

Dec. 20, 1955

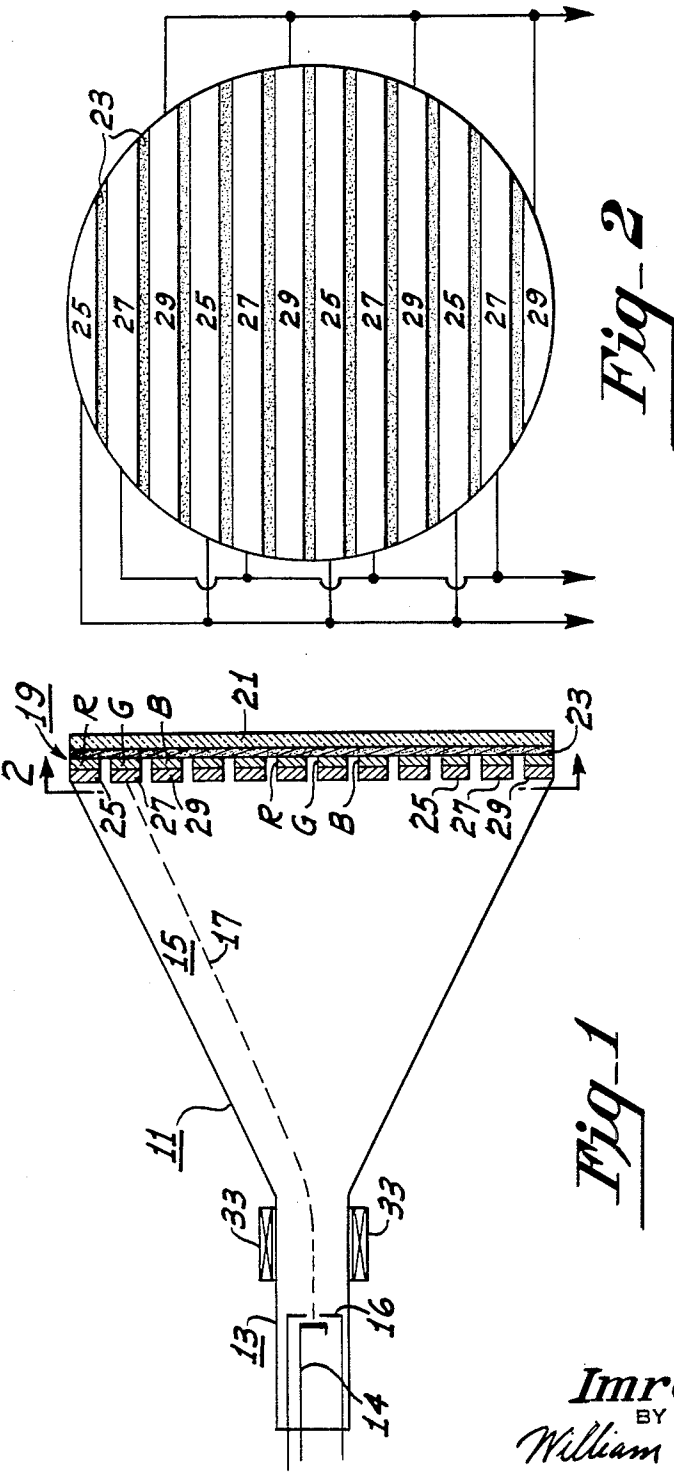
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2,728,010

COLOR KINESCOPE UTILIZING X-RAYS

Filed Jan. 30, 1951

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

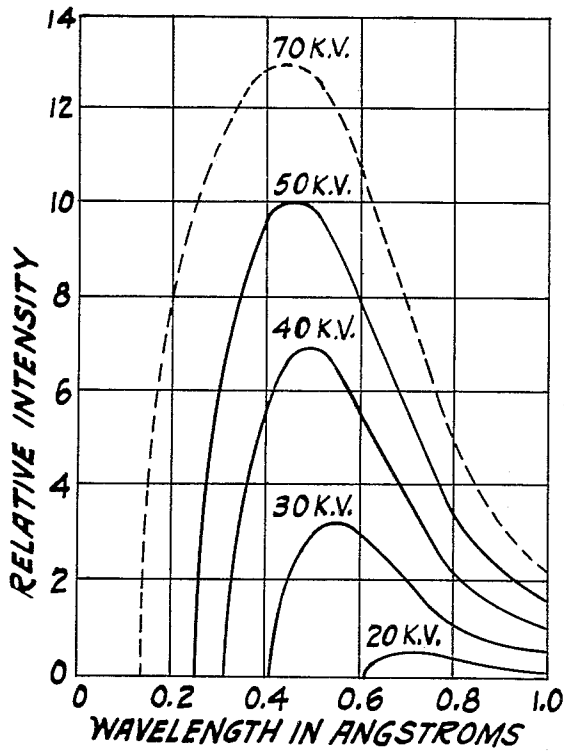


Fig-5

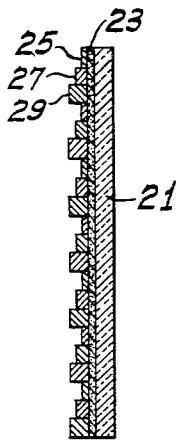


Fig-3

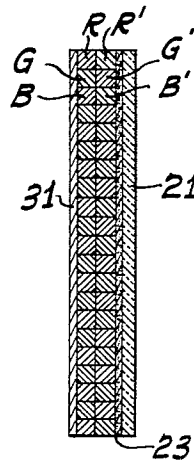


Fig-4

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1

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COLOR KINESCOPE UTILIZING X-RAYS

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10 Claims. (Cl. 313—92)

This invention relates to improvements in multi-color kinescopes for use in television and other systems for the communication of intelligence. In particular, it relates to a novel and improved target assembly for use in such kinescopes.

In certain types of color kinescopes, notably of the masked target variety, the colored light emissive areas of the screen are of sub-elemental visual dimensions and must be maintained in exact alignment with the apertures of the masking screen. This gives rise to serious manufacturing problems.

Accordingly, one object of the present invention is to provide a color kinescope which is free of alignment problems and therefore easier to manufacture.

Another object is to provide an improved kinescope wherein it is not necessary to lay down the phosphor target in discrete sub-visual areas.

Another object is to utilize X-rays as phosphor exciting agents in a kinescope.

The present invention is predicated on the fact that certain phosphor materials will absorb X-rays of one frequency and remain relatively insensitive to X-rays of other frequencies, and on the further fact that when these X-rays are absorbed the absorbing medium emits electrons. (Cf. "X-Rays in Theory and Experiment," Compton and Allison, pp. 17, 526 ff.) By using different color producing phosphors as the absorbing medium a multi-color kinescope is provided. The phosphors are blended into a mixture and need not be laid down in discrete areas.

In a preferred embodiment, a high velocity cathode ray beam bombards metallic targets to produce X-rays. These X-rays are then selectively filtered and directed toward the phosphor mixture. The different phosphors produce different colors as they are excited by the different frequencies of X-rays and a full color image results.

The invention is more completely described in connection with the accompanying two sheets of drawings in which:

Fig. 1 is a longitudinal section of a kinescope embodying a preferred form of the invention;

Fig. 2 is a plan view along the line 2—2 of Fig. 1 showing the target elements of the screen and the electrical connections thereto;

Fig. 3 is a cross section of an alternative screen structure in accordance with the invention;

Fig. 4 is a cross section of still another screen structure embodying the invention; and

Fig. 5 is a graph showing the X-ray spectrum resulting from bombardment of a tungsten target by different electron beam velocities. It will be referred to in the explanation of the invention.

The tube of Fig. 1 comprises an evacuated envelope 11 having a neck portion 13 and a main chamber 15. The neck portion 13 contains an electron source or gun comprising an electron emitter 14 and a control electrode 16. The electron beam 17 is directed into the main chamber 15 where it bombards a target or screen 19. The target 19, in the instant case, is supported upon the inner surface of the glass face plate or window 21 of the tube. It comprises a layer 23 of phosphor materials which are

2

sensitive to X-rays, a layer of metallic elements 25, 27, 29 which produce X-rays of different characteristic frequencies when bombarded by electrons, and a layer of filter elements R, G, B which permit the passage of X-rays of certain frequencies and block the passage of X-rays of other frequencies. The phosphor 23 is laid down on the face plate 21 and the filters R, G, B and metal strips 25, 27, 29 are superimposed on the phosphor by spraying through a screen, or in the form of individual strips of thin metal ribbon. The face plate 21 may be constituted of a lead glass to prevent X-rays from emanating from the face of the tube.

The layer 23 is a mixture of three different phosphors. Each of these phosphors is sensitive to a given frequency of X-rays and relatively insensitive to X-rays of other frequencies. Another characteristic of these phosphors is that when one of them is excited by X-rays of the frequency to which it is sensitive it emits red light. Another, in similar fashion emits green light; and the third, blue light. Examples of phosphors which possess these characteristics are: cadmium sulfide for red light, manganese activated zinc silicate for green light and calcium tungstate for blue light. These different phosphors need not be laid down in discrete areas of sub-visual dimensions as is necessary with the phosphor targets in most multi-color kinescopes. Instead, they are mixed together and settled upon the face plate 21 in a single coating. The different colors in the output from the tube are the result of the individual phosphors within the mixture being excited by the particular frequency of X-ray to which they are sensitive and radiating their characteristic colors.

In order to produce the different X-ray frequencies which will excite the different phosphors it is necessary first, to determine to what frequency of X-rays each of the color producing phosphors is sensitive; and then, to devise a means for bombarding the phosphor layer 23 with X-rays of these different frequencies in a selective manner controlled by color input signals.

The frequency to which the individual phosphors are sensitive may be determined from Tables of Emission and Absorption Wavelengths for the various elements involved. One such table is offered by M. Siegbahn in "Spektroskopie der Rontgenstrahlen," 2nd edition, Springer, Berlin 1931; and reprinted in "Structure of Metals," by C. S. Barrett, McGraw-Hill, as Appendix II on page 516.

Since only the absorbed X-rays cause excitation, by determining the K absorption edge frequency (which is the frequency of maximum absorption) for a particular phosphor one can find to what frequency that phosphor is sensitive. The absorption edge is a wavelength above which there is minimum absorption by the element and below which there is maximum absorption. In cases where the phosphor is a compound of several elements, the absorption edge of the element having the highest atomic number (i. e. the lowest absorption edge) is controlling. It is also convenient to note that the absorption edge of an element decreases as its atomic number increases.

Applying these principles and using the tables identified above it is found that the three phosphors proposed have the following absorption edges:

Phosphor:	K absorption edge
Cadmium Sulfide (CdS) (Red).....A.....	0.46
Manganese activated Zinc Silicate (ZnSiO ₄) (Green)	1.28
Calcium Tungstate (CaWO ₃) (Blue).....A.....	0.178

(The element having the highest atomic number in each of the above phosphor compositions has been underlined for facility in consulting the tables.)

It now becomes evident that to activate the red phosphor X-rays of approximately 0.46 A. are needed, to activate the green X-rays of approximately 1.28 A. are needed, and to activate the blue approximately 0.178 A. In order to obtain these frequencies it is advantageous to select for the metal strips 25, 27, 29 materials which when bombarded by electrons produce their strongest radiations in the proper portion of the X-ray spectrum. The same tables employed above are useful here. This time, check under the emission line and use the $K\alpha_1$ emission because it is the strongest radiation. From this operation the following combinations are obtained:

Phosphor	Absorption Edge, A.	Target	$K\alpha_1$ Emission, A.
CdS (red)-----	0.46	Antimony (Sb)	0.47
ZnSiO ₄ (green)-----	1.28	Germanium (Ge)	1.25
CaWO ₃ (blue)-----	0.178	Gold (Au)	0.18

With this information, it is now possible to make the

may be separated from each other by insulating material in order to keep the proper voltages on the proper strip and to keep stray electrons from bombarding the phosphor material 23 between the strips 25, 27, 29 if the scanning electron beam falls out of register with the metal targets.

In order to eliminate X-rays of undesired or spurious frequencies and make the color response of the kinescope more selective, filter elements R, B, G are interposed between the metallic elements 25, 27, 29 and the phosphor layer 23. The filter materials are selected by reference to the previously identified Tables of Emission and Absorption Wavelengths with the end in view of placing in the path of the X-rays an element with an absorption edge lower than the frequency which the particular metal strip 25, 27, 29 is supposed to provide for radiation of its particular color phosphor. This results in absorption of any X-rays below the critical frequency which might be present at low levels along with the characteristic $K\alpha$ radiation of the metal strip bombarded. For the phosphors and targets previously suggested, the following filters may be used:

Color Desired	Phosphor	Absorption Edge, A.	Metal Target	$K\alpha$ Emission, A.	Filter	Absorption Edge, A.
red-----	CdS	0.46	Sb	0.47	Indium (In)---	0.44
green-----	ZnSiO ₄	1.28	Ge	1.25	Gallium (Ga)---	1.19
blue-----	CaWO ₃	0.178	Au	0.18	Osmium (Os)---	0.167

metal strips 25 of antimony so that their X-rays will excite the red phosphor (CdS), to make the metal strips 27 of germanium to excite the green phosphor (ZnSiO₄), and to make the strips 29 of gold to excite the blue phosphor (CaWO₃).

Once the material of the strips 25, 27, 29 is decided upon, however, the problem of adequate radiation in the desired portion of the X-ray spectrum is not entirely solved. A metallic element will not produce X-rays of a given frequency, even if its K radiation predominates in that frequency, unless it is bombarded by electrons of the proper velocity. The book "Structure of Metals" referred to above discusses this problem on pp. 46 ff. and proposes the formula

$$\lambda_{\min.} = \frac{12,430}{V} \text{ A.}$$

for determining the shortest wave length of X-rays which will be emitted when a metal target is bombarded by electrons of a given velocity.

Since in this case the wavelength of X-rays desired is known, the necessary voltage can be determined by converting the above formula into:

$$V \text{ (voltage)} = \frac{12,430}{\lambda}$$

In this manner the following values for V are found:

Phosphor	Absorption Edge, A.	Voltage Required, kv.
CdS (red)-----	0.46	approx. 27
ZnSiO ₄ (green)-----	1.28	approx. 10
CaWO ₃ (blue)-----	0.178	approx. 70

Fig. 2 shows a plan view in schematic fashion of a method whereby the proper voltages are applied to the various metal strips 25, 27, 29 to insure that the electron beam 17 strikes them with the proper velocity. As shown, the strips 25, 27, 29 are superimposed on the filter strips R, B, G which lay directly on the phosphor and run across the entire face plate 21 of the tube. They could, however, be limited to the rectangular area in the center where the picture is customarily presented. The metal strips 25, 27, 29 may be spaced apart as shown, or they

In order to make the phosphor response more monochromatic the target arrangement shown in Fig. 4 may be used. Here, in addition to a filter R, G or B as explained above, there is inserted between the X-ray productive metal strip 25, 27, 29 and the phosphor screen 23 a second filter R', G', or B'. The second filter element is selected from the same tables and has an absorption edge above the $K\alpha$ emission line of the metal strip 25, 27, 29 with which it is associated. The result is what is known in the X-ray art as a "Ross Filter" the operation of which is explained in the book "Structure of Metals" cited above, at page 57 ff., in the Proceedings of the National Academy of Science, vol. 14 (1928) at page 20 ff., and in the Review of Scientific Instruments, vol. 10 (1939) at page 186 ff. The effect is to produce a strong monochromatic X-ray beam of a frequency between the absorption edges of the two filters.

Another feature of the target shown in Fig. 4 is a single sheet of metal 31 in the place of the individual strips 25, 27, 29. This metal sheet 31 is selected from one of the higher atomic numbers so that it will produce radiation across the desired portion of the X-ray spectrum. Tungsten is suggested but other metals with similar characteristics may be used. Consultation of the chart on page 45 of "Structure of Metals" (cited above), and reproduced as Fig. 5 of the drawings, shows that electrons bombarding a tungsten target above 70 kv. will produce X-rays across the frequency spectrum necessary to excite the phosphors used in the proposed color kinescope. It should be noted that the solid line curves are the exact reproduction of the graph presented in "Structure of Metals" and the values are taken from experiments performed by Ulrey. The dotted line covering the 70 kv. situation, however, is an extrapolation added to the original graph to suit the needs of the proposed kinescope. The leading edge of the extrapolated curve was located by the formula

$$\lambda_{\min.} = \frac{12,430}{V} \text{ A.}$$

which has been referred to above.

Another form of target is shown in Fig. 3. Here, the metal strips 25, 27, 29 act as their own filters. The electrons hit the back of the target and the resulting X-rays must travel through the target material before they strike

5

the phosphor layer 23. Since the $K\alpha$ emission is always of a higher frequency than the absorption edge of the target material, the thickness of the targets 25, 27, 29 may be so controlled that they themselves act as filters. The target materials are chosen as above so that their X-ray radiation is predominately in the region of the absorption edge of the phosphor.

The tube 11 as shown in Fig. 1 has only eleven target elements 25, 27, 29 running across its face. Actually, there should be many times this number. The invention is being demonstrated as used in a line sequential television system and there should be at least as many target elements with their associated filters R, G and B as there are raster lines in the particular system employed. Since the color lines are fixed by the filter elements R, G and B and each visual line may be made up of sub-elemental red, green and blue lines, a line sequential system might use as many as 1575 different target elements 25, 27, 29 with associated filters R, G and B to give each one of the 525 visual elemental lines its full color complement. A lesser number may be used with a consequent loss in image definition.

As shown in Fig. 1 the cathode ray beam 17 is caused to scan each of the target elements 25, 27, 29 successively through the action of the deflection coils 33. In order to assure perfect registry of the beam 17 with the target strips 25, 27, 29 any of the beam-to-line registry devices known to the color television art may be employed. An example is the control grille claimed in copending U. S. application of H. B. Law, Ser. No. 181,342, filed August 25, 1950; now U. S. Patent 2,602,145.

It should also be borne in mind that, although the invention has been described with reference to a line sequential system, it can be operated in a field sequential manner by scanning all of the lines productive of the same color in a single sequence. Or, it may be employed in an element sequential system if the targets and filters are laid down in dots instead of in lines. In any of these applications it will provide a color kinescope target assembly wherein all of the phosphor material is laid down in a single coating without any necessity for division into discrete sub-visual areas; and, furthermore, one in which the additional target structure may be superimposed directly on the phosphor material without any problem of mechanical alignment of phosphor elements with a shadow mask.

What is claimed is:

1. A luminescent screen electrode for a color kinescope comprising a light emissive layer constituted of a mixture of phosphor materials each capable of emitting light of a characteristic color when bombarded by X-rays of a particular frequency; said mixture of phosphor materials comprising CaWO_3 , CdS, and manganese activated ZnSiO_4 .

2. A cathode-ray device comprising an evacuated envelope containing an electron beam source and a target assembly, said target assembly comprising a layer of metal which will produce X-rays of a given frequency when bombarded by an electron beam, and a layer of phosphor material which luminesces when bombarded by X-rays of said given frequency.

3. The invention according to claim 2 and wherein said metallic elements productive of said different characteristic frequencies are of different physical dimension with reference to the path of said X-rays toward said phosphor layer.

4. A multi-color kinescope comprising an evacuated envelope having an electron beam source in one part thereof and a target electrode in another part thereof, said target electrode comprising a mixture of different phosphor materials, each of said different phosphor materials being predominately sensitive to X-rays of a characteristic wave length and emissive of a characteristically colored light when bombarded by X-rays of that wave length, means interposed between said electron beam

6

source and said target electrode for converting electrons from said source into X-rays of said critical wave lengths.

5. In a color kinescope the combination of means for producing X-rays of different wave lengths with a target electrode comprising a mixture of phosphor materials, different ones of the phosphor materials of said mixture being predominately sensitive to only X-rays of a given one of said different wave lengths.

6. The invention according to claim 5 and wherein said layer of metal is productive of a given band of X-ray frequencies, said phosphor layer comprises a mixture of different phosphors sensitive to different frequencies within said given band, and said first and second layers of X-ray filter elements comprise discrete filters within each layer, different ones of said discrete filters of said first layer having their K absorption edge lower than the K absorption edges of given ones of said different phosphors, and different ones of said discrete filters of said second layer being in physical register with said different filter elements of said first layer in paired fashion and having an atomic number lower than the phosphor having a higher K absorption edge than the filter of said first layer with which the filter of said second layer is paired.

7. A cathode ray device comprising an evacuated envelope containing: an electron gun; a metallic target in the path of electrons from said gun, said target being productive of X-rays when bombarded by electrons; a layer of X-ray filtering material which passes only given X-ray frequencies; and a layer of phosphor material sensitive X-rays of said passed frequencies.

8. A multi-color kinescope comprising an evacuated envelope containing an electron beam source and a target assembly located in the path of the electron beam from said source, said target assembly comprising: a layer of electrically separate metallic elements, different ones of said metallic elements being productive of X-rays of different characteristic frequencies when bombarded by electrons; and a layer of phosphor material, said layer comprising a mixture of different phosphors which are sensitive to different ones of said characteristic frequencies.

9. A target assembly for a cathode ray tube comprising a layer of metal capable of producing X-rays of a given frequency distribution when bombarded by electrons and a layer of phosphor material sensitive to X-rays of said frequency, interposed between said metal and phosphor layers a first layer of X-ray filter elements with a K absorption edge lower than said frequency, and a second layer of X-ray filter elements having an atomic number lower than said phosphor.

10. In a multi-color kinescope the combination of a metal target, means for bombarding said metal target with high velocity electrons to produce X-rays, an X-ray sensitive screen, including a mixture of phosphors having different atomic numbers, in the path of X-rays from said target, and a plurality of combinations of X-ray filter elements interposed between said target and said screen, each of said combinations comprising a filter element having an atomic number higher than, and a filter element having an atomic number lower than, the atomic number of one of the phosphors of said mixture.

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