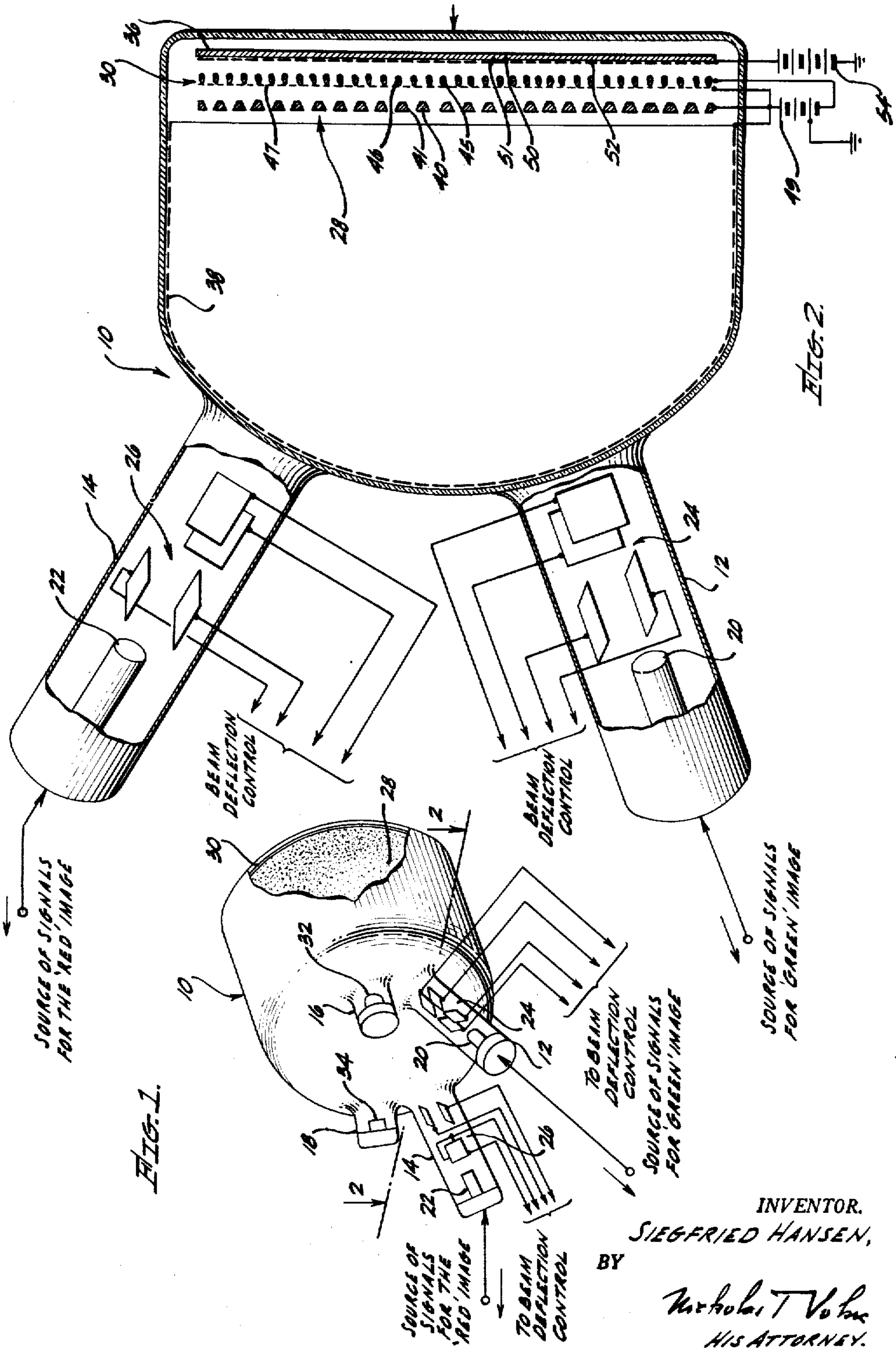
DIRECT-VIEWING COLOR STORAGE TUBE

Filed July 16, 1953 2 Sheets-Sheet 1

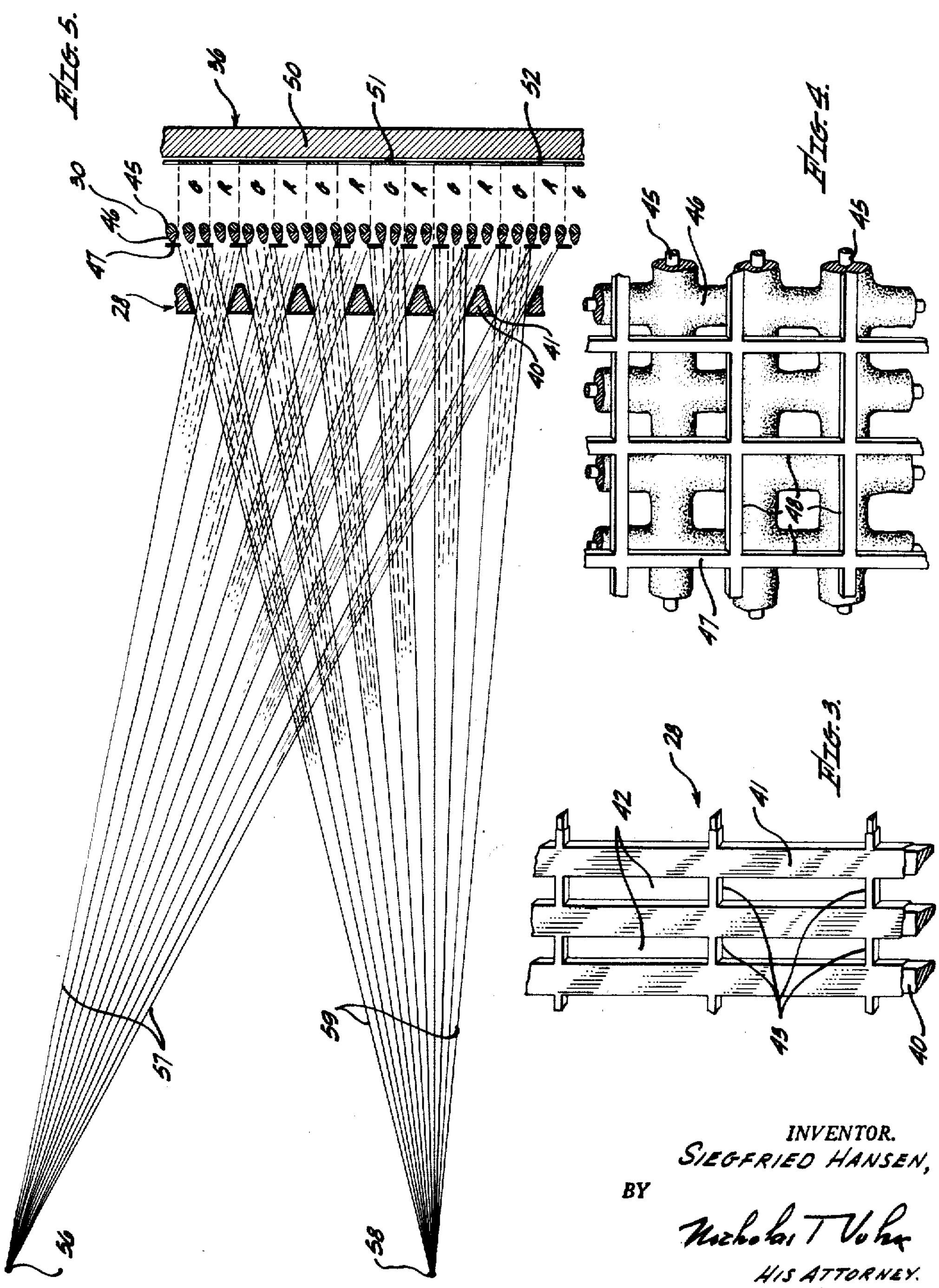


INVENTOR.
SIEGFRIED HANSEN,
BY
Nicholas T. Volsk
HIS ATTORNEY.

Oct. 21, 1958 S. HANSEN 2,857,551

DIRECT-VIEWING COLOR STORAGE TUBE

Filed July 16, 1953 2 Sheets-Sheet 2



INVENTOR.
SIEGFRIED HANSEN,

BY

Nicholas T Volsk

HIS ATTORNEY.

United States Patent Office

2,857,551

Patented Oct. 21, 1958

1

2,857,551

DIRECT-VIEWING COLOR STORAGE TUBE

Siegfried Hansen, Los Angeles, Calif., assignor, by mesne assignments, to Hughes Aircraft Company, a corporation of Delaware

Application July 16, 1953, Serial No. 368,341

5 Claims. (Cl. 315—12)

This invention relates to a direct-viewing color storage tube and more particularly to a storage tube capable of simultaneously producing a visual presentation of several multi-colored images.

One specific embodiment of the tube of the present invention is particularly adaptable to search radar systems. This embodiment provides for the presentation of two colors such as, for example, red and green. As is generally known, a type B search display presents the range and azimuth of a target. The tube of the present invention would enable a target indication to be presented in either red or green, depending upon its relative elevation, when incorporated in a radar system of this type. Alternatively, the tube would enable certain types of targets to be presented in color for identification purposes. Another embodiment of the direct-viewing color storage tube capable of presenting three colored images simultaneously, is, of course, particularly adaptable to color television systems.

The device of the present invention incorporates color presentation techniques in a direct-viewing storage tube of the type disclosed in a copending United States Patent application by Siegfried Hansen, Serial No. 299,363, filed July 17, 1952, now Patent 2,788,466, and entitled "Method and Apparatus for Utilizing Electron Bombardment Induced Surface Conductivity" by the same applicant. The tube of the present invention comprises an electron writing gun for each colored image to be presented. The electron beams produced by these writing guns are caused to scan rasters in register with each other on a storage surface provided by a foraminous target element. A mask is disposed adjacent to the target element and interposed between the electron beams and the storage surface. This mask is such that each electron beam is incident on non-overlapping areas of the storage surface. Each electron beam is intensity modulated in accordance with its respective colored image to produce a distinct charge pattern representative of each colored image on the scanned areas of the storage surface.

A viewing screen, disposed adjacent to the foraminous target element on the side opposite from the electron guns, has appropriate colored phosphor areas disposed in register with the areas of each charge pattern of corresponding color. A simultaneous visual presentation of the several charge patterns is then produced by directing flood electrons through the foramina of the target element contained within each elemental area of the storage surface in proportion to the charge thereon in a collimated beam to the viewing screen.

A basic problem that is generally encountered in colored television image presentation systems is that of flicker. This problem stems from the limited bandwidth allocated for the transmission of the frequencies constituting the image signal. This limited bandwidth requires that a compromise be made between the number of complete images or frames produced each second and the definition of the images. The number of frames

2

produced each second cannot be reduced beyond the point at which flicker occurs without concomitant undesirable effects. Hence the bandwidth available for definition purposes is determined by the frame repetition rate.

In the case of a color presentation, three distinct colored images generally constitute one frame. It is necessary that the repetition rate for each colored image be high enough to prevent flicker when viewed alone, as it is always possible for one color to predominate throughout large portions of the presentation. Thus, it is seen that a color presentation having the same definition as a black and white presentation would presumably require three times the bandwidth. In this connection, reference is made to an article entitled "Alternative Approaches to Color Television" by Donold G. Fink, which appears on pages 1124 to 1134 in vol. 39 of the Proceedings of the I. R. E., October 1951, where the above problem is discussed at length.

The advantages of the direct-viewing color storage tube of the present invention include, of course, all the advantages attributable to the direct-viewing type storage tube described in the aforementioned copending application by the same inventor, Siegfried Hansen. The more important advantages of this tube are the continuous bright display of the charge pattern, the controllable effective persistence of the screen, and the fast writing speed accomplished by the use of bombardment induced conductivity techniques. In its adaption to color presentation, it is quite obvious that the effective persistence of each image may be controlled so that the several different colored presentations may be made to appear simultaneously, thereby considerably decreasing the undesirable flicker. Employment of the color tube disclosed herein would enable the frame rate of successive presentations to be decreased to the extent necessary to provide for continuity of motion, thus creating a substantial saving in bandwidth which may be utilized to improve definition.

It is therefore an object of this invention to provide a direct-viewing color storage tube.

Another object of this invention is to provide a direct-viewing storage tube capable of simultaneously producing a plurality of multi-colored presentations of controlled persistence.

Still another object of this invention is to provide a direct-viewing color storage tube incorporating a separate writing beam for each color and an appropriate mask disposed in front of a storage surface scanned by the writing beams in such a manner that each writing beam is incident on distinct non-overlapping areas of the storage surface.

A further object of this invention is to provide a direct-viewing color storage tube utilizing flood electrons to simultaneously produce a visual presentation of a plurality of multi-colored images.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings, in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood that the drawings are for the purposes of illustration and description only, and are not intended as a definition of the limits of the invention.

Fig. 1 is a perspective view of a two-color embodiment of the tube of the present invention;

Fig. 2 is an enlarged cross sectional view of the tube shown in Fig. 1 taken along line 2—2 of that figure;

Fig. 3 is a perspective view of an enlarged portion of the color mask;

Fig. 4 is a perspective view of an enlarged portion of the target element; and

Fig. 5 is a cross sectional view of the geometrical relationship between the electron beams and enlarged portions of the color mask, target element, and viewing screen.

Referring now to Fig. 1, there is shown a perspective view of a tube of the present invention adapted for two-color presentation which is particularly suitable for radar applications. This tube comprises an evacuated envelope **10** having neck portions **12, 14, 16** and **18** disposed as shown in the figure. Neck portions **12, 14** house electron guns **20** and **22**, respectively, shown in schematic form, for producing electron writing beams. Electron beam deflecting means **24** and **26** are disposed axially about the electron beams produced by guns **20** and **22**, respectively. Deflecting means **24** and **26** are energized by appropriate beam deflection control signals to cause the electron beams to trace identical rasters on a target element **30** through a color mask **28**.

Neck portions **16, 18** are disposed immediately above the neck portions **12, 14**, and house sources of flood electrons **32, 34**, respectively. The sources of flood electrons are arranged so that flood electrons from the respective sources **32, 34** are directed uniformly over the area of target element **30** through color mask **28**. The flood electrons are directed through each elemental area of color mask **28** at an angle of incidence substantially the same as the angle of incidence of the electron writing beams when scanning the same elemental area. This is accomplished by positioning the sources **32, 34** of flood electrons as near to the respective paths of the electron writing beams as reasonably possible.

In order to explain more clearly the structure and manner of operation of the tube of the present invention, reference is made to Fig. 2. As can be seen in this figure, neck portions **12, 14** are arranged at an acute angle with each other so that the electron writing beams, produced by electron guns **20, 22** housed therein, are incident on target element **30** at substantially different angles over the entire area of its surface. Target element **30** is disposed in the right portion of envelope **10** facing the electron writing beams as shown in Fig. 2. Color mask **28** is positioned adjacent to target element **30** so as to periodically intercept the electron beams when scanning target element **30**. A viewing screen **36** is disposed adjacent to and in register with target element **30** on the side opposite from the color mask **28**. An electrode **38** provides a drift region between deflecting means **24, 26** and the color mask **28**.

Color mask **28** comprises a glass core **40** having a thin coating **41** of metal such as, for example, aluminum disposed uniformly over its outer surface. The glass core **40** may be fabricated by employing the "Corning Photoform Process" and the thin coating **41** of aluminum applied thereon by evaporation. A small portion of mask **28**, as employed in the two-color embodiment of the tube of the present invention, is shown in perspective in Fig. 3. The openings **42** for the two-color embodiment are equal in width to the solid sections and are several times their width in length. For example, the solid sections and the width of the openings may be of the order of 0.01" and the length of the openings may be of the order of 0.02". Cross pieces **43** which separate the openings **42** are for structural purposes and serve no direct function in the operation of the tube. The mask **28** is scanned by the electron beams in a direction substantially perpendicular to the length of the openings. The solid portions of the mask not exposed to the electron beams are made substantially narrower than the exposed solid portions so as not to intercept electrons entering openings **42** which will generally be penetrating through the mask **28** at an angle.

Target element **30** is shown in cross section in Fig. 2, and an enlarged portion of it is illustrated in Fig. 4. Target element **30** comprises a stainless steel wire screen or electro-formed nickel screen **45** having of the order of 300 wires per inch; screen **45** serves as a contrast control grid **45**. A layer **46** of dielectric material such as, for example, talc, is disposed over grid **45**, and an aluminum mesh **47**, having of the order of 100 meshes per inch, is in contact with layer **46** to serve as a collector grid **47**. The dielectric material comprising layer **46** must exhibit both bombardment induced conductivity and secondary electron emission characteristics. The surface of layer **46** appearing between the openings of collector grid **47** provides a storage surface **48**.

Color mask **28**, electrode **38**, and collector grid **47** of target element **30** are all maintained at a potential of the order of 200 volts positive with respect to ground by means of connections to the positive terminal of a potential source **49** and contrast control grid **45** is maintained at a potential of the order of −10 volts with respect to ground by means of a connection to the negative terminal of source **49**, an appropriate intermediate tap of which is connected to ground.

Viewing screen **36**, appearing in cross section in Fig. 2, comprises a glass pane **50** which may be the flat portion on the extremity of envelope **10** as viewed in the figure, a transparent conductive coating **51** and a phosphor layer **52**. Transparent conductive coating **51** is maintained at a positive potential of the order of 5000 volts with respect to ground by means of a connection to the positive terminal of a potential source **54**, the negative terminal of which is connected to ground.

Phosphor layer **52** consists of a series in parallel, horizontal stripes of color phosphor having essentially the same vertical dimension as the vertical dimensions of the openings in color mask **28**. These stripes may be alternately of, for example, red and green phosphors. The pitch of these stripes must have a pitch slightly greater than that of the openings of the color mask to allow for the parallax of the electron beam as it passes from mask **28** to the storage surface **48** of target electrode **30**. The manner in which such a screen having alternate color stripes with parallax correction may be produced is described in U. S. Patent No. 2,568,448 entitled "Parallax Correction in Color Television" which issued September 18, 1951, to this inventor, S. Hansen.

In order to more adequately illustrate the relation of the color stripes on the viewing screen **36** to the openings in the color mask **28**, reference is made to Fig. 5. This figure illustrates enlarged portions of the color mask **28**, target element **30** and viewing screen **36** disposed in correct relationship with one another to produce a two-color presentation with two electron beams having centers of deflection at points **56** and **58**. Lines **57, 59** connect the extremities of the openings of color mask **28** with the centers of deflection **56, 58** of the electron beams, respectively, each beam being modulated in accordance with a different color image such as, for example, red and green. The dashed areas between lines **57, 59** indicate the regions where the electron beams will penetrate through color mask **28** to target element **30**.

Proper operation of the tube of the present invention requires that the areas of storage surface **48** scanned by one electron beam do not overlap with the areas scanned by the other beam. Each beam will produce a charge on the scanned areas of the storage surface **48**, in a manner hereinafter described in more detail, to produce two integrated charge patterns.

Another phase of the operation of the tube involves directing flood electrons through the interstices included in each elemental area of storage surface **48** in proportion to the charge thereon to the viewing screen **36**. The red stripes of phosphor layer **52**, designated by "R," are disposed so as to be in register with the areas of storage surface **48** scanned by the electron beam modulated in accordance with the red image. Similarly, the green stripes, designated by "G" are disposed so as to be in register with the areas of storage surface 48 scanned by the electron beam modulated in accordance with the green image. Thus, as illustrated in Fig. 5, it is seen that the pitch of the color stripes comprising phosphor layer 52 must be somewhat greater than the pitch of the openings in color mask 28. The exact pitch, of course, is a function of the distances of the centers of deflection 56, 58 from each other and from the storage surface 48 of target element 30, the distance between color mask 28 and target element 30, and the size of the openings in color mask 28.

The operation of the tube of the present invention may be divided into three phases, namely, the producing of the charge replicas of the color images on the storage surface 48, the simultaneous production of a visual presentation of the color images, and the returning of the potentials constituting the charge replicas to a substantially fixed reference potential such as, for example, ground, prior to the producing of a subsequent charge replica on the storage surface 48. During the actual operation of the tube, these three phases of operation are generally taking place at the same time.

During the first phase of operation, the electron beams produced by electron guns 20, 22 (see Fig. 2) are caused to scan identical rasters on target element 30 through color mask 28. Alternate segments of the lines of each raster are intercepted by the color mask 28 so that the two electron beams together scan a single integrated raster on storage surface 48. As explained in the third phase of operation of the tube, the flood electrons charge the storage surface 48 of target element 30 to substantially ground potential. Hence a positive potential gradient exists from the storage surface 48 to the collector grid 47 inasmuch as the collector 47 is maintained at a potential of the order of 200 volts positive with respect to ground.

The cathodes of electron guns 20, 22 are maintained at a potential of the order of 3000 volts negative with respect to ground and the respective electron beams intensity modulated with the color image signals. An electron beam, upon being scanned over an elemental area of storage surface 48, releases electrons from their molecular bonds within the surface layer of dielectric material 46 in proportion to the intensity of the electron beam thereon. The electrons released from their molecular bonds may be referred to as conduction electrons. These conduction electrons are attracted to collector grid 47 through the molecular matrix comprising the surface layer of the dielectric material 46 to effect the charging of the scanned elemental area of storage surface 48 in a positive direction. Two integrated nonoverlapping charge replicas of the color images are thus produced on the storage surface 48 since the number of conduction electrons produced within each elemental area thereof is proportional to the intensity of the electron beam at the time of scanning the elemental area.

The second phase of operation comprises the directing of flood electrons through the interstices contained within each elemental area of the storage surface 48 in a collimated beam to the viewing screen 36 to produce a simultaneous presentation of the color images. The first step of this phase of the operation is the directing of the flood electrons uniformly over the area of the storage surface 48 which is complicated due to the color mask 28 being disposed between the sources of the flood electrons and the target element 30. This complication is overcome by disposing the flood guns 32, 34 in the proximity of the centers of deflection of the electron writing beams produced by electron guns 20, 22, respectively. Thus the flood electrons penetrate through the color mask 28 at substantially the same angle as the associated electron writing beam and, hence, are directed over substantially the same areas scanned by the electron beam.

The next step in the second phase of operation is to direct the flood electrons through the interstices within each elemental area of the storage surface 48 in proportion to the charge predominating thereon in a collimated beam to the viewing screen 36. In order to accomplish this, the cathodes of the flood guns 32, 34 are maintained at substantially ground potential so that, in the absence of a positive charge on storage surface 48, the flood electrons are repelled by negative voltage applied to contrast control grid 45. The effect of a positive charge established on storage surface 48 is to combine with the electric field from viewing screen 36 to produce field penetration through the contrast control grid 45. The increased predominance of a positive charge on an elemental area of storage surface 48, of course, produces increased field penetration through contrast control grid 45 to the viewing screen 36, thus allowing increased numbers of flood electrons to flow through the interstices within the elmental area of storage surface 48. The electrons penetrating through target element 30 are accelerated in a collimated beam to the appropriate color stripes of phosphor layer 50 by the high positive voltage applied to conductive coating 51 to produce a simultaneous visual presentation of the charge replicas of the color images.

The third phase of operation of the tube of the present invention comprises returning the potentials constituting the charge replica to a reference potential prior to being charged positive again by an electron writing beam. This phase of the operation is controlled by the potential of the collector grid 47 relative to the potential of the cathodes of flood guns 32, 34. As previously stated, it was specified that the layer 46 of dielectric material which provides storage surface 48 possesses secondary electron emission characteristics. Thus storage surface 48 will have a concomitant critical potential where the secondary electron emission ratio is unity. Maintaining the collector grid 47 at approximately 1.3 times this critical potential with respect to the cathodes of flood guns 32, 34 will produce normal persistence of the charge replicas. The function of the process of returning the potentials constituting the charge replica to a reference potential consists first in charging all the potentials less than the critical potential to the potential of the cathodes of the flood guns 32, 34 simultaneously with the charging of the potentials greater than the critical potential to the potential of the collector grid 47 by secondary electron emission. In general, the entire area of storage surface within an opening of grid 47 will be either charged to the potential of the cathodes of the flood guns or to the potential of the collector grid 47. Continued action of the flood electrons on an area charged to the potential of the collector grid 47 causes this area to "shrink" away from the meshes of grid 47 until the entire area is at the potential of the flood gun cathode.

It is realized that other modes of operation may be effected by merely increasing or decreasing the voltage of collector grid 47 relative to the critical potential. That is, increasing this voltage will increase the persistence by decreasing the rate at which the areas of storage surface within the openings of grid 47 that are charged to the potential thereof will shrink until the charged areas remain substantially fixed in size. Utilization of this mode of operation would require additional means for "erasing" the charge replica prior to producing a subsequent one. On the other hand, the collector grid voltage may be lowered until the entire initial charge produced by the writing beams is discharged directly to the potential of the flood gun cathodes. This latter mode may be desirable for television applications of the disclosed tube, whereas the former mode is adaptable to certain types of radar presentations.

For television applications it would be necessary to use at least three different electron guns for writing purposes. In the event that it is desired to use the same type of mask as mask 28 of the embodiment hereinbefore described, it would be necessary to reduce the size of the openings 42 to approximately one-half the width of the solid sections. The electron guns would be angularly disposed with each other in a common plane in order that the electron beams produced by the guns penetrate through the openings of the mask at different angles. A viewing screen having phosphor stripes of an appropriate color in register with the area of the storage surface scanned by each electron beam and flood guns disposed near the center of deflection of each electron beam are employed in the same manner as in the prior embodiments.

It is, of course, apparent that various other modifications of the masking arrangements may be employed in practicing the disclosed invention which are within the teachings of the present disclosure.

What is claimed as new is:

1. A direct-viewing electronic color storage tube for the visual presentation of a plurality of image signals in color, said tube comprising means for producing a plurality of electron beams, means for controlling the intensity of each of said electron beams with an image signal, a storage screen having a storage surface on one side thereof, means for scanning intermittent non-overlapping elemental areas of said storage surface with each of said electron beams, said areas for each beam being intermittent in the direction of scan and interlaced in the direction of scan with the intermittent areas scanned by the other said beams to produce a plurality of integrated charge replicas on said storage surface corresponding, respectively, to said image signals, a viewing screen disposed coextensive with and adjacent to said storage screen on the other side thereof, said viewing screen including a fluorescent screen for developing light of predetermined color in register with each of said plurality of charge replicas, and means for directing a collimated flow of electrons through said storage screen in proportion to the charge on said storage surface to produce a color presentation of each of said charge replicas on said viewing screen.

2. The direct-viewing electronic color storage tube as defined in claim 1 wherein said means for scanning intermittent non-overlapping elemental areas of said storage screen with each of said electron beams includes a conductive mask disposed adjacent to said storage screen on said one side thereof to periodically intercept said electron beams.

3. A direct-viewing electronic color storage tube for the visual presentation of a plurality of image signals in color, said tube comprising means for producing a plurality of high energy electron beams; means for controlling the intensity of each of said electron beams with an image signal; a target element including a conductive screen, a layer of dielectric material that exhibits secondary electron emission disposed on one side of said conductive screen coextensive with the meshes thereof, and a conductive mesh disposed in contact with said layer of dielectric material whereby the portions of the surface of said layer of dielectric material within the openings of said mesh provide a storage surface; means for maintaining said conductive mesh at a first potential level; means for maintaining said storage surface at a second potential level negative with respect to said first potential level to produce a positive potential gradient from said storage surface to said conductive mesh; means for scanning intermittent non-overlapping elemental areas of said target element with each of said electron beams, said areas for each beam being intermittent in the direction of scan and interlaced in the direction of scan with the intermittent areas scanned by the other said beams to liberate secondary electrons from said storage surface in proportion to the beam intensity thereon whereby said secondary electrons are attracted to said conductive mesh by said potential gradient to produce a plurality of integrated charge replicas on said storage surface corresponding, respectively, to said image signals; a viewing screen disposed coextensive with and adjacent to said conductive screen on the other side thereof, said viewing screen including a fluorescent screen adapted to provide light of predetermined color in register with each of said plurality of integrated charge replicas; and means for directing a collimated flow of electrons through said target element in proportion to the charge thereon to said viewing screen to produce a color presentation of each of said charge replicas.

4. A direct-viewing electronic color storage tube for the visual presentation of two image signals in color, said tube comprising first and second electron guns for producing, respectively, first and second high energy electron beams of elemental cross sectional area; means for controlling the intensity of said first and second electron beams with the image signals; a target element including a conductive screen, a layer of dielectric material that exhibits secondary electron emission disposed on one side of said conductive screen coextensive with the conductors thereof, and a conductive mesh disposed in contact with said layer of dielectric material, to separate the surface of said layer of dielectric material within the openings of said mesh to provide a subdivided storage surface; means for maintaining said conductive mesh at a first potential level; means for maintaining said storage surface at a second potential level negative with respect to said first potential level to produce a positive potential gradient from said storage surface to said conductive mesh; means for scanning alternate non-overlapping elemental areas of said target element with said first and second electron beams to liberate secondary electrons from each scanned elemental area of said storage surface in proportion to the beam intensity thereon, said secondary electrons being attracted to said conductive mesh by said potential gradient to produce two sets of integrated charge replicas on said storage surface corresponding to said two image signals; a viewing screen disposed coextensive with and adjacent to said conductive screen on the other side thereof, said viewing screen including a fluorescent screen for developing light of predetermined color in register with each of said two integrated charge replicas; and means including an electron flood gun disposed adjacent the path of each of said electron beams for directing respectively a collimated flow of electrons through said target element in proportion to the two sets of charge replicas thereon to said viewing screen to produce a color presentation of said charge replicas.

5. A direct-viewing electronic color storage tube for the visual presentation of a plurality of image signals in color, said tube comprising means for producing a plurality of high energy electron beams; means for controlling the intensity of each of said electron beams with an image signal; a target element including a conductive screen, a layer of dielectric material that exhibits secondary electron emission disposed on one side of said conductive screen coextensive with the conductors thereof, and a conductive mesh disposed in contact with said layer of dielectric material to separate said target element into portions of the surface of said layer of dielectric material within the openings of said mesh to provide a subdivided storage surface; means for maintaining said conductive mesh at a first potential level; a conductive mask disposed coextensive with an adjacent to the storage surface of said target element; means for directing flood electrons emanating from a second potential level that is negative with respect to said first potential level through said mask and uniformly over said target element to charge each elemental area of storage surface substantially to said second potential level to produce a potential gradient from said storage surface to said conductive mesh; means for scanning each of said beams over said target element through said mask for bombarding intermittent non-overlapping areas of said storage surface by each of said electron beams to liberate secondary electrons from said storage surface in proportion to the intensity of the electron beam thereon which are attracted to said conductive

mesh by said potential gradient to produce a plurality of integrated charge replicas on said storage surface corresponding, respectively, to said image signals; a viewing screen disposed contiguous to and coextensive with said target element having a different color phosphor for each said electron beam in register respectively with said intermittent non-overlapping areas of said storage surface, whereby said flood electrons penetrate through the target element in proportion to the charge on said storage surface to produce a color presentation of each of said charge replicas on said viewing screen.

References Cited in the file of this patent

UNITED STATES PATENTS

2,532,339	Schlesinger	Dec. 5, 1950
2,547,638	Gardner	Apr. 3, 1951
2,659,026	Epstein	Nov. 10, 1953
2,674,704	Weimer	Apr. 6, 1954
2,761,089	Haeff	Aug. 28, 1956

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,857,551 October 21, 1958

Siegfried Hansen

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, lines 39 and 40, for "Method and Apparatus for Utilizing Electron Bombardment Induced Surface Conductivity" read -- Direct-Viewing Storage Tube --; column 7, line 9, for "area" read -- areas --; column 8, line 62, for "with an" read -- with and --.

Signed and sealed this 3rd day of March 1959.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents