of electrons onto the exposed surface of said porous layer at a first velocity, means for projecting an input scene onto said second photoelectrically emissive cathode to liberate an electron image therefrom corresponding to said input scene, means for projecting said electron image at a second velocity higher than said first velocity onto said target through said electrically conductive means and into said porous layer to generate secondary electrons within said porous layer, means for establishing a potential across said porous layer less than 10^4 volts per centimeter to permit conduction of said secondary electrons through the voids in said porous layer and means for providing a uniform magnetic field having its lines of force perpendicular to said cathodes and said target to focus the electrons liberated from areas on each of said photoemissive sensitive cathodes onto correspondingly positioned areas of said target, said magnetic field producing means surrounding said envelope and extending beyond the ends thereof and providing a magnetic field of a strength greater than 1000 gauss.

6. A radiation detection system comprising an evacuated envelope, said evacuated envelope including an input photocathode onto which radiation of a scene to be detected is directed, a storage target electrode spaced from said input photocathode including a first and second surface, said first surface facing said input photocathode, said storage electrode including a porous layer of secondary emissive material, an electrically conductive means provided on one surface of said porous layer facing said input photocathode, means for accelerating electrons emitted by said input photocathode to a velocity greater than 5,000 volts onto said first surface and through said electrically conductive means and into said porous layer to generate secondary electrons, means for establishing a field across said porous layer of less than 10^4 volts per square centimeter to permit secondary electron conduction of secondary electrons to said electrically conductive means through the voids in said porous layer to establish a positive charge on the second surface of said target in response to electron bombardment from said input photocathode, means for directing an electron scanning beam onto said second surface of said target to derive an electrical signal from said conductive means corresponding to the scene radiation directed onto said input photocathode, said electron scanning means comprising a read-

ing photocathode positioned on the side of said target facing said second surface of said target and spaced therefrom, means for scanning a light beam over said reading photocathode to produce said electron scanning electron beam and magnetic field producing means surrounding said envelope for focusing the electrons emitted from said input photocathode and said reading photocathode, said magnetic field producing a field of greater than 1000 gauss perpendicular to said storage target and said photocathodes.

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