SHADOW MASK HAVING APERTURES AT INTERSECTIONS OF BARREL-SHAPED AND PIN-CUSHION SHAPED LINES

Original Filed Nov. 17, 1969

5 Sheets-Sheet 1

Fig. 1

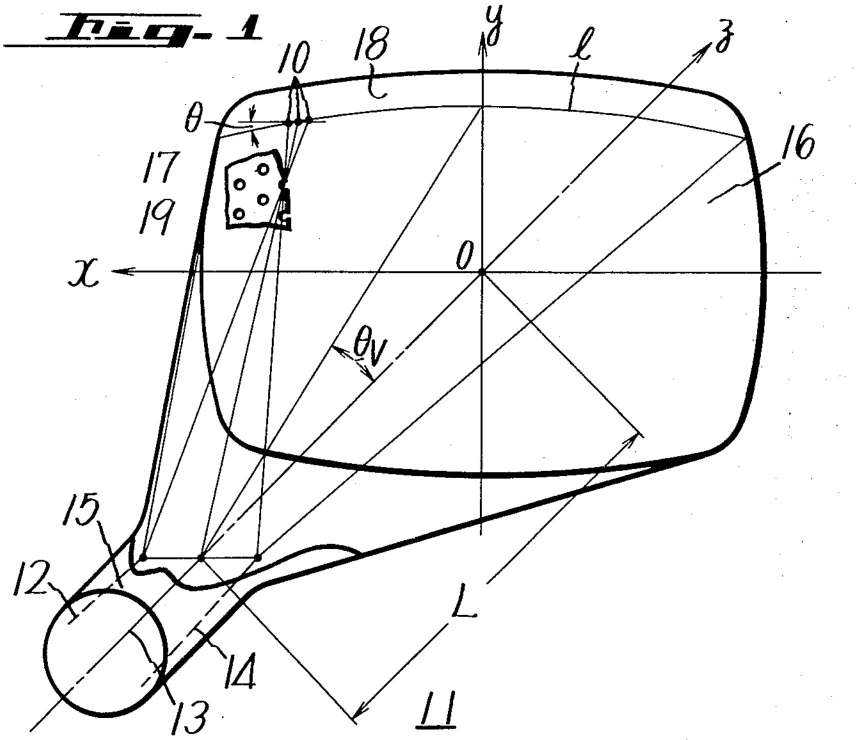

Fig. 2 PRIOR ART

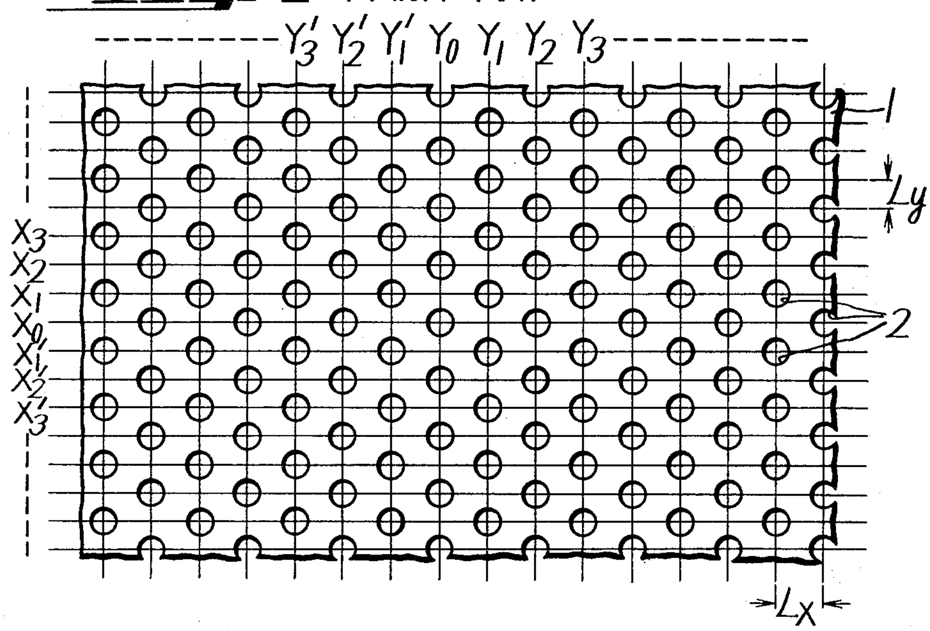

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Fig. 3A PRIOR ART

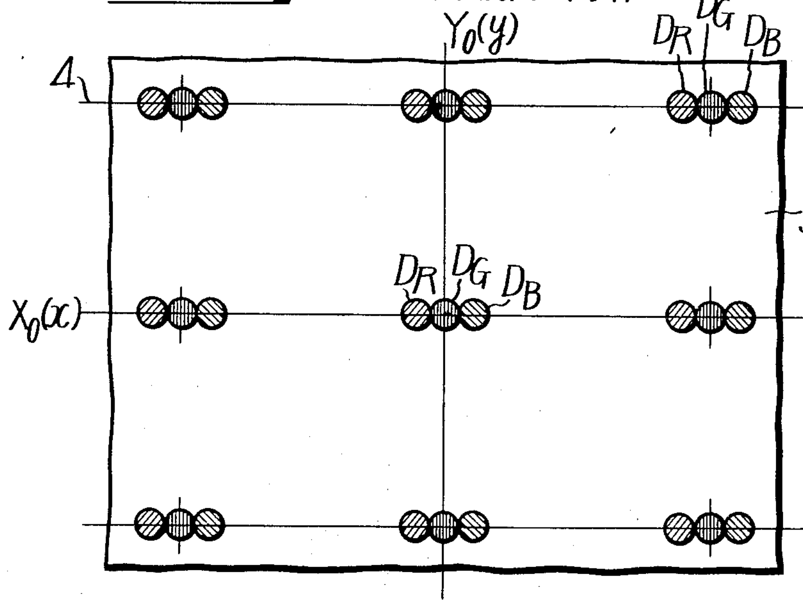

Fig. 3B PRIOR ART

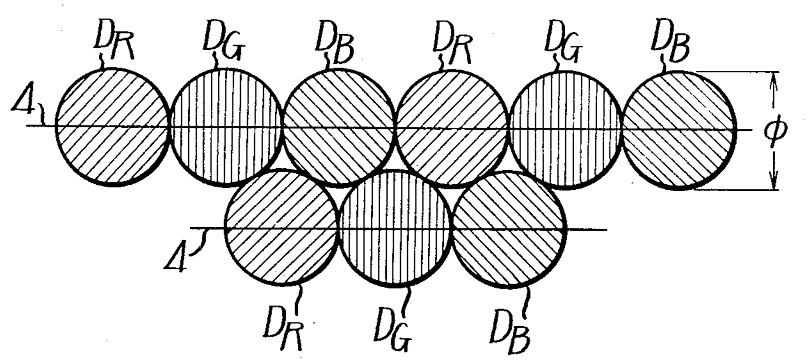

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Fig. 4

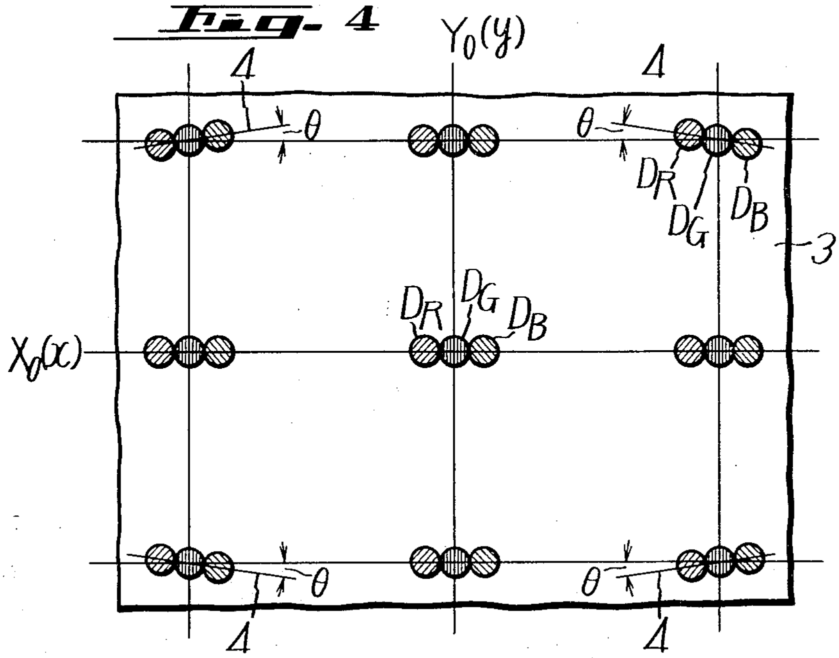

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Fig. 5A PRIOR ART

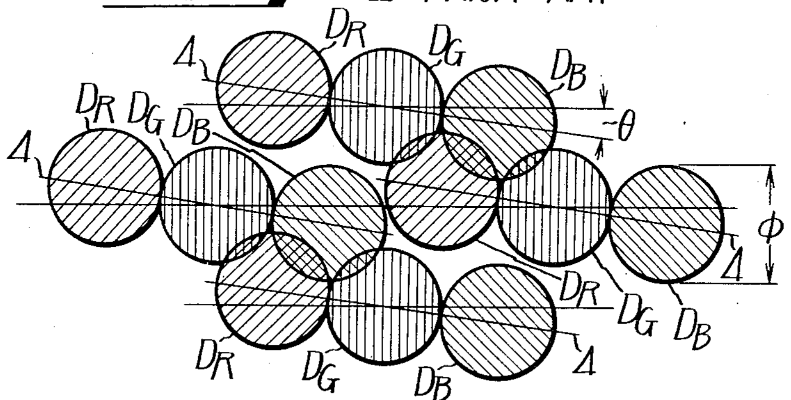


Fig. 5B PRIOR ART

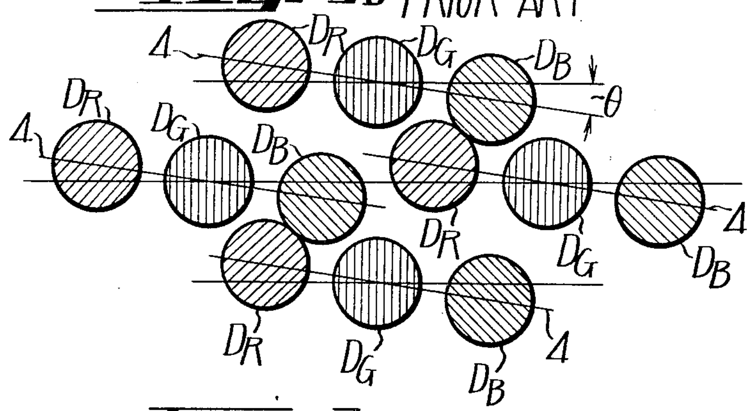
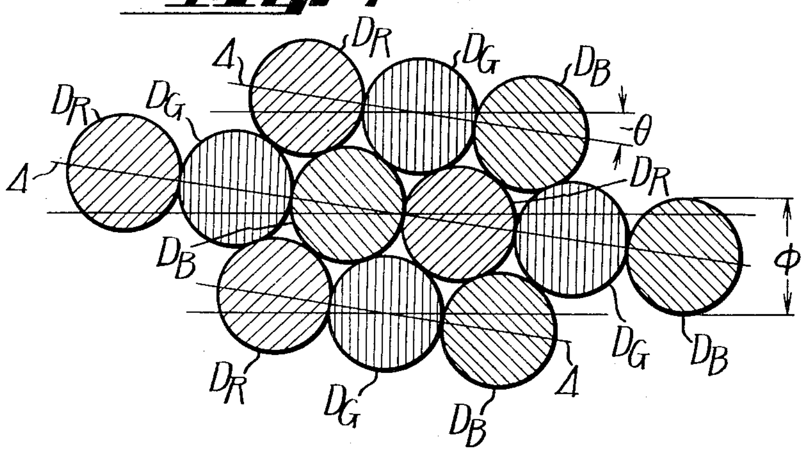


Fig. 7



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March 20, 1973 YOHSUKE NARUSE ET AL 3,721,853

SHADOW MASK HAVING APERTURES AT INTERSECTIONS OF BARREL-SHAPED AND PIN-CUSHION SHAPED LINES

Original Filed Nov. 17, 1969 5 Sheets-Sheet 5

Fig. 6

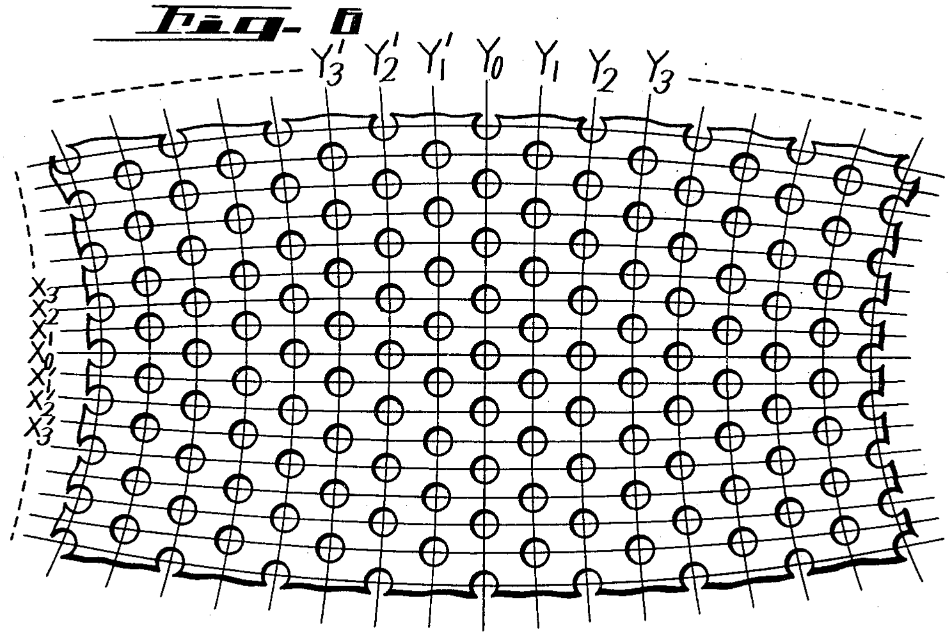
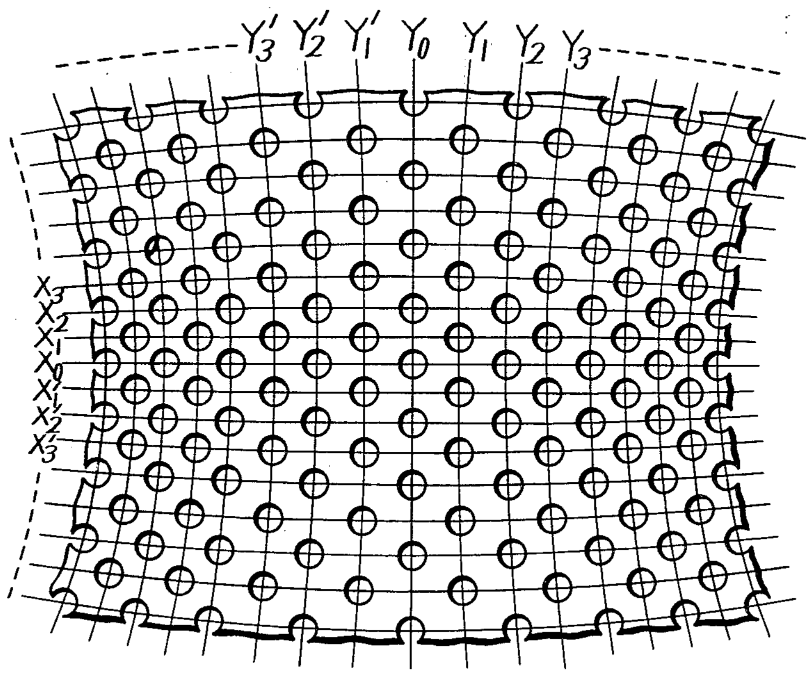


Fig. 8



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SHADOW MASK HAVING APERTURES AT INTERSECTIONS OF BARREL-SHAPED AND PINCUSHION SHAPED LINES

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Continuation of abandoned application Ser. No. 877,183, Nov. 17, 1969. This application Dec. 1, 1971, Ser. No. 203,600

Int. Cl. H01j *29/06, 31/20*

U.S. Cl. 313—85 S **4 Claims**

ABSTRACT OF THE DISCLOSURE

In a color cathode ray tube having a curved phosphor screen, an apertures shadow mask and electron beam generating means for generating three in-line electron beams aligned in a horizontal direction, the apertures of the shadow mask are arranged in intersecting rows extending along barrel-shaped lines extending in the horizontal direction and along pin-cushion shaped lines extending in the vertical direction, an all of the rows are orthogonally related at each of the intersections thereof.

This invention relates to an improved shadow mask, and more particularly to a color cathode ray tube in which the improved shadow mask is used to ensure exact landing of the electron beams on the respective color dots or phosphors of the tube. This application is a continuation of our copending application Ser. No. 877,183, filed Nov. 17, 1969.

Conventional types of color cathode ray tubes comprise an electron gun for emitting an electron beam, a color screen and a shadow mask or aperture grill for beam selection, in which each of the apertures in the mask or grill exactly corresponds to a respective one of the color dots to cause the beam to land precisely on predetermined color dots for reproducing a color picture. However, due to certain causes the beam landing is not carried out accurately and mislanding and/or misconvergence can result. This is particularly serious at the peripheral areas of the screen.

The present invention is directed to a shadow-mask type color cathode ray tube in which a plurality of electron beams are deflected horizontally and vertically while being aligned in a common plane so as to scan a curved screen through a shadow mask and the transmission factor of the electron beams through the shadow mask is increased to provide for enhanced brightness in the reproduced picture.

Accordingly, one object of this invention is to provide an improved shadow mask.

Another object of this invention is to provide an improved shadow mask in which the apertures are arranged in a particular pattern.

Another object of this invention is to provide a novel color cathode ray tube in which each electron beam is made to exactly impinge on a respective predetermined color dot.

Another object of this invention is to provide a color cathode ray tube which is bright and free from color misregistration.

Another object of this invention is to provide a color cathode ray tube which employs an in-line gun.

Still another object of this invention is to provide a color cathode ray tube employing an improved shadow mask having bored therethrough a plurality of apertures in a particular pattern and in which the color dots on the screen are closely packed together at the peripheral portion of the screen.

The above, and other objects, features and advantages of this invention, will become apparent from the following detailed description of illustrative embodiments which is to be read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a diagrammatic perspective view, partly cut away, of a cathode ray tube, and to which reference will be made in explaining this invention;

FIG. 2 is a schematic diagram of a shadow mask used in a conventional shadow-mask type color cathode ray tube;

FIGS. 3A and 3B are schematic diagrams showing the relative arrangement of picture elements on a flat screen in a plane perpendicular to the central axis of a cathode ray tube employing the shadow mask depicted in FIG. 2;

FIG. 4 is a schematic diagram showing the relative arrangement of the picture elements on a spherical screen when using the shadow mask shown in FIG. 2;

FIGS. 5A and 5B are enlarged schematic diagrams showing the relative arrangement of the picture elements on the screen of FIG. 4 and to which reference will be made in explaining this invention;

FIG. 6 is a schematic diagram illustrating one example of a mask of a shadow-mask type color cathode ray tube according to this invention;

FIG. 7 is an enlarged schematic diagram showing the relative arrangement of the picture elements on a spherical screen when using a mask according to this invention; and

FIG. 8 is a schematic diagram illustrating a mask according to another example of this invention.

For a better understanding of this invention a description will be given first of a shadow mask type color cathode ray tube identified generally by the reference number **11** on FIG. 1 and in which red, green and blue electron beams **12**, **13** and **14** arranged in line in a common horizontal plane **15** are deflected horizontally and vertically by deflection means (not shown) while remaining in a common plane **16**, and are thereby caused to scan an outwardly curved spherical screen **18** through a shadow mask **17**. In this case the relationship between apertures **19** of the shadow mask **17** and phosphor dots on the screen **18** is of prime importance, and will be hereinbelow discussed with reference to the drawings.

This will be described first in connection with a conventional type of shadow mask **1** depicted in FIG. 2, and in which horizontal and vertical lines . . . . . X_3, X_2, X_1, X_0, X_1', X_2', X_3' . . . . . and . . . . . Y_3, Y_2, Y_1, Y_0, Y_1', Y_2', Y_3' . . . . . are drawn on the shadow mask **1** as viewed in the direction of the central axis z of the tube. The shadow mask **1** is shown to be of the type having apertures **2** located at intersections of even-number horizontal and vertical lines . . . . . X_2, X_0, X_2' . . . . . and . . . . . Y_2, Y_0, Y_2' . . . . . and at intersections of odd-number horizontal and vertical lines . . . . . X_3, X_1, X_3' . . . . . and Y_3, Y_1, Y_3' . . . . .

With such an arrangement, and assuming that the phosphor screen **3** is in a plane perpendicular to the central axis z of the tube and that red, green and blue phosphor dots D_R, D_G and D_B on the screen **3** are formed by the usual light or electron beam printing method employing a light or electron beam passing through the center of horizontal and vertical deflection of the beam, then the phosphor dots D_R, D_G and D_B of a diameter ϕ which form a picture element for each aperture **2** of the mask **1** are sequentially arranged on the horizontal lines . . . . . X_3, X_2, X_1, X_0, X_1', X_2', X_3' . . . . . in the form of horizontal rows of triplets as shown in FIGS. 3A and 3B. In view of the requirement for closely packed hexagonal arrays of the phosphor dots D_R, D_G and D_B on the phosphor screen **3**, the spacing Lx of adjacent vertical columns of apertures of the shadow mask 3 is selected to be $\sqrt{3}$ times the spacing Ly of adjacent horizontal rows of apertures (FIG. 2).

In case of a shadow mask tube **11** (FIG. 1) having a spherical screen **18** and using an in-line gun, the in-line beam triplets **10** passing through an aperture **19** of the mask **17** land at the screen on a line that is tilted with respect to the original line of alignment of the three beams as shown in FIG. 4, and this phenomenon is referred to as the twist of landing in-line beam triplets. The twist phenomenon is fully understood as a purely geometrical effect owing to the combination of in-line alignment of three beams and a spherical screen. Considered with the coordinate system illustrated in FIG. 1, the three beams **12, 13** and **14** passing through the aperture **19** of the shadow mask **17** form the flat plane **16** which is parallel to the x-axis of the tube and which makes an angle of θ_V (the angle of vertical deflection) to the x–z plane, and this flat plane **16** intersects the spherical screen **18** which has its center O on the z-axis. The landing points of the in-line beam triplet **10** thus occur on an intersection line l, which is an arc of ellipse when viewed from the z-axis direction and is expressed as follows.

$$x^2+\left(1+\frac{1}{\tan^2\theta_V}\right)y^2+\frac{2(R-L)}{\tan\theta_V}y+L^2-2RL=0 \qquad \text{(Eq. 1)}$$

where R is the radius of curvature of the spherical screen **18**, and L is the distance from the deflection center of the beams to the center of the screen.

This is the cause of the twist of a landing in-line beam triplet, and the mathematical expression of the angle twist is obtained by differentiating Equation 1 and using the relation of

$$\tan\theta_V=y/(\sqrt{R^2-x^2-y^2}-R+L)$$

Thus, it follows that

$$\tan\theta=\frac{dy}{dx}=-\frac{xy}{R_2-x^2-(R-L)\sqrt{R^2-x^2-y^2}} \qquad \text{(Eq. 2)}$$

where θ is the angle of twist measured counterclockwise from the positive x-axis.

The approximate form of the Equation 2 is

$$\tan\theta=-\frac{xy}{RL} \qquad \text{(Eq. 3)}$$

With twisting of the landing in-line beam triplet as has been described above, and if the diameter of the phosphor dots D_R, D_G and D_B on the phosphor screen is selected to be the same as that ϕ previously described with reference to FIG. 3 in view of the requirement for the closely packed hexagonal arrays of the dots, the phosphor dots D_R, D_G and D_B corresponding to one of the horizontal rows of apertures 2 will overlap those of adjacent horizontal rows of apertures because of the fixed relative arrangements of adjacent apertures, as depicted in FIG. 5A. To avoid this, the diameter of the apertures of the shadow mask may be reduced in accordance with the angle θ and the diameter ϕ of the phosphor dots on the screen 3 reduced correspondingly. Thus, in the case of the conventional shadow mask with an in-line gun, the landing allowance considerably decreases in consequence of the twist phenomenon of the landing beam triplets (FIG. 5A). The object of this invention is to provide a shadow mask which compensates for this twist phenomenon completely by accommodating the alignment of the apertures to the geometrical twist of the landing beam triplets. In order to achieve such accommodation, each generally horizontal row of the aligned apertures on the spherically shaped or curved shadow mask and the line passing through the deflection centers of the three electron beams must be included on a single flat plane. Considering the fact that the radius of the spherically curved shadow mask is nearly equal to the radius R of the inner surface of the face plate of the tube on which the screen is provided and neglecting the length of the gap between the shadownmask and the screen as compared with L, the generally horizontal alignment lines of the apertures must be arcs of the ellipses given by the Equation 1 which is the solution of the differential equation of the geometrical twist. A conversion of the integral constant θ_V in Equation 1 leads to the following expression.

$$x^2+\frac{R^2+(R-L)^2-2(R-L)\sqrt{R-y_0^2}}{y_0^2}y^2-2\,\frac{(R-L)^2-(R-L)\sqrt{R^2-y_0^2}\,y}{y_0}+L^2-2RL=0 \qquad \text{(Eq. 4)}$$

where,

$y \gtrless 0$ for $y_0 \gtrless 0$, and

y_0 is a parameter which is the intercept of the y-axis by the curve.

The group of arcs of ellipses (Eq. 4) form a "barrel-shaped" group of curves . . . . . X_3, X_2, X_1, X_0, X_1', X_2', X_3' . . . . . as shown in FIG. 6 The generally vertical alignment lines of the apertures must be "pin-cushion" shaped so as to orthogonal to the generally horizontal alignment lines at all intersections with the latter throughout the shadow mask.

The generally vertical alignment lines can be obtained by solving the following differential equation which is the inverse and opposite sign of the equation of geometrical twist (Eq. 2).

$$\frac{dy}{dx}=\frac{R^2-x^2-(R-L)\sqrt{R^2-x^2-y^2}}{xy} \qquad \text{(Eq. 5)}$$

The solution of Equation 5 is obtained as follows.

$$x=x_0\left\{\frac{R^2-(R-L)\sqrt{R^2-x^2-y^2}}{R^2-(R-L)\sqrt{R^2-x_0^2}}\right\}^{\frac{(R)^2}{R-L}} x\exp\left\{\frac{\sqrt{R^2-x^2-y^2}-\sqrt{R^2-x_0^2}}{R-L}\right\} \qquad \text{(Eq. 6)}$$

where x_0 is a parameter which is the intercept of the x-axis by the curve.

The thus obtained curves (Eq. 6) intersect at right angles the group of curves obtained from Equation 4 throughout the whole shadow mask plane. Equation 6, however, can be written in the following approximate form which results in an error of +1°, at most, in the orthogonal relationship between the horizontal and vertical alignment lines.

$$x=\frac{RL}{x_0}\pm\sqrt{\left(\frac{RL}{x_0}-x_0\right)^2-y^2} \qquad \text{(Eq. 7)}$$

for $x_0 \gtrless 0$.

This is the "pin-cushion" group of the arcs of circles . . . . . Y_3, Y_2, Y_1, Y_0, Y_1', Y_2', Y_3', ... as shown in FIG. 6.

The above Equations 4, 6 and 7 were derived on the basis of a spherically curved shadow mask. Thus, these equations define the alignment lines of the apertures on the spherically curved shadow mask when viewed from the

z-axis direction. However, when a flat shadow mask is pressed into a nearly spherical plane, the displacements of the aperture positions occurs almost only in the z-direction and the displacement in the x–y plane is negligibly small, so that these equations can be interpreted to define the alignment lines of the apertures on the flat shadow mask which is thereafter curved spherically.

The foregoing description has referred to the case in which the phosphor screen **3** is spherical but the same is true of the case in which the screen is a cylindrical surface having its axis extending in a vertical direction. In this case, however, the inclination angle with respect to the horizontal of the generally horizontal row of the triplet of the phosphor dots D_R, D_G and D_B for each aperture **2** of the mask is as follows.

$$\tan\theta=\frac{dy}{dx}=-\frac{xy}{R^2-x^2-(R-l)\sqrt{R^2-x^2}} \quad \text{(Eq. 8)}$$

corresponding to the Equation 2.

Accordingly, in this case the generally horizontal alignment lines of the apertures are made "barrel-shaped"; and the generally vertical alignment lines of the apertures are made "pin-cushioned" so as to be orthogonal to the horizontal alignment lines throughout the shadow mask plane and apertures are positioned at the intersections of the horizontal and vertical alignment lines. The curve of the horizontal alignment lines is obtained by solving the differential Equation 8 to obtain an equation corresponding to Equation 4 and by satisfying the resulting equation, while the curve of the vertical alignment lines is obtained by solving the following differential equation which is the inverse and opposite sign of the Equation 8:

$$\frac{dy}{dx}=\frac{R^2-x^2-(R-l)\sqrt{R^2-x^2}}{xy} \quad \text{(Eq. 9)}$$

to obtain an equation corresponding to the Equation 4 and by satisfying the resulting equation. Thus, the same results as the aforementioned can be obtained.

Although the present invention has been described in connection with the case where the electron beams respectively corresponding to red, green and blue colors enter the position of the horizontal and vertical deflection means while being aligned in a common horizontal plane, the invention is also applicable to the case where these electron beams enter the position of the deflection means while being aligned in a common vertical plane. In the latter case, however, it is necessary, of course, to use a shadow mask having apertures formed at intersections of generally horizontal alignment lines which are "pin-cushioned" and generally vertical alignment lines which are "barrel-shaped."

Further, this invention has been described in connection with color cathode ray tubes in which the screen **3** is spherical and cylindrical, but it will be understood that the invention is also applicable to any other desired outwardly curved screen.

The remaining problem is the determination of the values of the parameters x_0s and y_0s, namely the determination of the pitch distribution throughout the shadow mask plane. In the corner regions of the shadow mask plane, the horizontal pitches are enlarged because of the "pin-cushioned" nature of the generally vertical alignment lines and the vertical pitches are reduced because of the "barrel-shaped" nature of the generally horizontal alignment lines. Therefore, if x_0s and y_0s are selected simply to be linear, i.e. $x_{0m}=mx_{00}$ and $y_{0n}=ny_{00}$ under the condition of $x_{00}=\sqrt{3}\,y_{00}$, the face-centered right-hexagonal array of the apertures does not also occur in the corner regions of the shadow mask.

It is possible, however, to have the face-centered right-

hexagonal array of the apertures throughout the whole shadow mask plane. For this purpose, along the x-axis, in the outward x-directions, the horizontal pitches are quadratically decreased and along the y-axis, in the outward y-direction, the vertical pitches are quadratically increased. Mathematically the setting of the x_0s and y_0s becomes as follows:

$$x_{0m}=mx_{00}(1-\alpha m^2)$$
$$y_{0n}=ny_{00}(1+\beta n^2)$$

where

$$\alpha=x_{00}^2/6RL=y_{00}^2/2RL$$
$$\beta=y_{00}^2/6RL$$

in which y_{00} is the standard pitch (pitch at the center of the shadow mask) between apertures.

For this choice of the values of x_0s and y_0s, at the opposite ends of the x-axis, the pitches are reduced by about 10% as compared with the pitch at the center, and at the opposite ends of the y-axis the pitches are enlarged by about 6% as compared with the pitch at the center. Further, from the center toward the four diagonal regions of the shadow mask, the pitches measured along the diagonals have the same value as the pitch at the center. Thus, the described variation of pitches results in the almost complete face-centered right-hexagonal array of the apertures throughout the whole shadow mask plane, and therefore it is sufficient to use round apertures. The shadow mask thus produced is shown in FIG. 8.

Although illustrative embodiments of this invention have been described in detail herein with reference to the drawings, it will be apparent that many modifications and variations may be effected therein without departing from the scope of the novel concepts of this invention.

What is claimed is:

1. A color cathode ray tube comprising an outwardly curved face plate having a screen with triads of different phosphor dots on its inner surface, a shadow mask within the tube spaced from said screen and having substantially the same curvature as said screen, said mask having an aperture extending therethrough for each of said triads, and means for generating three electron beams which are directed toward said screen in a common plane and which intersect each other at an aperture of said mask for impinging on corresponding phosphor dots of the respective triad, the apertures of said mask being arranged in spaced intersecting rows that extend generally parallel to said plane and generally at right angles to said plane, the rows which intersect at the center of said mask being straight and the remainder of said rows being longitudinally curved with the radius of curvature of each row being inversely proportional to its distance from said center of the mask, the curved rows which extend generally parallel to said plane being concave toward said center of the mask so as to form a barrel-shaped array of said rows, the curved rows which extend generally at right angles to said plane being convex toward said center of the mask so as to form a pin-cushion shaped array of said rows, all of said rows being orthogonally related to each other at each of the intersections thereof, and said phosphor dots of each of said triads being arranged side-by-side on a line substantially parallel to the row containing the respective mask aperture which extends generally parallel to said plane.

2. A color cathode ray tube according to claim **1**, in which said common plane is horizontally directed with the generally horizontal rows of said apertures forming said barrel-shaped array and the generally vertical rows of said apertures forming said pin-cushion shaped array.

3. A color cathode ray tube according to claim **1**, in which, at a median of said mask extending at right angles to said plane, the spacing between said rows extending generally parallel to said plane increases progressively from said center of the mask toward the opposite ends of said median, and, at the other median of said mask, the spacing between said rows extending generally at right angles to said plane decreases progressively from said center of the mask toward the opposite ends of said other median.

4. A color cathode ray tube according to claim 3, in which, along the diagonals of said mask, the spacing between adjacent apertures is substantially the same at said center of the mask as at the ends of said diagonals.

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ROBERT SEGAL, Primary Examiner

U.S. Cl. X.R.

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