Dec. 18, 1956 E. E. SHELDON 2,774,901

TUBE FOR ELECTRO-MAGNETIC IMAGES

Original Filed July 8, 1947

Fig. 1

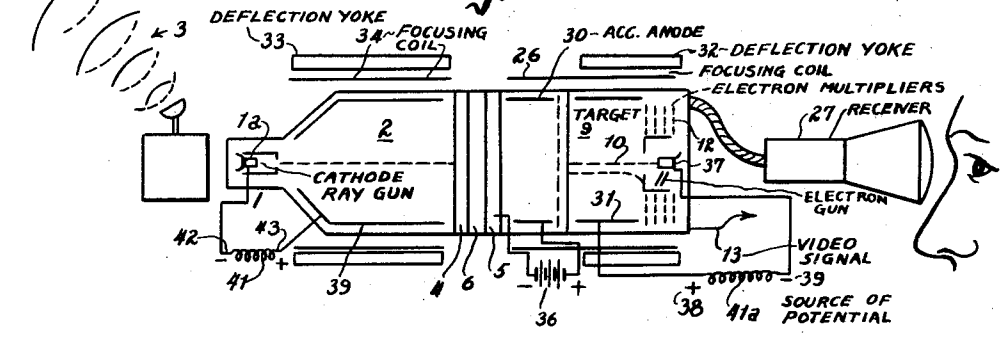


Fig. 2

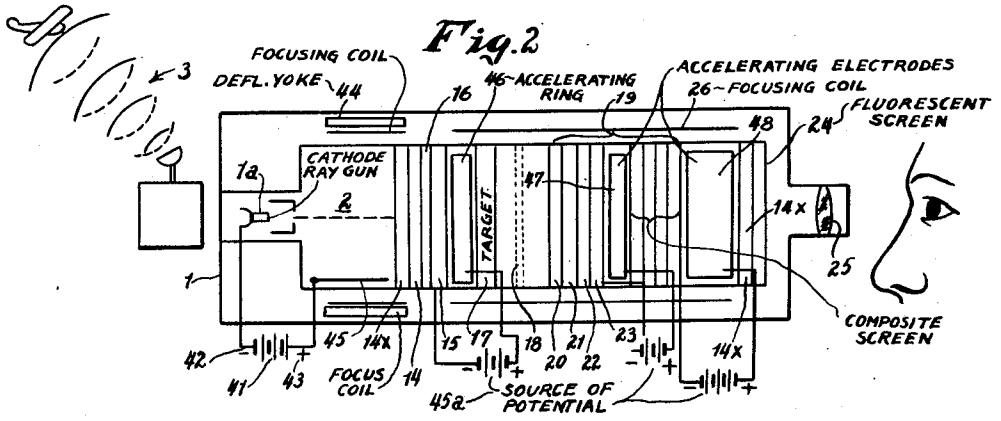
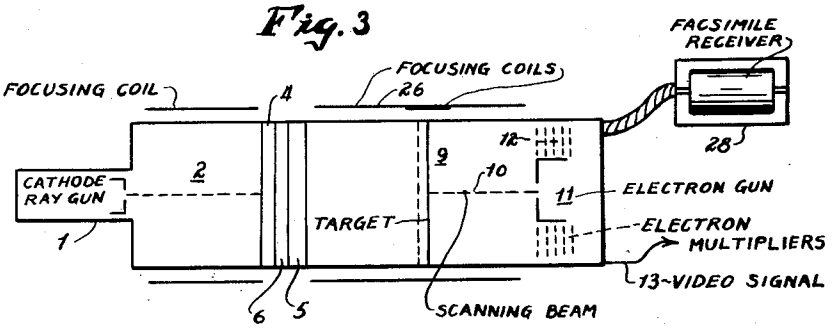


Fig. 3



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TUBE FOR ELECTRO-MAGNETIC IMAGES

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Original application July 8, 1947, Serial No. 759,531, now Patent No. 2,586,391, dated February 19, 1952. Divided and this application January 8, 1952, Serial No. 265,463

18 Claims. (Cl. 313—65)

This invention relates to an improved method and device for intensifying and magnifying, and televising of images and refers more particularly to method and device for intensifying, magnifying and televising radar images or other micro-wave images, and represents a division of my copending application Serial No. 759,531, filed on July 8, 1947, now U. S. Patent No. 2,586,391, issued February 19, 1952.

One primary object of this invention is to provide a method and device to produce intensified radar or other micro-wave images. This intensification will enable to overcome the inefficiency of the present examinations of radar images of a long persistence. At the present level of illumination of the fluorescent radar image of a long persistence the human eye has to rely exclusively on scotopic (dark adaptation) vision, which is characterized by a tremendous loss of normal visual acuity in reference both to detail to the contrast and to the speed of vision. The purpose of this invention is to enable the observer to use his photopic vision, in order to inspect radar images in daylight.

Another object of this invention is to make it possible to obtain enlarged radar images for examination by many persons simultaneously.

Another object of this invention is to increase the sensitivity of radar image receivers to the radar signals.

Still another object is to provide more contrasting radar images than was possible until now.

The novel tube for reproduction of radar or other microwave images is characterized by the use of a composite screen comprising a fluorescent layer or layers, a light transparent separating layer and a photoemissive layer. The electron beam modulated by radar or other microwave image is converted in said tube by said composite screen into an intensified electron image. The composite screen described above was found to perform most efficiently when the fluorescent layer comprises plural phosphors, one of which is responsive to the electron beam and the other one to the light emitted by said electron-reactive phosphor.

In another embodiment of this invention the intensified electron image may be reproduced in the same tube on a fluorescent screen mounted at the end wall of said tube.

This invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawings by way of example only preferred embodiments of the inventive idea.

In the drawings:

Fig. 1 shows a novel pick-up tube;

Fig. 2 shows a modification of the novel pick-up tube; and

Fig. 3 shows the pick-up tube as illustrated in Fig. 1 in combination with a facsimile receiver.

Reference will now be made to Figure 1, which illustrates the new tube to accomplish the purposes outlined above.

The radar or other microwave signals 3 activate and

modulate cathode-ray beam 2 from the electron gun 1. The cathode 1*a* of the electron gun 1 is provided with a negative potential. The second anode 39 may be in the form of a conducting coating on the inside surface of the tube envelope and is supplied with a positive potential in relation to the potential of the cathode of the electron gun. The proper operating potentials may be applied to the electrode of the electron gun from potential source 41. Between its terminals 42 and 43 a potentiometer or a bleeder resistance may be connected in order that the relative potentials of the various electrodes may be properly selected. The horizontal and vertical scanning motion of the electron beam 2 across the fluorescent layer 4 is provided by the deflection yoke 33 having a horizontal and a vertical deflection coil. The deflection coils are energized by a cyclically varying current of a suitable wave form which may be obtained from a horizontal deflection generator and from a vertical deflection generator. Deflection generators are well known in the art and are therefore not shown in the drawings. The cathode-ray beam transforms the radar signals into visual pattern on the fluorescent layer 4 of the composite screen 4—6—5 which represents a photocathode of the pick-up system. The visual image is transformed into photoelectron image in the photoemissive layer 5 of the composite screen which is in close apposition to the fluorescent layer 4, as otherwise the loss of definition would be of such a degree that the sharpness of the image would be destroyed. It is also necessary to include between the fluorescent and photoemissive layers a light transparent very thin barrier layer 6 such as e. g. of mica, glass, organic material or of plastic to prevent chemical interaction. The barrier layer preferably should be electrically conducting. This arrangement results in 20–30 increase in light available on the photocathode, as compared with the present optical systems for focusing the radar images on the photocathode. Further improvement of the operation can be obtained by the use of a proper voltage and by the use of a thin layer of aluminum positioned on the surface of the composite screen 4—6—5 nearest the cathode ray beam modulated by the radar signals, in order to increase by reflection the transfer of light to the photoemissive surface. This pick-up system can be applied in tubes operating on deflection modulation as well as on intensity or velocity modulation principle, in tubes of electrostatic or of magnetic type, or in tubes of any television system desired.

The fluorescent layer of composite screen can be of cascade type such as e. g. ZnS—Ag on ZnS; CdS:Cu or Al_2O_3 on ZnS:Ag or of single layer type such as e. g. Zn(Mg)F_2:Mn or ZnSCu(Ag); $Cs_2P_2O_7$:Dy or ZnS—CdS:Ag:Cu.

The satisfactory photoemissive substances would be e. g. cesium oxide, cesium oxide with silver, potassium, or lithium or cesium on antimony or bismuth. The fluorescent and photoemissive layers should be so correlated that under the influence of the cathode rays there is obtained maximum photoemissive effect. Between the photoemissive layer 5 of the composite screen and the storing target 9 is an accelerating anode or ring 30 which may be in the form of a conducting coating on the inside surface of the tube envelope. This conducting surface is maintained positive with respect of the photoemissive surface 5 by means of a source of potential 36. The photoelectrons from the photoemissive layer 5 are focussed upon the target 9 by means of magnetic or electromagnetic coil 26 which surrounds the major portion of the entire tube. The photoelectron image of radar signals is now focussed by means of magnetic fields 26 on the target 9 which is scanned by slow electron beam 10 from the cathode-ray gun 11. The electron gun 11 produces the electron beam for scanning the target 9. The cathode 37 of the gun is maintained at a negative potential. The first and second anode 31 are supplied with a positive potential in

respect to potential of the cathode of the gun. The second anode may be in the form of a conducting coating on the inside surface of the tube envelope. The proper operating potentials may be applied to the electrodes of the electron gun from the potential source 41*a*, which may be a battery. Between its terminals 38 and 39 is potentiometer or a bleeder resistance may be connected in order that the relative potentials of various electrodes may be properly selected.

The scanning rate can be changed in case of long persistence of radar images to get advantage of a longer storage effect which results in a marked gain in signal to noise ratio and represents another important advantage of this novel tube.

The focussing and deflecting elements for controlling the electron beams 2 and 10 are not indicated in detail as they are well known in the art. The electron image from the target 9 after multiplication by multistage multipliers 12 is converted into video signals 13 which after amplification may be sent either by high frequency system or by coaxial cable to the final receiver. In the final receiver 27 the radar image can be intensified by any degree desired so that the observer can inspect it in daylight, or may be photographed or may be recorded by means of facsimile 28 system, see Figure 3.

Another advantage of this invention is that the radar image in the final receiver may be magnified by electron optical system which is not shown in the drawing since it is well known in the art, to the desired degree so that it can be inspected by many observers, or it may be projected on a special viewing screen by Schmidt optical system with a desired magnification.

The contrast of radar image can be markedly increased on the final receiver by means of non-linear high gamma amplification in the amplifier system of the receiver.

In alternative of this invention the intensification and magnification of radar or other microwave images was accomplished by means of another novel image tube, which is shown in Figure 2. The electron gun 1 produces beam of electrons 2 which is modulated by radar signals 3 and produces their fluorescent image on the fluorescent layer 14 of the composite screen 14*x*—14—16—15. The cathode of the electron gun 1 is provided with a negative potential. The second anode 45 may be in the form of a conducting coating on the inside surface of the tube envelope and is supplied with a positive potential in relation to the potential of the cathode of the electron gun. The proper operating potentials may be applied to the electrodes of the electron gun from the potential source 41. Between its terminals 42 and 43 a potentiometer or a bleeder resistance may be connected in order that the relative potentials of the various electrodes may be properly selected. The horizontal and vertical scanning motion of the electron beam 2 across the fluorescent layer 14 is provided by the deflection yoke 44 having a horizontal and a vertical deflection coil. The deflection coils are energized by a cyclically varying current of a suitable wave form which may be obtained from a horizontal deflection generator and from a vertical deflection generator. Deflection generators are well known in the art and are therefore not shown in the drawings.

The fluorescent layer 14 is coated with electron pervious light reflecting layer 14*x* on the side of electron beam 1 and with a photoemissive layer 15 on the opposite side. A thin light transparent chemically inactive barrier layer 16 is placed between the fluorescent and photoemissive layers to prevent their chemical interaction. This composite screen represents a photocathode of the pick-up-section of intensifying system which transforms radar or microwave image into electron image and transmits it to the final viewing screen 24 in the same vacuum tube with desired intensification and magnification. Therefore, this novel radar tube is characterized by elimination of the optical lens system present in other image tubes, which resulted in 20 fold gain in the light reaching the photocathode from the radar screen. This gain of incident light allowed to activate the intensifying system, described below, which was impossible before as with the amount of light available after the passage through the focussing optical system the signal to noise ratio was too low for satisfactory results.

The fluorescent 14 and photoemissive layers 15 should be so correlated that under the influence of the cathode rays there is obtained a maximum output of photoemission. Fluorescent substances for cascade screens that may be used are ZnS—Ag on ZnS; CdS:Cu or Al_2O_3 on ZnS:Ag or of single type such as e. g. Zn(Mg)F_2:Mn or ZnSCu(Ag); $Cs_2P_2O_7$:Dy or ZnS—CdS:Ag:Cu. While I do not want to be bound by any theory, the benefits of the construction of my screen in which two different phosphors are used, may reside in the fact that one of said phosphors is responsive to electrons and emits fluorescent light when irradiated by electrons, whereas the other phosphor is sensitive to said fluorescent light emitted by the first phosphor. It is an inherent property of ZnSAg or Al_2O_3 to emit fluorescent light when irradiated by electrons and in the blue region of spectrum. As a result the total light output of said fluorescent means is larger than that of a single fluorescent layer. Some benefits of my invention may be realized by the construction of my composite screen in which a single fluorescent layer is used, but in the preferred embodiment of the invention plural phosphor layers are used, as was explained above. The satisfactory photoemissive materials will be a caesium oxide, caesium oxide activated by silver, caesium with antimony, or antimony with lithium or potassium. The barrier layer 16 between the fluorescent and photoemissive surfaces can be an exceedingly thin transparent film of mica, ZnF_2 or of a glass or suitable plastic.

Further, the photoemissive pick-up section was designed to improve its efficiency. The previous intensifying tubes used photoemissive layers of an insulated mosaic type. In my tube the insulating mosaic is replaced with the photoemissive layer of semi-transparent type. This layer is characterized by emission of electrons on the side opposite to the side of the incident light. The photoelectrons emitted from the photoemissive layer in a pattern corresponding to the incident light pattern are focussed by means of magnetic and/or electric fields on the target 17 which serves as a secondary emission electrode and electron storage place. This division of the photo-surface into the photoemissive section and secondary emission-storage section allows to obtain many-fold gain in efficiency as compared with the mosaic type of photoemissive surfaces where both photoemissive action and storage are combined in one layer. In some cases it may be desirable to use a cooling system for a photocathode and secondary emission electrode to inhibit thermionic emission.

Between the photoemissive layer 15 of the composite screen and the target 17 is an accelerating anode or ring 46 which may be also in the form of a conducting coating on the inside surface of the tube envelope. This conducting surface is maintained positive with respect of the photoemissive surface 15 by means of a source of potential 45*a*. The photoelectrons from the photoemissive layer 15 are focused upon the target 17 by means of magnetic or electromagnetic coil 26 which surrounds the major portion of the entire tube.

The previous combinations of fluorescent and photoemissive layers were not successful because of detrimental chemical interaction of both layers, due to lack of a barrier between them.

Further intensification of the radar image was obtained by the use of novel image amplification system. The amplification section of the tube 19 consists of one or a few screens, each of them composed of a very thin, light-reflecting electron pervious layer 20, of a fluorescent layer 21 and of a photoemissive layer 23 in close apposition to

each other. It is important to include a thin conducting light transparent chemically inactive barrier layer between the fluorescent and photoemissive layers **22**. The light reflecting layer **20** may be omitted in low voltage tubes. The electrons from the pick-up section of the image tube are focused by magnetic or electro-static fields on the fluorescent layer of an amplifying screen described above. The luminescence of the fluorescent layer of the amplification screen will cause the electron emission from the photoemissive layer of the screen. This process can be repeated a few times, using a few screens described above, resulting in marked intensification of the original electron image. The accelerating electrode **47** serves to accelerate photoelectrons from the photoemissive layer **23** on the next composite screen. The accelerating electrode **48** serves to accelerate photoelectrons from the composite screen to the fluorescent screen **24**. The accelerating electrodes may be in the form of ring-electrodes or in the form of conducting coating on the inside surface of the glass envelope. The accelerating electrodes are provided with a positive potential from an external source of power, as described above.

In another variety of intensification to be used in this invention there is an additional multiplier section **18** which consists of a few stages of multipliers.

The electrons leaving the amplifying section are considerably accelerated by means of high voltage electrostatic fields. The accelerating system can be of a conventional type well known in the art. Much better results with higher voltages will be achieved with an electrostatic multi-lens system.

Next the electron image may be demagnified if its additional intensification is desired. The electron diminution of the image, in order to gain its intensification is well known in the art, therefore does not have to be described in detail.

The diminished electron image is projected on the fluorescent screen at the end of the tube **24**, where it can be viewed by the observer directly or by means of an optical magnifying eye piece **25** or may be photographed. The use of an optical eye piece to magnify optically the electronically diminished image appearing on the fluorescent screen, is also well known in the art, therefore does not need further description.

On the other hand, if magnification of the radar image is needed it can be accomplished by electron optical means. The available energy of the electron image will allow 20–30 times magnification of the image with still sufficient luminosity of the fluorescent image.

The combination of the above described features of the novel tube allows to obtain a marked intensification of the original radar or other microwave image; therefore, it will be possible now to use a much finer grain of fluorescent screens **14** and **24** than was practical until now and to improve this way the detail and contrast of the final image, which was another purpose of this invention.

The focusing and accelerating electro-magnetic and/or electrostatic fields are not indicated in detail since they are well known in the art and would only serve to complicate the illustrations.

Although particular embodiments and forms of this invention have been illustrated, it is understood that modifications may be made by those skilled in the art without departing from the true scope and spirit of the foregoing disclosure.

It should be understood that the term "phosphors" used in the specification and in the claims represents only materials which emit luminescent light as it is defined in the standard text books on luminescence, such as by H. Leverenz entitled "Luminescence of Solids" and published by John Wiley in 1950.

I claim:

1. A vacuum tube comprising in combination means for producing a beam of electrons and an imperforate screen for receiving said beam of electrons, said screen comprising in that order a continuous light reflecting and pervious to electrons layer, fluorescent means, said light reflecting layer having one side exposed and the opposite side facing said fluorescent means, adjacent to said fluorescent means and extending over a major portion of one side of said fluorescent means, said fluorescent means furthermore comprising a plurality of different phosphors emitting luminescent light, one of said phosphors being responsive to electrons and at least one of said phosphors being responsive to luminescent light emitted by said phosphor responsive to electrons, and a light transparent, continuous and electrically conducting layer mounted on the side of said fluorescent means opposite to the side which is adjacent to said light reflecting layer, outside of said fluorescent means and facing said fluorescent means and extending over a major portion of one side of said fluorescent means.

2. A device as defined in claim 1 in which said means for producing said beam of electrons comprise an electron gun.

3. A device as defined in claim 1 in which said different phosphors are in contact with each other.

4. A device as defined in claim 1 in which said different phosphors are in different layers.

5. A composite screen comprising in combination in that order a light-reflecting continuous layer, fluorescent means, said light reflecting layer being adjacent to said fluorescent means, facing said fluorescent means and extending over a major portion of one side of said fluorescent means, said fluorescent means comprising a plurality of different from each other phosphors, one of said phosphors being responsive to electrons and at least one of said phosphors being responsive to luminescent light emitted by said phosphor responsive to electrons and a light transparent continuous and electrically-conducting layer facing said fluorescent means, mounted on the side of said fluorescent means opposite to the side which is adjacent to said light reflecting layer, outside of said fluorescent means and extending over a major portion of one side of said fluorescent means.

6. A device as defined in claim 5 in which said different phosphors are in different layers successively disposed one after another.

7. A composite screen comprising in combination in that order a light reflecting and electron pervious continuous layer, fluorescent means, said light reflecting layer being adjacent to said fluorescent means, facing said fluorescent means and extending over a major portion of one side of said fluorescent means, said fluorescent means comprising a plurality of different from each other phosphors, one of said phosphors being responsive to electrons and at least one of said phosphors being responsive to luminescent light emitted by said phosphor responsive to electrons, and a light transparent, continuous and electrically conducting layer facing said fluorescent means, mounted on the side of said fluorescent means opposite to the side which is adjacent to said light-reflecting layer, outside of said fluorescent means and extending over a major portion of one side of said fluorescent means.

8. A device as defined in claim 7 in which said different phosphors are in contact with each other.

9. A device as defined in claim 7 in which said different phosphors are in different layers successively disposed one after another.

10. A device as defined in claim 7 in which said phosphors are in contact with each other.

11. A vacuum tube comprising within said tube in combination an imperforate screen comprising in that order a continuous light reflecting layer, fluorescent means, said light reflecting layer facing said fluorescent means, being adjacent to said fluorescent means and exteding over a major portion of one side of said fluorescent means, said fluorescent means receiving radiation

through said light reflecting layer and comprising a plurality of different phosphors emitting luminescent light, one of said phosphors being responsive to electrons and at least one of said phosphors being responsive to luminescent light emitted by said phosphor responsive to electrons, and a photoemissive layer facing said fluorescent means, having an exposed and continuous surface, receiving light from said fluorescent means and emitting a beam of electrons in response to said light, and a screen for receiving said beam of electrons.

12. A device as defined in claim 11 in which said light reflecting layer is electron-pervious.

13. A device as defined in claim 11 in which said screen for receiving said beam of electrons comprises an electron-pervious and light-reflecting layer, and a fluorescent layer.

14. A device as defined in claim 13 in which said fluorescent means comprise zinc sulphide activated with silver.

15. A device as defined in claim 13 in which said fluorescent means comprise zinc sulphide activated with cadmium.

16. A device as defined in claim 13, in which said imperforate screen is spaced apart from the end wall of said tube.

17. A device as defined in claim 11, in which said photoemissive layer comprises an element of the group consisting of antimony and bismuth.

18. A device as defined in claim 11, in which said photoemissive layer comprises an element of the group consisting of antimony and bismuth in combination with an element of the group consisting of potassium and lithium.

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