# United States Patent [19]

**Kaplan**

[11] **3,900,757**

[45] **Aug. 19, 1975**


[54] **SHADOW MASK AND PHOSPHOR SCREEN FOR COLOR CATHODE RAY TUBE HAVING MAJOR AXES OF APERTURES AND ELEMENTS CANTED TO BEAM SCAN DIRECTION**


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[73] Assignee: **Zenith Radio Corporation,** Chicago, Ill.



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[21] Appl. No.: **371,901**

[52] **U.S. Cl.** ..... **313/402;** 313/408; 313/470

[51] **Int. Cl.**[2] ..... **H01J 29/07;** H01J 29/30; H01J 31/20

[58] **Field of Search** ..... 313/85 S, 403, 408, 470, 313/472



[56] **References Cited**

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*Primary Examiner*—Robert Segal

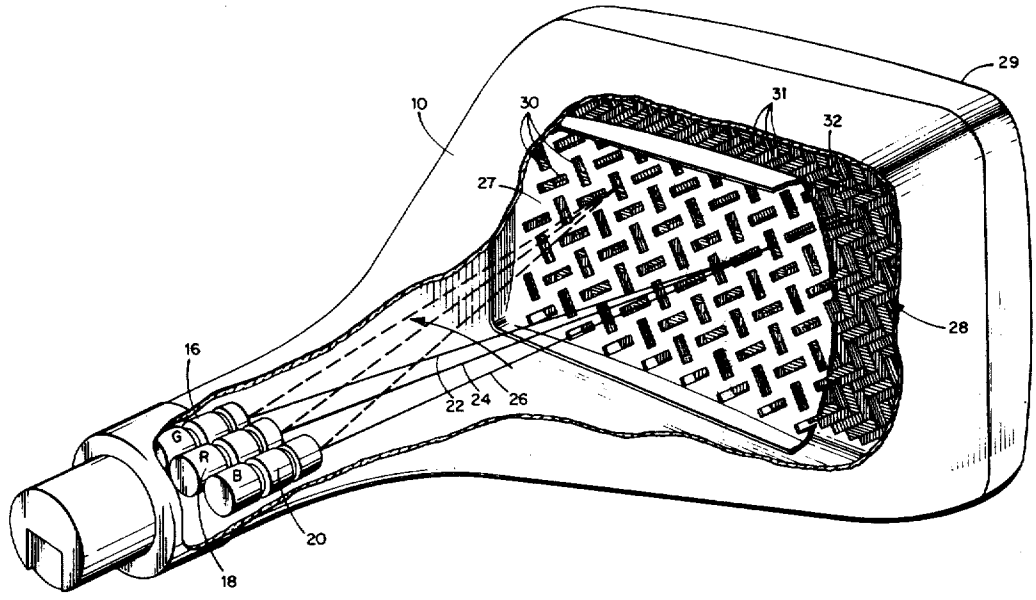
*Attorney, Agent, or Firm*—John H. Coult



[57] **ABSTRACT**

This disclosure depicts in a shadow mask-type color cathode ray tube a number of embodiments of a novel shadow mask and associated phosphor screen. In preferred embodiments depicted, the shadow mask has a plurality of rows of elongated apertures and the associated screen has a plurality of rows of corresponding elongated phosphor elements which are arranged such that the major axes of the apertures and elements in each row of apertures and elements are parallel and canted relative to the direction of electron beam scan. In certain embodiments, the apertures in any given row of apertures and the phosphor elements in any given row of elements have an angle of canting which is of opposite polarity to the angle of canting of their counterparts in adjoining rows. In other embodiments the angle of canting of the apertures and associated phosphor elements is the same for all rows. A number of embodiments are disclosed which have configurations of mask apertures and associated phosphor elements which renders them, in principle, free of moire pattern generation.


**25 Claims, 20 Drawing Figures**



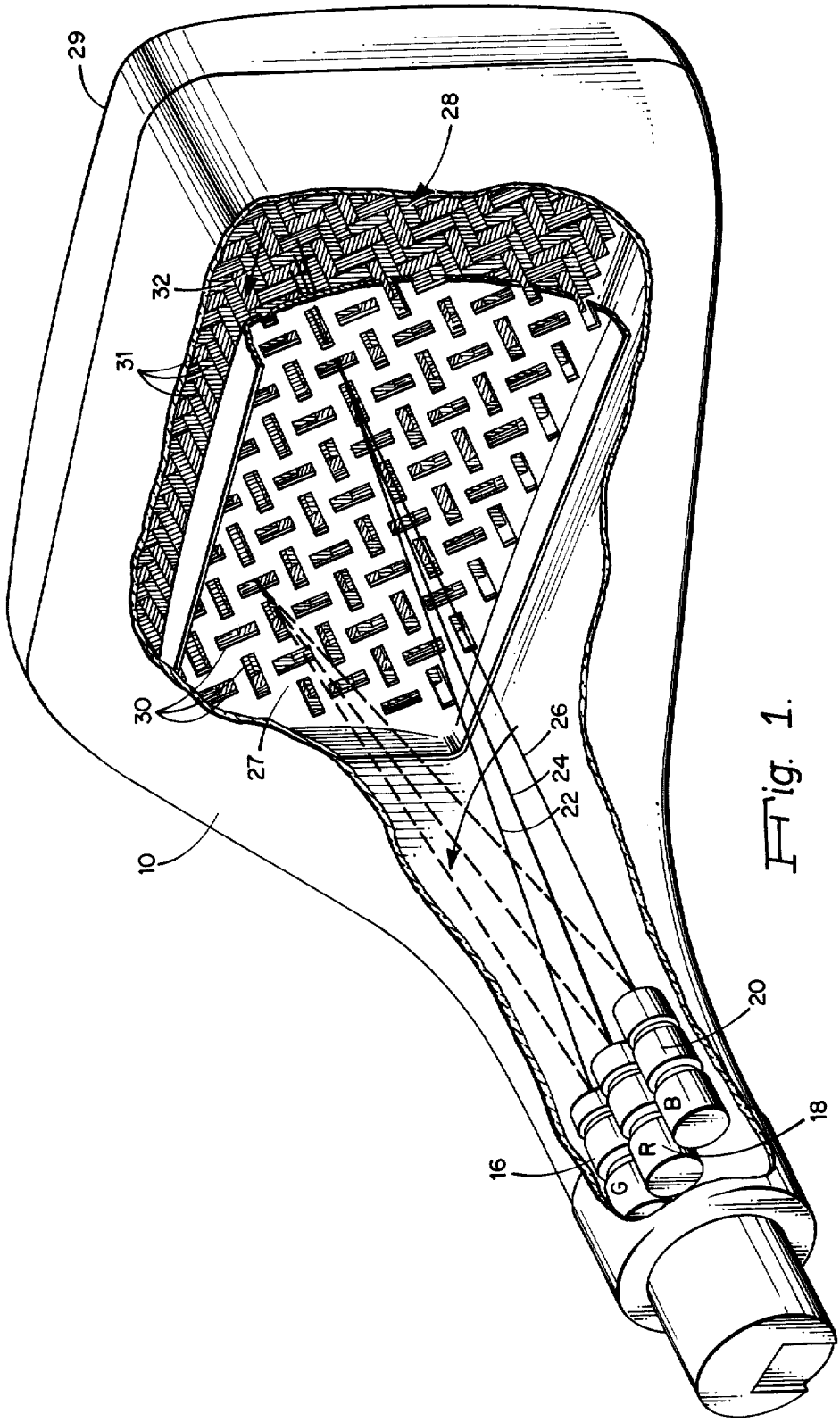



Fig. 1.

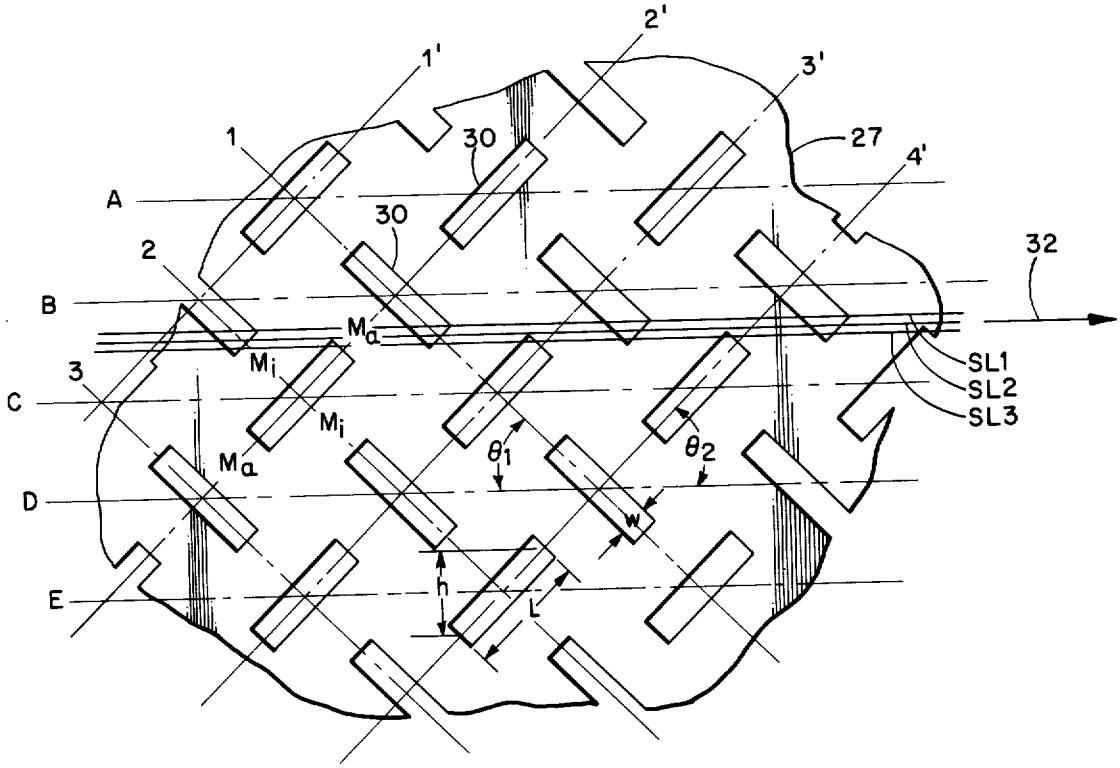

2'
1'
3'
1
30
27
4'
A
30
2
32
B
Ma
Mi
3
SL1
SL2
SL3
C
Mi
Ma
θ1
θ2
D
w
h
L
E

Fig. 2.

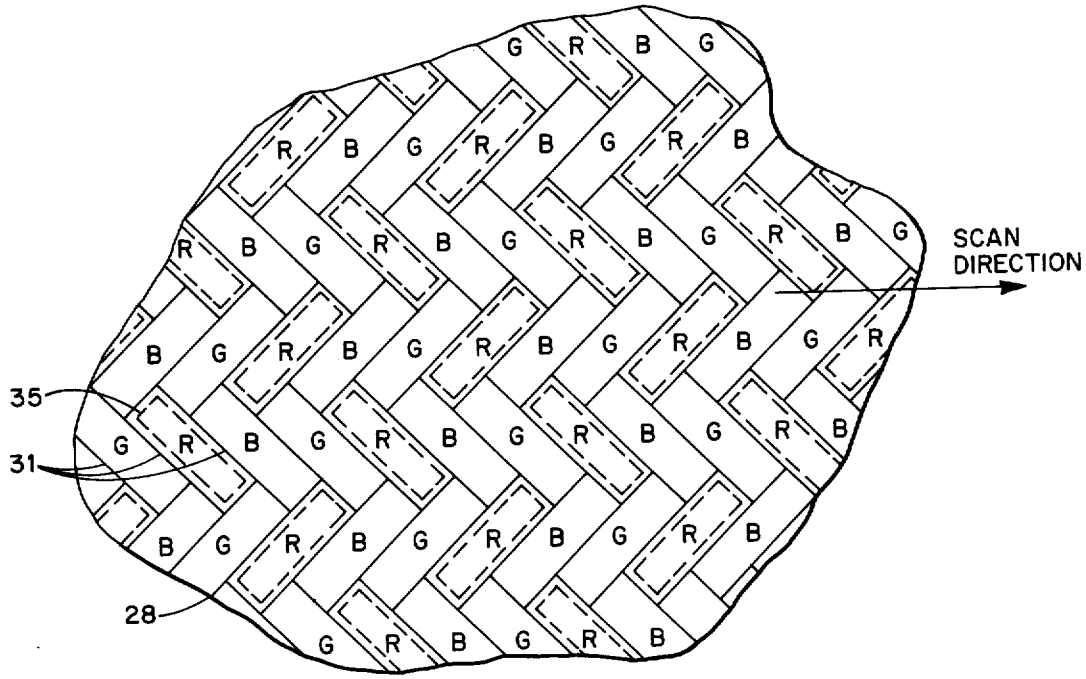

SCAN
DIRECTION
35
31
28

Fig. 3.

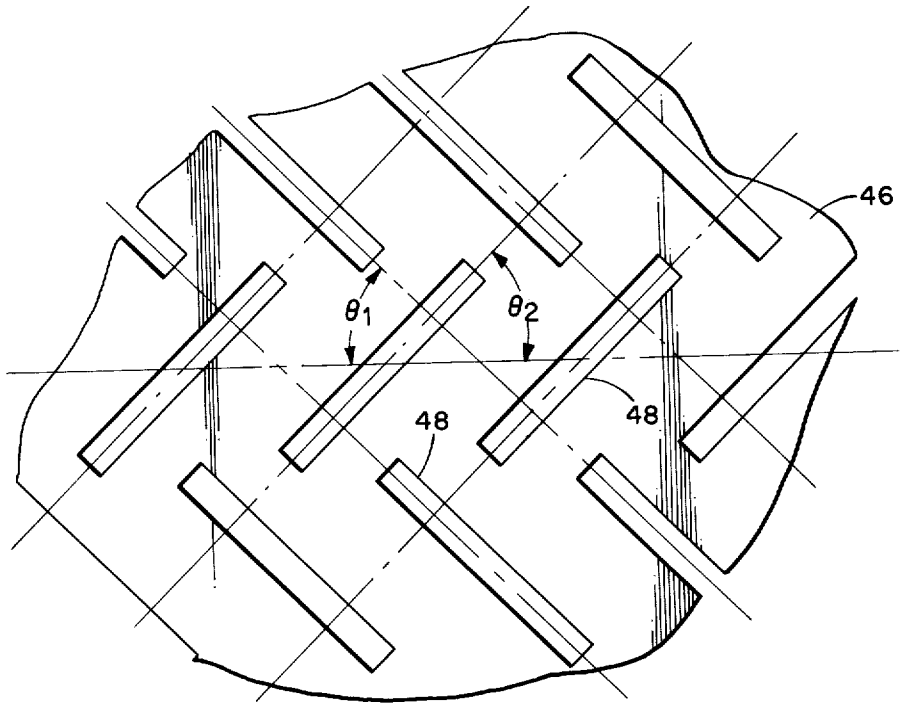

46
θ1
θ2
48
48

Fig. 4.

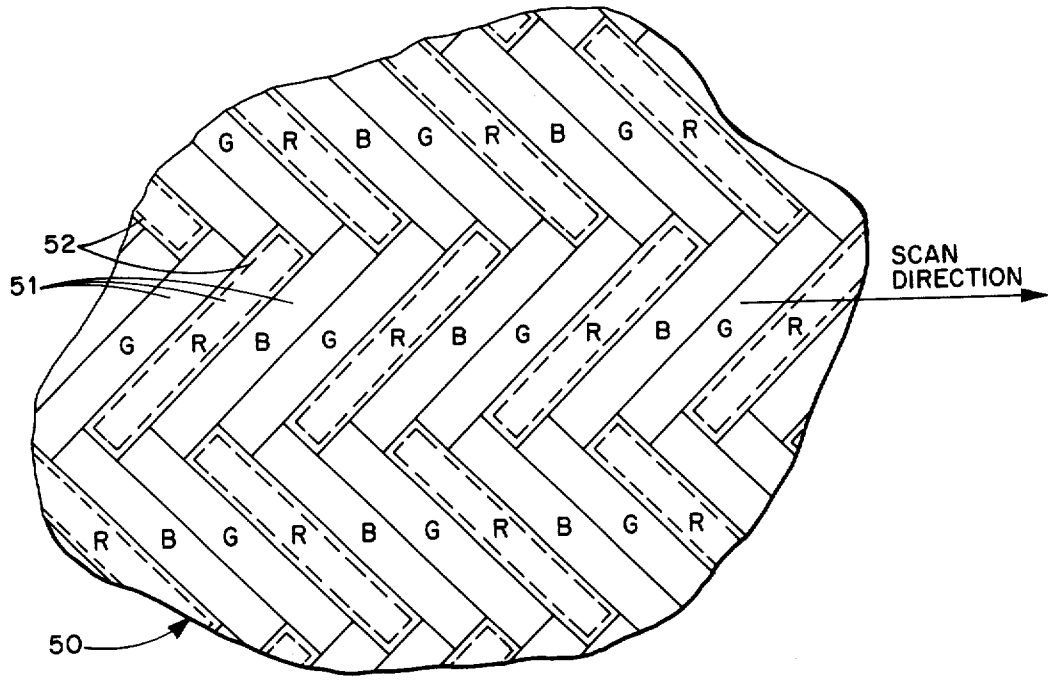

G R B G R B G R
52
51
SCAN DIRECTION
G R B G R B G R B G R
R B G R B G R B G R
50

Fig. 5.

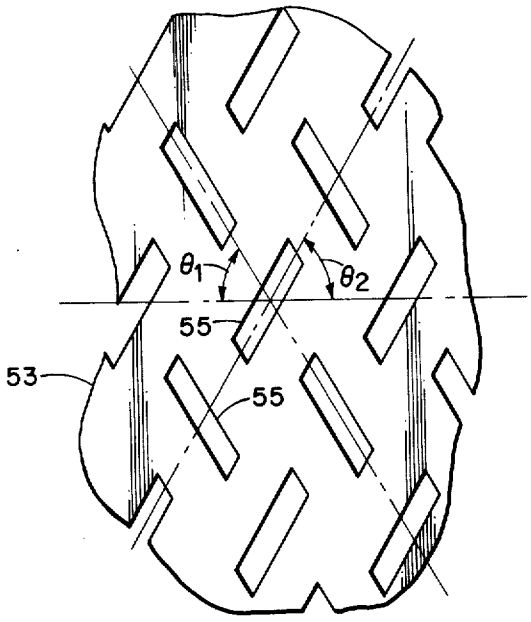



Fig. 6.

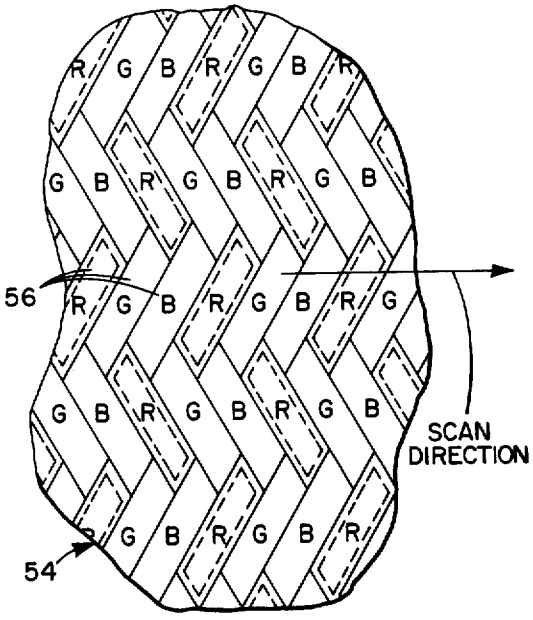



Fig. 7.

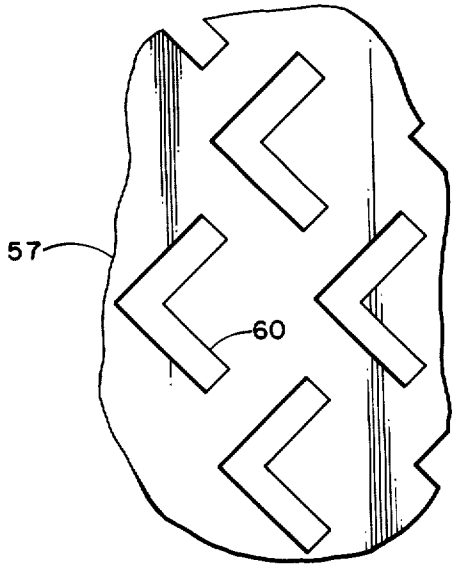



Fig. 8.

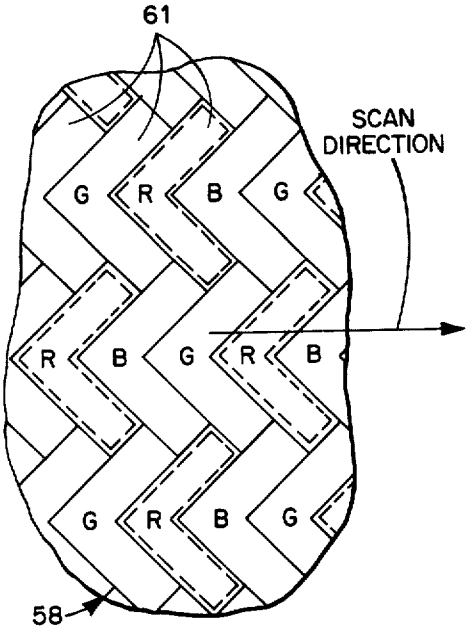



Fig. 9.

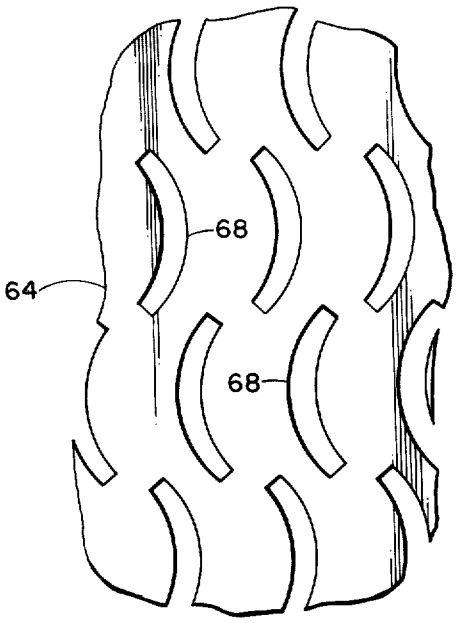



Fig. 10.

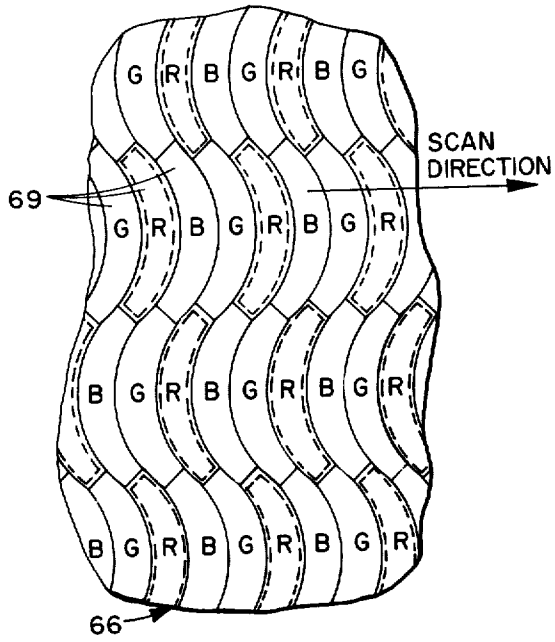



Fig. 11.

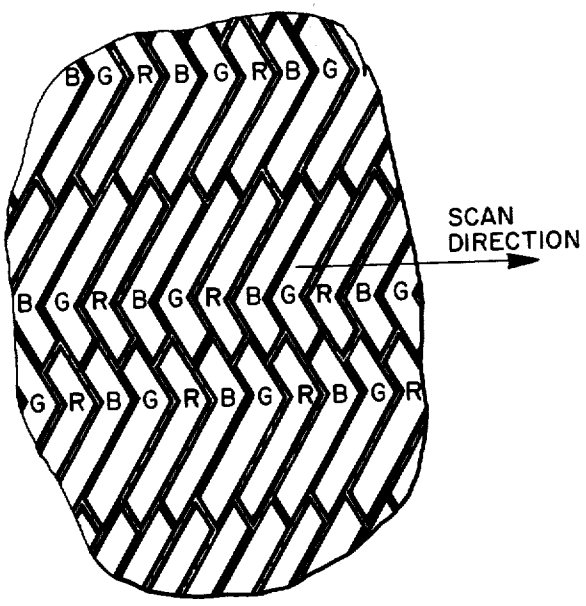



Fig. 14.

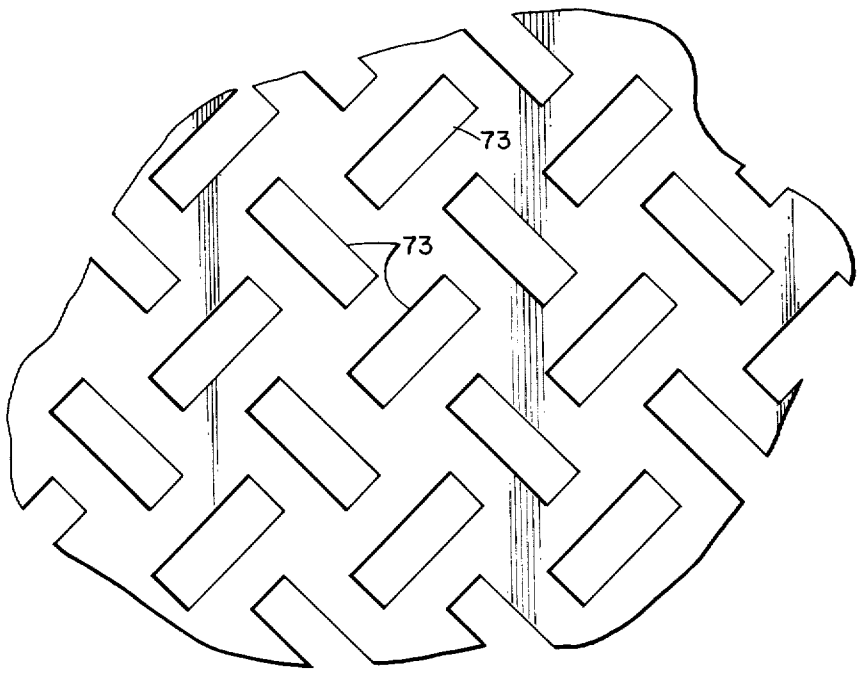



Fig. 12.

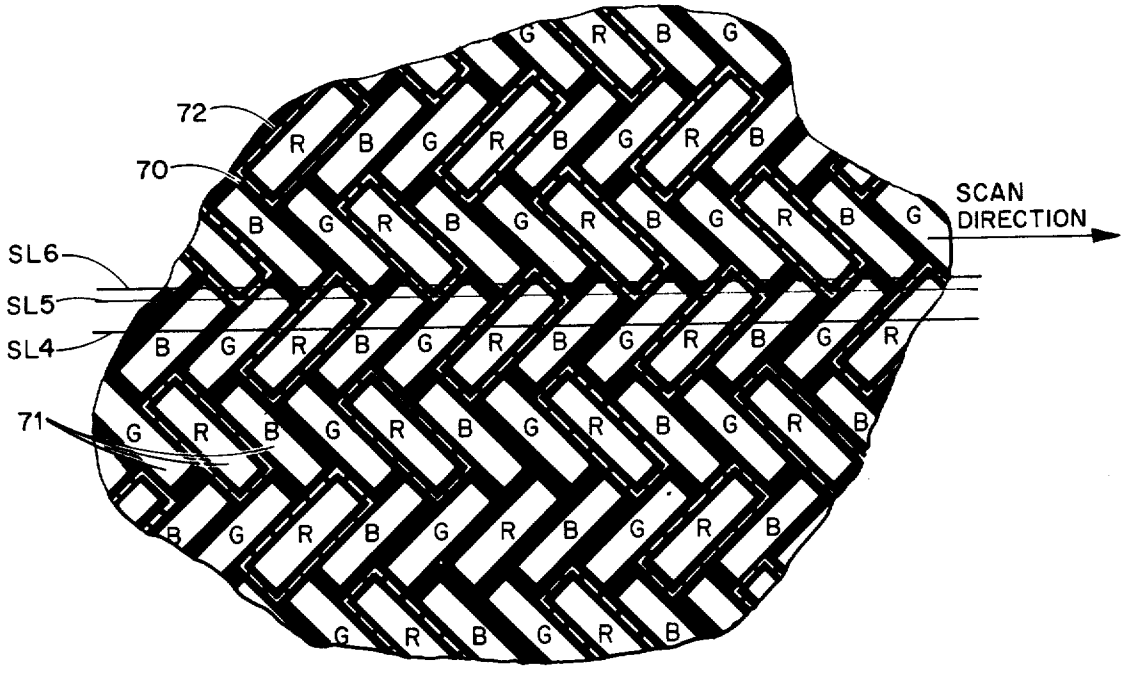



Fig. 13.

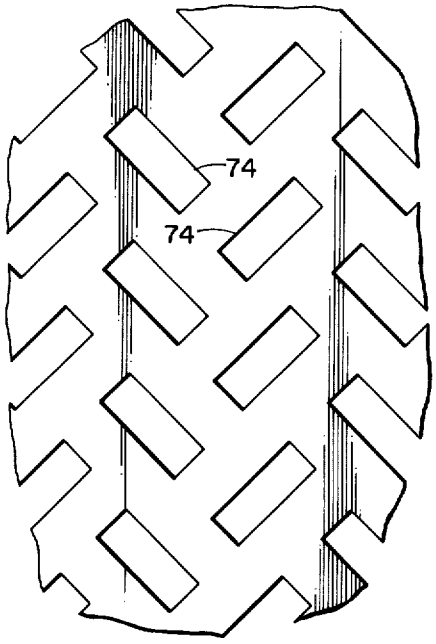



Fig. 15.

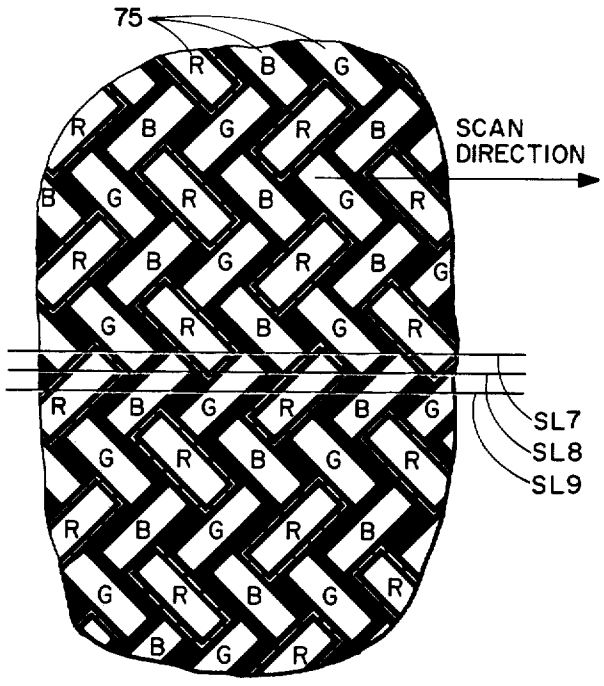



Fig. 16.




Fig. 17.

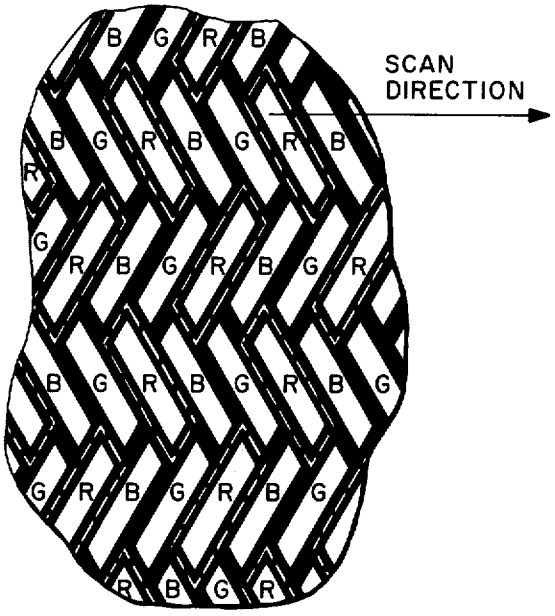



Fig. 18.

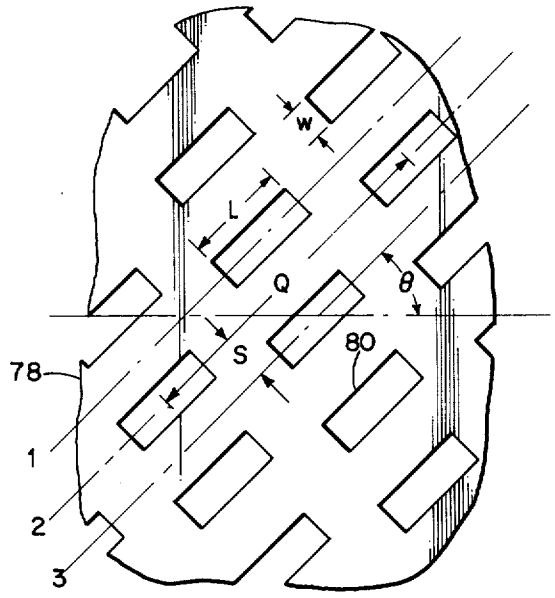

w
L
Q
θ
S
80
78
1
2
3

Fig. 19.

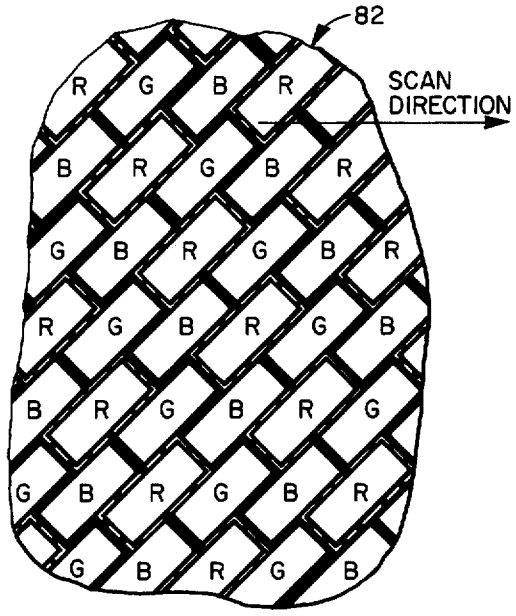

82
SCAN DIRECTION
R G B R
B R G B R
G B R G B R
R G B R G B
B R G B R G
G B R G B R
G B R G B

Fig. 20.

# SHADOW MASK AND PHOSPHOR SCREEN FOR COLOR CATHODE RAY TUBE HAVING MAJOR AXES OF APERTURES AND ELEMENTS CANTED TO BEAM SCAN DIRECTION

## BACKGROUND OF THE INVENTION

One of the most significant performance criterion of color television receivers is the brightness of the images displayed. One limitation on the brightness of the images displayed by color cathode ray tubes of the commercial type employing a "shadow mask" has been the relatively high absorption of electron beam current by the shadow mask. This condition is due primarily to the relatively low percentage of electron-transmissive areas in most commercial shadow masks.

Shadow masks of the type used with dot-triad tubes, hereinafter termed "dot masks", although offering relatively high structural strength and thus an ability to be formed and to withstand shocks and handling abuse during assembly, do not represent the ultimate in shadow mask construction. The packing density of the phosphor elements in dot-triad-type tubes is not optimum and results in wasted areas between the phosphor dots. Dot-triad-type television tubes of the negative guardband character (described in more detail below), represented by the CHROMACOLOR-brand tubes manufactured by the assignee of this invention, have greater electron beam transmission and image brightness than standard tubes as a result of the use of enlarged mask apertures and higher panel transmissions. However, the practicable maximum transmission factor achievable even with this tube is limited by the nature of the dot-triad geometry and by the weakening of the mask strength due to the reduced interstitial areas between the mask apertures.

The theoretical maximum transmission (with zero guard band) of conventional dot masks is roughly 30%. The maximum transmission of commercial dot masks of the type not employing negative guard bands is approximately 16–18%. Negative guardband dot masks as produced by the assignee of this invention have an effective electron beam transmission in the order of 23%.

Commercial cathode ray tubes have been developed in which the color selection electrode does not have apertures, but rather has an array of vertically oriented slits. This type of mask is hereinafter termed a "slit mask". This type of tube has a theoretical idealized (no guardband) transmission of 33⅓%, however, due to the fact that no structural support is offered in the vertical direction, such color selection electrodes are not capable of being formed into a spherical configuration, but rather must be supported in a cylindrical or planar contour. Since a cylindrical or planar configuration in a thin sheet or wire grid format is not self-supporting, such slit masks must be stretched taut in order to assure stability and precision in the location of the slits relative to the associated phosphor screen. As a consequence, a very rigid, heavy and costly frame must be provided for tensing a slit mask. Other problems, such as vibration of the slats or wires which are used to define the slits, are also present with this type of mask. Examples of slit masks of the type described may be found in U.S. Pat. Nos. 3,363,129; 3,573,528 and 3,638,063.

Yet another approach has been to compromise the intrinsically high electron transmission of slit masks in favor of increased structural strength by providing vertically spaced "tie bars" in the slits. The tie bars are provided in sufficient number and are of sufficient individual width to impart enough structural strength to the mask to allow it to be formed into a self-maintained spherical or other curved configuration. Shadow masks of this type are commonly termed "slot masks". Slot mask tubes are customarily used with strip-type phosphor screens. A slot mask has the advantage of being capable of being formed into a spherical configuration; however, the described tie bars are found to interfere with the electron beam raster pattern to form moire patterns which may seriously degrade the reproduced picture quality. Further, the marginal structural stength of slot masks and the practical difficulties encountered in attempting to adapt the slot mask and associated phosphor screen geometry for negative guardband operation has limited the utility thereof.

The theoretical limit for slot masks, due to the necessary presence of the described tie bars, is in the order of 27%, without consideration of the tolerance bands or guard bands which must be provided in the manufacture of commercial television tubes.

Attempts have been made to overcome the described problems of structural weakness and moire pattern generation in slot mask tubes by staggering the slots in alternate columns of slots, or by causing the direction of the tie bar lines to be selected according to predetermined guidelines. It has been found however, that these attempts to improve slot mask geometry have resulted in only marginal improvements in the performance of this type of color tube. Examples of slot-type aperture masks can be found in U.S. Pat. Nos. 2,863,079; 3,247,412; 3,186,884 and 3,633,058.

## OBJECTS OF THE INVENTION

It is a general object of this invention to provide for use in color cathode ray tubes of the shadow mask-type an improved shadow mask and associated phosphor screen. It is an object to provide an improved shadow mask which is neither a slot mask nor a dot mask, but which has the more significant positive attributes of each of these types of masks while having a minimum of the undesired attributes thereof.

More specifically, it is an object of this invention to provide an improved shadow mask which has in its idealized configuration an electron beam transmission equal to the 33⅓0% theoretical maximum transmission of slit masks, and yet which has a relatively high structural strength approaching that of dot masks.

It is still another object to provide for use in shadow mask-type color cathode ray tubes a shadow mask and associated phosphor screen in which moire pattern generation is eliminated.

It is still another object to provide an improved shadow mask and associated phosphor screen which produce excited phosphor areas which are elongated and yet which, because their arrangement in a novel pattern which has low visibility to the eye, may be made coarser and hence more efficient than the phosphor elements in slot-mask and slit-mask type tubes.

## BRIEF DESCRIPTION OF THE DRAWINGS

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description taken in

conjunction with the accopanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. **1** is a schematic perspective view of a partially assembled color cathode ray tube, broken away to illustrate a novel shadow mask and associated phosphor screen representing a preferred embodiment of this invention;

FIGS. **2** and **3** are enlarged elevational views which illustrate the aperture mask and associated phosphor screen shown in FIG. **1**;

FIGS. **4** and **5** illustrate schematically an aperture mask and associated phosphor screen representing an alternate embodiment of this invention;

FIGS. **6** and **7** illustrate another aperture mask and associated phosphor screen which might be constructed to implement the principles of this invention;

FIGS. **8–9** illustrate an aperture mask and associated phosphor screen representing still another embodiment of this invention;

FIGS. **10** and **11** depict a shadow mask and associated phosphor screen representing a variation of the FIGS. **8–9** embodiment;

FIGS. **12** and **13** are views of a shadow mask and phosphor screen which are similar to the mask and screen depicted in FIGS. **1** and **3**, but which are constructed in a negative guardband with guard bands of light-absorptive material around each of the phosphor elements;

FIG. **14** depicts a negative guardband phosphor screen representing yet other embodiments of this invention;

FIGS. **15** and **16** are views of a shadow mask and phosphor screen representing an embodiment of the invention intended to be free of moire pattern generation;

FIGS. **17** and **18** depict phosphor screens representing two other embodiments of the invention which are intended to eliminate moire pattern generation; and

FIGS. **19** and **20** are views of a shadow mask and phosphor screen representing still another embodiment of the invention in which all rows of mask apertures and associated phosphor elements are canted in a like direction.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

By this invention there is provided a novel shadow (aperture) mask and associated phosphor screen which may be implemented in color cathode ray tubes of the shadow mask type. As discussed briefly above, the shadow mask concept taught by this invention is neither a modified slot mask, which is essentially a slit mask to which tie bars have been added to increase its structural strength, nor a dot mask, but rather involves a new type of shadow mask combining the salient positive attributes of both the slot masks and dot masks.

FIGS. **1–3** illustrate a preferred implementation of the invention. In FIG. **1** there is illustrated in highly schematic form, and with certain non-pertinent components removed, a cathode ray tube including an envelope **10** within which is supported an electron gun assembly. The electron gun assembly is shown as including guns **16, 18** and **20** for generating electron beams **22, 24, 26** carrying green, red and blue video information, respectively. For reasons which will become evident as this description continues, the guns **16, 18, 20** are arranged substantially coplanarly, an arrangement which is commonly termed an "in-line" gun assembly. In the interest of simplifying the FIG. **1** illustration to clarify the principles of this invention, the means for deflecting, focusing and converging the electron beams are not shown but may be of conventional construction.

The FIG. **1** cathode ray tube is shown as including a novel shadow mask **27** and associated phosphor screen **28** constructed in accordance with the principles of this invention. The shadow mask **27** is shown in highly schematic form with exaggerated aperture size and spacing from the screen **28**. The phosphor screen **28** is deposited on a faceplate **29** comprising part of the tube envelope **10**.

In accordance with this invention the novel shadow mask **27** comprises a sheet of electrically conductive material such as steel having formed therein a plurality of horizontal rows of elongated electron-transmissive apertures **30**, labeled A, B, C, etc., in FIG. **2**. The apertures **30** are arranged such that the major axes $M_a$ of each aperture **30** in each row is canted at a predetermined angle relative to the direction of electron beam scan across the mask and screen, depicted by arrow **32**. The apertures **30** in any given row have an angle of canting which is of opposite sense to the angle of canting of adjoining rows. The angle of canting of the apertures **30** in rows A, C and E is designated $\theta_1$; the angle of canting of the apertures **30** in rows B and D is designated $\theta_2$. By way of example, in the illustrated preferred embodiment the angles of canting $\theta_1$, $\theta_2$ of the apertures **30** in adjoining rows is each preferably selected to be approximately 45° for reasons to be given at length below.

In the preferred embodiment illustrated in FIGS. **1–3**, the oppositely canted adjoining rows of apertures are staggered (horizontally offset), preferably by one half of the aperture period in the scan direction, as shown. By this arrangement, the mask **27** is such that the apertures in the aperture pattern are substantially equally spaced each from the others, measured along major axis $M_a$ and minor axis $M_i$ of the apertures. Viewed in another way, the mask apertures are arranged such that each aperture is spaced from neighboring apertures on all sides by a distance which is at least an aperture width. As a reesult of this novel mask aperture (and phosphor element) geometry, the structural strength of the mask is maximized. In an idealized form wherein aperture size tolerances are not considered, the aperture mask **27** has a transmission factor of substantially 33⅓%, the theoretical limit for a shadow mask.

The novel aperture mask **27** constructed to implement the principles of this invention has a unique geometry which is susceptible of description in many different ways. The mask has been described above in terms of rows of canted apertures in which adjoining rows are staggered and oppositely canted. It is evident that the mask **27** may also be described from a different viewpoint — not as rows of canted apertures but rather as interleaved arrays of apertures angled with respect to each other.

In more detail, the mask **27** may be described as comprising first and second arrays of apertures which are angled with respect to each other and oriented respectively at angles $\theta_1$ and $\theta_2$ with respect to the direction of electron beam scan across the mask. In FIG. **2**, one array of apertures comprises lines of apertures **1, 2, 3,**

etc.; the other array of apertures comprises lines 1', 2', 3', etc. In each line the apertures are spaced from each other and are aligned in the direction of the array. The two arrays can be described as being interleaved such that the apertures in one array are located in the interaperture spaces in the other array. In the illustrated preferred embodiment the first and second arrays are perpendicular to each other and are oriented at 45° with respect to the direction of electron beam scan across the mask. It can be seen that by this arrangement, the minimum strength dimension for one array of apertures coincides with the maximum strength dimension for the other array, thus causing the mask to have an overall high strength.

As shown clearly in FIG. 1, the phosphor screen 28 associated with the aperture mask 27 comprises mutually interleaved patterns of red, blue and green phosphor elements 31, each pattern corresponding generally to the pattern of apertures 30 in the mask 27. The patterns are offset in the direction of electron beam scan such that the red, blue and green phosphor elements 31 are exposed through the mask 27 nly to the red-associated, blue-associated and green-associated electron beams 24, 26 and 22, respectively. The well-known principles of parallax barrier color selection employed in the operation of cathode ray tubes of the shadow mask-type dictate the geometry of the patterns of phosphor elements and their relative positions in the screen. An exposition of these principles may be found in my article, "Theory of Parallax Barriers", Journal of the Society of Motion Picture and Television Engineering, Volume 59, pages 11–20 (July, 1952).

The phosphor screen 28 is shown enlarged in FIG. 3. The images of the pattern of apertures 30 in the aperture mask 27, as projected for example by the red-associated electron beam 22, are shown in broken lines at 35 within the confines of the red phosphor elements. The difference in size between each phosphor element and the area thereof which is excited by the associated electron beam (shown exaggerated) is termed a tolerance band or "guard band", more particularly a "positive" guard band. These positive guard bands (shown exaggerated and discussed in more detail below) between the images 35 and the phosphor element boundaries have been provided to accommodate the tolerances which must be provided in the manufacture and operation of commercial cathode ray tubes.

This invention encompasses embodiments in which the aspect ratios L/W of the apertures 30 and associated phosphor elements 31 (see FIG. 2) may have a fixed value within a range of ratio values. It is believed, however, that the preferred aspect ratio of the apertures and phosphor elements for a 25 inch diagonal V tube as shown in FIGS. 1–3 is in the range of about 2:1 to 6:1, preferably approximately 3:1. In order that an understanding may be reached of the principles involved in selecting an optimum aspect ratio for the mask apertures and phosphor elements for a particular application or embodiment, the reasoning by which a 3:1 optimum aspect ratio was selected will be given.

Assume that the screen height of a 25 inch V tube is 15.6 inches, and that the number of active scanning lines is 475. The scan line spacing for this tube is thus 0.033 inch. It has been shown in the prior art that moire pattern effects are minimized if the ratio of the scan line spacing to the pitch of the shadow mask is either appproximately 1.1 or approximately 0.80–0.83. If the effective vertical pitch of the mask apertures is selected in accordance with the first condition of minimized moire effects (a ratio of 1.1), then the effective vertical pitch of the apertures 30 in the mask 27 is equal to 0.030 inch. Thus the aperture height $h$, which is equal to the effective vertical pitch or period of the apertures, is also 0.030 inch. Assuming a preferred aperture geometry wherein $\theta_1=\theta_2=45°$, then $L=\sqrt{2}\,h=0.042$ inch.

The aperture width W is preferably selected approximately midway between the values of 0.017 inch, which is the phosphor dot diameter of a typical convention positive guardband 25 inch V tube, and 0.012 inch, which is the width of the phosphor strips of a proposed slot mask tube of approximately equivalent resolution. Choosing a value of W of 0.014 results in an aperture aspect ratio of approximately 3:1 (0.042 divided by 0.014).

Referring particularly to FIG. 3, the projected aperture images 35 reveal in exaggerated scale a positive guard band (one in which the phosphor element is larger than the beam spot, as discussed in detail below as would be necessary in the manufacture and operation of real-world television tubes of the standard type. In practice, for a 25 inch V tube, a center guardband tolerance of ±1 mil is typically provided. The mask apertures 30 in the illustrated preferred embodiment would thus have projected dimensions of approximately 0.012 × 0.040 inch. The projected aperture images 35 would be somewhat larger due to expension of the electron beam between the mask and screen.

In the illustrated preferred embodiment, the angles $\theta_1$ and $\theta_2$, the angles which the major axis of the apertures make with respect to the direction of electron beam scan across the mask, are described as each being approximately 45°. This optimized angle $\theta_1$ , $\theta_2$ is arrived at as follows. It can be seen that if the angles $\theta_1$ and $\theta_2$ are varied together in one direction (and the associated phosphor pattern varied correspondingly, of course), at one extreme, the lines 1, 2, etc., approach alignment with direction of the electron beam scan (see arrow 32), resulting in a condition wherein the parallax condition (which must be met for mutually exclusive color selection by the electron beams) is lost. If $\theta_1$ and $\theta_2$ are varied together in the opposite sense away from the 45° optimized value, then the lines of apertures 1', 2', etc., again approach alignment with the direction of electron beam scan 32. Thus it is clear that the optimum values of $\theta_1$ and $\theta_2$ for maximized satisfaction of the parallax color selection condition is 45°. Also, it is believed that the condition of minimized moire pattern generation also exists at values $\theta_1$ and $\theta_2$ equal to 45°.

As will become clear as this description continues, the values of $\theta_1$ and $\theta_2$ may be selected to be different from each other for certain applications. The overall geometry of the aperture pattern would thus have an asymmetry. Further, it is within the compass of this invention that $\theta_1$ and $\theta_2$ may be equal but have some value other than 45°. In such an arrangement the lines of apertures 1, 2, etc., and 1', 2', etc., would not intersect perpendicularly.

The transmission efficiency of the described preferred shadow mask can be seen to be roughly 80% of the idealized theoretical maximum of 33⅓% or about 27% absolute — a value which is substantially above that of the brightest dot mask or slot mask tubes being manufactured at this time. It is thus seen that by this invention there is provided an improved shadow mask

and associated phosphor screen for a color cathode ray tube which offers not only a high degree of structural strength but a relatively high transmission factor as well.

As will become very evident as this description proceeds, numerous other geometries, arrangements, orientations, configurations, aspect ratios, pitches and scales of the mask apertures and associated phosphor elements are encompassed by this invention. For example, as will become evident as this description proceeds, an aspect ratio of 3:1 may not be optimum for all applications. Other aspect ratios may be selected in order to achieve a predetermined condition of minimized moire effects, maximized transmission, or to optimize or maximize some other desired condition or consideration.

The shape of the apertures shown in the FIGS. 1–3 embodiment is rectangular, however it should be understood that in practice, due to the imperfect nature of manufacturing processes, the geometries of the apertures may have rounded corners or may otherwise vary from an ideal configuration of exact rectangularity. Further, as will be pointed out in more detail below, for some applications it may be desirable to intentionally cause the shape of the apertures to have a rhomboid configuration, or other configuration which is easier to fabricate, which results in reduced moire effects or which yields some other desired characteristic such as maximized mask transmission or structural strength.

FIGS. 4 and 5 illustrate an alternative embodiment of the invention wherein the aspect ratio of the apertures and associated phosphor elements is greater than the aspect ratio of the apertures and associated phosphor elements in the FIGS. 1–3 embodiment. FIG. 4 depicts a mask **46** having apertures **48** formed therein; FIG. 5 illustrates a phosphor screen **50** comprising interleaved patterns of red, blue and green phosphor elements **51**. The images of the apertures **48** in the mask **46**, as projected by the red-associated electron beam, are shown at **52**. In the FIGS. 4–5 embodiment the aspect ratio of the apertures **48** and associated phosphor elements **51** is approximately 6:1; the shape of the apertures **48** and phosphor elements **51** is again shown as being generally rectangular; angles $\theta_1$ and $\theta_2$ are depicted as being each equal to 45°.

The aperture-screen geometry shown in the FIGS. 4–5 embodiment has the advantage, relative to the FIGS. 1–3 embodiment, of producing greater overall electron transmission through the mask, and thus greater tube image brightness. However, it can be seen that as the aspect ratio of the apertures is increased, the structural strength of the mask **46** decreases. Thus for applications wherein it is desired to maximize the electron beam transmission factor of a mask, a greater aspect ratio would be selected than in applications wherein maximized mask strength is desired.

FIGS. 6 and 7 depict yet another mask **53** and associated phosphor screen **54** which may be constructed in accordance with this invention. In the FIGS. 6–7 embodiment the angles of canting $\theta_1$ and $\theta_2$ of the apertures **55** in the mask and phosphor elements are equal; however, $\theta_1$ and $\theta_2$ have the value which is less than 45°, for example 60°. As a result, in this embodiment the mask apertures **55** and associated phosphor elements **56** are rhomboid-shaped, rather than being of rectangular shape as in the above-described embodiments.

FIGS. 8–9 illustrate a mask **57** and associated phosphor screen **58**, representing yet another embodiment of this invention in which the mask apertures and associated phosphor elements are reverse bent relative to the direction of electron beam scan. In the FIGS. 8–9 embodiment the phosphor elements in each row of elements and the apertures in the associated shadow mask **57** are joined with their oppositely canted counterparts in one adjoining row such as to form a plurality of row pairs of composite, V-shaped mask apertures **60** and phosphor elements **61**. The FIGS. 8–9 embodiment offers the advantage, relative to the above-discussed embodiments, of increased transmission, since the guard bands which would be provided at the joined ends of the combined mask apertures according to the above teachings, are eliminated. As may be expected, however, the elimination of the interstitial areas between the joined mask apertures results in a mask having reduced structural strength, as compared, for example, with the FIGS. 1–3 mask **27**.

As will become evident as this description proceeds, the FIGS. 8–9 embodiment may be varied, inter alia, by altering the relative lengths of the legs of the apertures and phosphor elements, by changing the aspect ratio of or the angle subtended by the legs, by modifying the configuration of and/or relative orientation (from one row pair to the next) of the composite apertures and elements, or by varying the angular orientation of the apertures and elements.

For example, whereas in the FIGS. 8–9 embodiment the mask apertures **60** and associated phosphor elements **61** are shown as having a V-shape and a like orientation from one row pair to the next. FIGS. 10-11 illustrate a mask **64** and associated phosphor screen **66** which are similar to the FIGS. 8–9 mask and screen, but modified such that the composite mask apertures **68** and phosphor elements **69** are reverse bent relative to the direction of electron beam scan, but in a U-shape, rather than a V-shape, and have an alternately opposite orientation from one row pair to the next. The apertures and elements may, alternatively, have the same, rather than alternately opposite, orientation from one rwo (row pair) to the next. The U-shaped configuration may offer greater ease of fabrication than the V-shaped configuration of FIGS. 8–9 embodiment. Many other reverse bent configurations or doubly reverse bent (such as an S-shape) are encompassed by this invention.

The principles of this invention are fully applicable to shadow mask color tubes of the types having a matrix or "black surround" of light-absorptive material between the phosphor elements. The various types of black surround tubes include the positive guardband type in which phosphor elements are larger than the beam spots falling thereon, negative guardband type in which the beam spots are larger than the phosphor elements, and hybrid types having both positive and negative guardband components, as described in detail in a copending application of L. Dietch, Ser. No. 186,885, filed Oct. 6, 1971, assigned to the assignee of this invention.

FIGS. 12–13 show a mask and phosphor screen similar to the FIGS. 1–3 mask and screen, but of a negative guardband construction, rather than positive guardband construction. A black surround or guard band **70** is provided around each of the phosphor elements **71**. The guard bands **70** are preferably of the character de-

scribed and claimed in U.S. Pat. No. 3,146,368 - Fiore et al., assigned to the assignee of this invention, as shown.

Negative guardband color cathode ray tubes such as the CHROMACOLOR-brand color tubes manufactured by the assignee of this invention provide enhanced brightness and contrast. As explained in detail in the Fiore et al patent, in negative guardband tubes, the relative sizes of the electron beam spot and the impinged phoshor element are reversed. In FIG. **12**, for example, the images of the mask aperture, as projected by the red-associated electron beam, are shown in broken lines at **72**. Compare the FIG. **12** screen with the FIGS. **1–3** maskscreen which is of the positive guardband type. In FIG. **12**, the projected aperture images **35**, rather than the phosphor elements **31** are in abutting relationship. The projected aperture images **35** are smaller than the phosphor elements **31** by the assigned tolerance band (guard band).

It is noteworthy that in slot mask tubes, it is difficult, if not impossible from a practical operational standpoint, to provide black surround material in the interstitial areas between the phosphor elements which correspond to the tie bar locations. The result is that in these interstitial areas, ambient light is reflected to the viewer, thus reducing the contrast of the displayed images, typically by as much as 10%.

FIG. **14** depicts a phosphor screen representing still another embodiment of the invention in a negative guardband-type tube. The FIG. **14** screen represents a variation on the FIGS. **8–9** embodiment in a number of respects — the aspect ratio of the legs of the phosphor elements and associated mask apertures (not shown) is 4:1 and 2:1, rather than being 3:1 in both legs. The legs of the phosphor element and associated mask apertures are oriented at 30° to the vertical, rather than at 45° as in FIGS. **8–9**. Thus the FIG. **14** embodiment illustrates that, as in each of the above-described embodiments, the aspect ratios, angles of orientation, guardband mode, and symmetry may be varied in accordance with the principles of this invention to achieve a desired performance, economy or other characteristic or property of the end product color tube.

It is an important object of this invention to provide for use in shadow mask-type color cathode ray tubes, novel aperture mask and associated phosphor screen structures which, in principle, do not result in moire pattern generation. In a shadow mask color tube moire patterns caused by interference between the electron beam raster and the aperture mask or screen may be eliminated by providing a mask-screen structure having the property that the excited phosphor area and thus the cumulative luminous output of the screen (for constant electron beam intensity) is substantially constant for electron beam scansions across the screen at any vertical position and for any horizontal element or slice of the electron beam scansion.

In each of the described embodiments of this invention the above-stated condition for moire free operation are achieved if considered in an idealized state wherein zero tolerance (guard) bands are provided. However, let us now consider the effect of introducing guard bands to provide the necessary real-world latitudes in tube manufacture and operation.

As discussed at some length above, two types of guardband modes are provided in shadow mask color tubes: 1) the positive guardband mode in which the beam spots are caused (by selection of appropriate mask aperture size) to be smaller by the allotted tolerance value or guard than the associated phosphor elements, and 2) the negative guardband mode in which the beam spots are caused to be larger by the allotted tolerance value than the associated phosphor elements.

The positive guardband mode is exemplified, for example, by the FIGS. **1–3** embodiment. In the FIGS. **1–3** embodiment, the apertures **30** are caused to be smaller than the phosphor elements **31** by the allotted tolerance value, typically 1–2 mils. As described above, the portion of the phosphor elements which are illuminated by the electron beam passing through the apertures **30** in the mask **27** is represented by the broken line projected images **35**, shown for the red-associated electron beam only. The beam spot positions are shown at their nominal locations in the centers of the red phosphor elements.

It can be seen in FIG. **2** that with the apertures **30** reduced in size, as shown, to provide the necessary guard bands, elemental scan line $SL_1$ (representing a portion or slice of a full electron beam scan line) has a greater cumulative transmission through the mask **27**, and thus excites a greater phosphor area, than the elemental scan line $SL_2$. Elemental scan line $SL_2$ in turn has a greater cumulative transmission than the elemental scan line $SL_3$ which intersects the extreme tips of the aperturs **30** and has an extremely low value of transmission through the mask. Restated, in the FIG. **2** embodiment, as a result of the provision of guard bands, the cumulative beam transmission through the mask **27** depends to a certain extent upon the vertical position of the beam on the mask. It can be seen clearly from FIG. **2** that the difference in the cumulative transmission of the elemental scan lines and thus of overall electron beam transmission for beam scansions at different vertical positions on the mask is due to the way in which the tips of the apertures **30** interleave at the aperture row boundaries.

To consider the question of moire pattern generation in a negative guardband color tube, reference may be had to FIGS. **12–13**. In the FIGS. **12–13** embodiment the cumulative electron beam transmission through the mask is substantially constant for electron beam scansions across the mask in any vertical position and for any element of the electron beam, however, due to the provision of the light-absorptive guard bands **70** surrounding the phosphor elements **71**, the excited phosphor area and thus the luminous output of the FIG. **13** screen, will vary depending upon the vertical position which the electron beam spot assumes as it scans across the screen. To elaborate, it can be seen in FIG. **13** that an elemental electron beam scan along line $SL_4$ will result in a greater cumulative luminous output from the screen than a scan along elemental scan line $SL_5$. A scan along elemental scan line $SL_6$ which traverses the interleaved extreme tips of the phosphor elements, produces an even lower luminous output from the screen.

Thus, in summary, in the positive guardband mode, the reduction in mask aperture size necessary to provide guard band results in variations in the electron beam transmission through the mask for different vertical positions of the electron beam. In the negative guardband mode, the luminous output of the screen is sensitive to the vertical beam position due to the way in which the phosphor element tips interleave from row to row when of reduced size.

In other embodiments of this invention, described below, there are provided aperture mask and associated phosphor screen structures which overcome the described variation in luminous output from the screen as a function of beam vertical position. In each of the moire-free mask-screen embodiments to be described, the cumulative excited phosphor area, and thus the cumulative luminous output of the screen (assuming a constant beam current) is the same for any vertical position of the beam. This is due to the full interleaving of the excited phospor tip areas.

FIGS. **15–16** illustrate a negative guardband mask-screen embodiment which meets the above-stated condition for moire pattern elimination. The FIGS. **15–16** embodiment represents a modification of the FIGS. **1–3** embodiment and geometry in which the tips of the phosphor elements in each row have been fully interleaved with the tips of the phosphor elements in adjoining rows of elements such as to meet the above-described condition for freedom from moire pattern generation. It can be seen from FIG. **16** that the luminous output from the screen for elemental scan lines $SL_7$, $SL_8$ and $SL_9$ or any other selected elemental scan line will be equal, thus satisfying the above-stated condition for a moire-free tube structure.

FIGS. **17** and **18** depict phosphor screens representing yet other embodiments of the invention, shown as being executed in the negative guardband mode, which also offer the potential of essentially moire-free operation. Both have rhomboid-shaped phosphor elements; the FIG. **18** version has the advantageous property, relative to the FIG. **17** version, of having all sides of phosphor elements and associated mask apertures (not shown) parallel with respect to adjacent elements. Both embodiments meet the condition for moire elimination — namely that for any element of the electron beam scansion for the cumulative excited phosphor area and thus luminous output of the screens is independent of the beam vertical position as it scans across the screen. The moire free mode may also be applied to positive guardband tube patterns.

The FIGS. **15–16** embodiment is preferred over the FIGS. **17** or **18** embodiments for the reason that the reactangular aperture-element geometry is easier to fabricate than a rhomboid geometry.

A feature of mask-screen embodiments according with this invention which has not yet been discussed involves their reduced visibility to the viewer. It has been found that pattern geometries of the phosphor elements according to this invention, particularly the geometries in which the elements are canted in alternately opposite directions from one row to the next, results in an overall screen pattern which is less perceptible to the viewer than a conventional vertical strip pattern, for example. The implications of this are that the phosphor element patterns according to this invention can be made coarser than a pattern of vertical strips of equal visibility to the viewer. Since the guard bands which must be provided are of absolute width, i.e., their width is independent of the width of the guarded phosphor elements, mask-screen structures constructed according to this invention can be made more efficient than, e.g., corresponding structures in continuous strip slit-mask or slot-mask tubes.

As explained at length above, the preferred embodiments of this invention utilize mask aperture patterns and associated phosphor element patterns in which the angle of canting of the apertures and phosphor elements in adjoining rows is alternated from row to row. This invention, however, encompasses other embodiments which incorporate the principles of this invention and yet which do not necessarily employ the described angle alteration principle.

FIGS. **19** and **20** depict yet another embodiment of the principles of this invention which has high efficiency, a high degree of mask strength, freedom from moire pattern generation, and low visibility of the screen structure, and yet which utilizes mask apertures and associated phosphor elements which are canted at a like angle in every row. In the FIGS. **19** and **20** embodiment a shadow mask **78** has formed therein a plurality of equally spaced parallel lines of elongated aligned apertures **80.** The lines of apertures **1, 2,** etc., are oriented at a predetermined angle $\theta$ with respect to the direction of electron beam scan across the mask, the apertures in each line being regularly spaced at period Q and have an individual length l which is at most Q/3, where Q is the aperture spacing or period in the direction of the lines **1, 2,** etc. The apertures **80** have a width w which is at most equal to the spacing S of the lines. The apertures **80** are staggered from one line to the next, as shown.

The phosphor screen **82** shown in FIG. **20** includes mutually interleaved patterns of red, blue and green phosphor elements, as labeled, each pattern corresponding to the array of apertures in the mask and being displaced in the direction of electron beam scan such that the patterns of red, blue and green phosphor elements are exposed through the mask **78** only to the red-associated, blue-associated and green-associated electron beams, respectively.

As discussed briefly above, the FIGS. **19–20** embodiment, as with the other embodiments described above, has the geometric property that phosphor elements of like colors do not line up contiguously to establish a line pattern which is perceivable by a viewer observing the screen. It is mandatory in the construction of commercially acceptable tubes of the line-screen type, because of the high visibility of line structures, that the line width must be reduced below the width of corresponding phosphor elements in dot mask tubes. It can be seen in the FIG. **20** screen that the phosphor elements of like color do not line up in any direction. No straight line can be drawn across the screen **82** in any direction which will intersect in succession phosphor elements having the same emission color. By this novel phosphor element pattern geometry, tubes may be constructed according to this invention which have greater phosphor element width than the width of the strip phosphors in slit mask or slot mask tubes and thus, taking into consideration the required guardband provisions, which have greater efficiency than such prior art line-screen structures.

As illustrated in FIGS. **19–20,** in the preferred embodiment, the angle of canting, $\theta$, is substantially equal to 45° and the aspect ratio, that is the ratio of length l to width W of the apertures and associated phosphor elements, is between 2:1 and 6:1, preferably approximately 3:1.

The FIGS. **19–20** embodiment may be constructed in either positive guardband mode, as shown for example in FIGS. **1–3,** or in the negative guardband mode as shown, for example, in FIGS. **12** and **13.**

It should be noted that the FIGS. 19–20 embodiment incorporates the above-described teachings of this invention relating to the elimination of moire patterns.

It is believed that the above description of the preferred embodiments of the invention makes it quite clear that the invention is not limited to the particular details of construction of embodiments which are illustrated only, but rather that the principles of this invention can be implemented in color tubes incorporating aperture masks and associated phosphor screens having a wide variety of geometries, configurations, aspect ratios, pitches, scales, guardband modes, absolute and relative arrangements and orientations, and other characteristics and parameters. Thus changes may be made in the above-described mask-screen structures without departing from the true spirit and scope of the invention herein involved.

I claim:

**1.** A shadow mask for use in a color cathode ray tube, comprising a sheet of electrically conductive material having formed therein a plurality of rows of elongated, equally spaced, electron-transmissive apertures which are arranged such that the major axes of the apertures in each row are parallel and canted relative to the direction of electron beam scan across the mask, the apertures in any given row having an angle of canting which is of opposite polarity to the angle of canting of the apertures in adjoining rows.

**2.** The mask defined by claim **1** wherein the apertures in any given row of apertures are staggered relative to the apertures in adjoining rows.

**3.** The mask defined by claim **2** wherein adjoining rows of apertures are staggered by approximately one-half of the aperture period in the scan direction.

**4.** The mask defined by claim **3** wherein the angle of canting of the apertures is equal in all rows but of alternately opposite polarity from one row to the next.

**5.** The mask defined by claim **4** wherein said apertures are substantially rectangular in shape.

**6.** The mask defined by claim **4** wherein said angle of canting of the apertures is substantially 45°.

**7.** The mask defined by claim **1** wherein the length to width ratio of each aperture is in the range of about 2:1 to 6:1.

**8.** The mask defined by claim **7** wherein said length to width ratio of each aperture is approximately 3:1.

**9.** The mask defined by claim **6** wherein the length to width ratio of each aperture is in the range of about 2:1 to 6:1.

**10.** The mask defined by claim **9** wherein said length to width ratio of each aperture is approximately 3:1.

**11.** A shadow mask for use in a shadow mask-type color cathode ray tube, comprising a sheet of electrically conductive material having formed therein a pattern of elongated electron-transmissive apertures arranged in first and second arrays of apertures angled with respect to each other and oriented at angles $\theta_1$ and $\theta_2$, respectively, with respect to the direction of electron beam scan across the mask, each array comprising lines of spaced, aligned apertures, the apertures in said lines being staggered from one line to the next, the two arrays being interleaved such that the apertures in one array reside transversely in the inter-aperture spaces in the other array.

**12.** The mask defined by claim **11** wherein said first and second arrays are substantially perpendicular and wherein $\theta_1$ and $\theta_2$ are each substantially 45°.

**13.** In a color cathode ray tube, the combination comprising:

means for generating first, second and third substantially horizontally coplanar, mutually intersecting electron beams for carrying red, blue and green video information respectively;

a shadow mask located at the locus of convergence of said beams, said mask comprising a sheet of electrically conductive material having formed therein a plurality of rows of elongated, equally spaced, electron-transmissive apertures which are arranged such that the major axes of the apertures in each row are parallel and canted relative to the direction of electron beam scan across the mask, the apertures in any given row having an angle of canting which is of opposite polarity to the angle of canting of the apparatus in adjoining rows; and

a phosphor screen spaced from said mask and including mutually interleaved patterns of red, blue and green phosphor elements, each pattern corresponding to said pattern of apertures in said mask and being displaced horizontally such that said patterns of red, blue and green phosphor elements are exposed through said mask only to said first, second and third electron beams, respectively.

**14.** The combination defined by claim **13** wherein the length to width ratio of each aperture and associated phosphor elements is in the range of about 2:1 to 6:1.

**15.** The combination defined by claim **14** wherein said length to width ratio of each aperture is approximately 3:1.

**16.** The combination defined by claim **13** wherein adjoining rows of apertures in said mask and adjoining rows of phosphor elements on said screen are staggered.

**17.** The combination defined by claim **16** wherein the angle of canting of the apertures in said mask and the associated phosphor elements is equal in all rows but of alternately opposite polarity from one row to the next.

**18.** The combination defined by claim **17** wherein said angle of canting of the apertures in said mask and of the associated phosphor elements is substantially 45°.

**19.** The combination defined by claim **17** wherein said apertures and associated phosphor elements are substantially rectanglar in shape.

**20.** The combination defined by claim **13** wherein said phosphor elements in said pattern of elements are separated each from the others by guard bands of light-absorptive material.

**21.** The combination defined by claim **20** wherein adjoining rows of apertures in said mask and associated adjoining rows of phosphor elements are staggered by approximately one-half of the aperture period in the scan direction.

**22.** The combination defined by claim **13** wherein said mask apertures and associated phosphor elements in any given row of apertures and elements are staggered relative to the apertures and elements in adjoining rows.

**23.** The combination defined by claim **32** wherein said apertures and associated phosphor elements are substantially rectangular in shape.

**24.** The combination defined by claim **23** wherein said angle of canting of said apertures and phosphor elements is substantially 45°.

25. In a color cathode ray tube, the combination comprising:

electron gun means for generating first, second and third substantially horizontally coplanar, mutually intersecting electron beams for carrying red, blue and green video information respectively;

a shadow mask located at the locus of convergence of said beams, said mask comprising a sheet of electrically conductive material having formed therein a pattern of elongated electron-transmissive apertures arranged in first and second arrays of slots angled with respect to each other and oriented respectively at angles $\theta_1$ and $\theta_2$ with respect to the direction of electron beam scan across the mask, each array comprising lines of spaced slots having common alignment and being staggered from one line to the next, the two arrays being interleaved such that the apertures in one array are located in the inter-aperture spaces in the other array; and

a phosphor screen spaced from said mask and including mutually interleaved patterns of red, blue and green phosphor elements, each pattern corresponding to said pattern of apertures in said mask and being displaced horizontally such that said patterns of red, blue and green phosphor elements are exposed through said mask only to said first, second and third electron beams respectively.

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