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IMAGE INTENSIFIER

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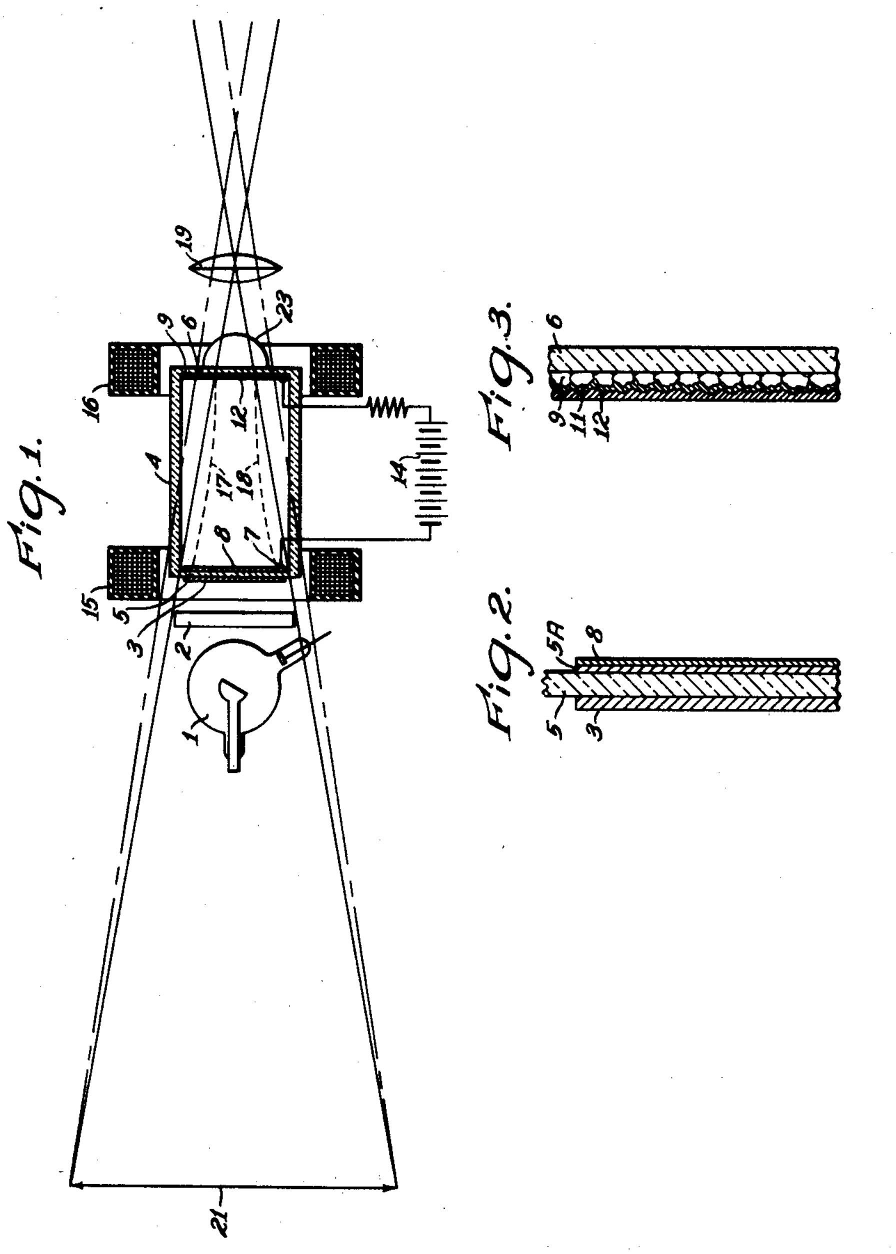

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IMAGE INTENSIFIER

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3 Claims. (Cl. 250—71)

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Our invention relates to fluorescent devices and, in particular, covers a method of, in effect, amplifying the intensity of an optical image produced on a fluorescent screen.

Fluorescent screens are devices known in the art by means of which visible light images are produced which are replicas of the energy intensity, point by point, of incident radiation of some known invisible type. For example, fluorescent screens are employed with X-ray tubes to make visible the pattern which results when a stream of X-radiation pases through some material object, such as a part of the human body. While such radiation patterns are frequently recorded by their effect on photographic plates, it is highly desirable, for certain purposes, such as the observation of the movements of the human heart, for an operator to be able to watch the changes in the pattern from instant to instant by causing it to be rendered visible by a fluorescent screen. However, in actual practice, the intensity of the image produceable today by known fluorescent screen-materials is so low that it is only with great difficulty that such fluorescent images may be observed in the case of many human organs. It is impossible in these instances to raise the intensity of the image by increasing the X-ray intensity because of the injurious effects of over-intense X-radiation on the human body. Some means which will produce an image which is a replica of greatly amplified intensity of a relatively weak fluorescent image is, accordingly, desired in the arts.

One object of our invention is, accordingly, to provide an arrangement for reproducing in greatly amplified intensity an image or pattern on a fluorescent screen.

Another object of our invention is to provide an arrangement for reproducing an optical image in greatly amplified intensity.

Another object of our invention is to provide an X-ray apparatus which shall produce on a fluorescent screen an image in which the ratio of the intensity of the light image to the intensity of the X-radiation is much higher than has been possible with X-ray apparatus of the prior art.

Still another object of our invention is to provide an X-ray apparatus in which visible images are produced instantaneously which are replicas of the pattern of the X-ray field and which are of a much higher order of visibility than was possible with X-ray apparatus of the prior art.

Another object of our invention is to provide a method of increasing the intensity of an optical image which is a replica of a given electron image.

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A further object of our invention is to provide a method of greatly increasing the intensity of the optical-image replica which may be produced from an electron image of a given intensity.

Other objects of our invention will become apparent upon reading the following description, taken in connection with the drawing in which

Fig. 1 illustrates an embodiment of our invention as applied to an X-ray apparatus.

Fig. 2 is an enlarged sectional detail view of the end 5 of the tube.

Fig. 3 is a similar enlarged sectional detail view of the opposite end 6 of the tube.

Referring in detail to the drawing, 1 symbolizes a source of X-rays which is being used, in a manner too well known in the art to require detailed description, to irradiate an object 2 and thereby produce upon a fluorescent screen 3 a visible pattern or image indicative of the extent to which X-rays are absorbed in different portions of the object 2. Phosphorescent materials, such as are employed to form screen 3, for use in producing visible replicas of X-radiation fields are known in the art and are frequently referred to as X-ray phosphors; for example, screens embodying calcium tungstate are among the most satisfactory known to the prior art for this purpose. However, as is disclosed in the copending application Serial No. 771,113, filed August 28, 1947, of one of the present applicants, R. L. Longini, a fluorescent screen which is considerably more effective in producing light output for a given intensity of X-radiation can be produced by the employment of zinc sulphide with an admixture of the order of 0.01% of an activator and of about 20% of an alkali halide flux such as sodium chloride.

While the visible image thus produced on the fluorescent screen 3 is of the order of five times as intense as those produceable by prior art screens, a greatly intensified replica of this image may be produced by the arrangement constituting our present invention in accordance with the following description.

The means for producing an image of amplified intensity in accordance with our invention comprises a vacuum-tight cylindrical tube 4 having opposite ends 5 and 6 comprising thin walls of glass, preferably of uniform thickness. The interior face of the end wall 5 is provided with a conductive coating 5A which is transparent to light. While there are a number of ways in which such coatings may be produced, one method is to coat the glass by sublimation with a coating of metallic gold, or silver, so thin that it is transparent to light. An electric terminal 7 makes it possible to complete an electric circuit to the aforesaid conductive coating 5A and fix its electrical potential relative to the other surfaces in the interior of tube 4. The surface of the conductive coating is covered in turn by a coating 8 of some suitable photo-electric material, such, for example, as antimony treated with caesium.

The opposite end 6 of tube 4 is coated on its interior face with a layer 9 of some substance which produces a luminous image when bombarded with electrons; though many such substances are known, we have found zinc-cadmium-sulphide to be a particularly satisfactory material for this purpose. The zinc-cadmium-sulphide is preferably settled from a water mixture.

Where caesium is employed as a component of the photo-electric layer 8, it is necessary to protect the layer 9 from chemical attack by the caesium vapor diffused thereto by means of some protective coating 11, which may, for example, be potassium silicate. In order to prevent projection back onto photo-electric layer 8 of light resulting from the bombardment of the zinc-cadmium-sulphide by electrons emanating from photo-electric layer 8, we provide a further coating 12 of aluminum, so thin as to transmit such electrons to the fluorescent layer 9. The layer 12 may, for example, be produced by evaporation of aluminum in vacuo.

The visible image produced on the X-ray phosphor screen 3 by the source 1 will produce an electron image, which is substantially a replica of it in intensity distribution, over the end wall 5, and by means of a suitable voltage source 14, the electrons forming such image may be accelerated and caused to impinge on the layer 9 and produce a luminous image thereon, which is an amplification in intensity of the luminous image produced by the X-rays on the X-ray phosphor screen 3. However, in order to insure that the image so produced on screen 9 is an accurate replica of the electron image, it may in some cases be desirable to provide an axial magnetic field symmetrical about the axis of the cylindrical tube 4. Such magnetic field, when used, may conveniently be produced by a pair of direct-current field coils 15 and 16 fed from a suitable direct-current source, not shown. The use of such field coils in connection with electron images is believed to be too well known in the art to require a detailed description.

By making the screen 8 concave inward, or by properly adjusting the strength of this magnetic field, the trajectories followed by the electrons composing the electron image in traversing the space between screens 3 and 9 may be controlled in such a way as to contract the dimensions of the image at the screen 9. The greater this contraction of the dimensions of the image produced on screen 9, the greater the brightness of the light composing that image, the brightness being substantially inversely proportional to the square of the image diameter. The trajectories of the electron paths to form such a contracted image are symbolized by the dotted lines 17, 18 inside the tube 4.

While, as indicated above, the brightness of the light image produced on the screen 9 may be made much greater than that of the light image on the screen 3, and this brightness may be increased through a wide range by contracting the radial dimensions of the image through adjustment of the above-mentioned magnetic field due to coils 15 and 16, the image on the screen 9 may be inconveniently small, although very bright, when so contracted. Under such circumstances, it is desirable to view this image through a suitable magnifying optical system which is symbolized by the lens 19. It will be understood that the showing of the lens 19 is merely symbolical of much more elaborate optical systems which are conventional in the optical art. The optical system 19 may be so formed, in ways well known in the optical art, to produce, for an observer using the optical system, a virtual image 21 which is a magnified replica of the intense light image on the screen 9. A hemispherical lens 23 covering the image on the screen 9 may be used to minimize halation and increase the optical efficiency.

It can be shown by the established laws of light optics that the brightness of the image which will be seen by an observer viewing the screen 9 through any optical system will, neglecting losses by reflection and absorption, be given by the following equation:

$$B' = B_2 \sin^2 \frac{\theta}{2} \tag{1}$$

where B_2 is the brightness of the object and θ is the total angle of the converging light subtended at the retina. If additional optical elements are used such that θ is still determined by the eye, the brightness of the image on the retina is substantially unchanged. Such an additional optical system may magnify the image size many times.

On the other hand, the brightness B_2 of the image generated by the electron impact on the screen 9 can, in turn, be shown by the laws of electron optics to be given by the following equation:

$$B_2 = aB_1(D_1/D_2)^2 \tag{2}$$

where D_1 is the diameter of image on screen 3 and D_2 is the diameter of the electron phosphor image on screen 9. B_1 is the brightness of the image on screen 3 and a is a factor of proportionality depending on the photo-electric sensitivity.

Combining Equations 1 and 2 shows that the brightness B' of the image seen by the observer is given by the following equation:

$$B' = aB_1(D_1/D_2)^2 \sin^2 \frac{\theta}{2} \tag{3}$$

It will be observed from Equation 3 that the brightness B' of the image on the retina of the observer is increased as the diameter D_2 of the image produced by electron impact on screen 9 is reduced. It is correspondingly highly advantageous to adjust the electron optical system by means of regulating the form and strength of the magnetic field set up by coils 15 and 16 to contract greatly the diameter D_2 of the image produced by electron impact on the screen 9. It would, in fact, be possible theoretically thus to attain substantially any desired ratio of intensity between the brightness of the image seen by the observer in the optical system 19 to the brightness of the image on fluorescent screen 3 by sufficiently reducing the diameter D_2. In actual practice there are limitations set by distortion of the electron image when the attempt is made to too greatly reduce the value of D_2, and also by distortion produced by the size of the crystal grains in screen 9 and by difficulties of design of the optical system 19 when the value of

D_2 is too small. However, the principle which we have described above is of general applicability and has resulted in our being able to magnify the brightness of the fluorescent image in X-ray work many fold.

It is possible to employ our invention to photographic purposes. The image on screen 12 can be contracted to a very high degree making it brighter inversely proportional to its area. This bright image may then be photographed at high speed making no attempt at this time to increase the image size. It is obvious to those versed in the art that such resulting photograph may be enlarged or directly viewed at much greater magnification. In this case the intensity of the accompanying light source for viewing or projecting can make up for a small aperture of the viewing or projecting means. The reduction in size of the image at the electron phosphor will later be counteracted by the projector or viewer. Moving pictures may be possible with the above-mentioned device that are not possible without it. Likewise, it may be observed that while the system is described in connection with intensification of an optical image on a fluorescent screen, it is applicable generally to the intensification of optical images of other types. Since, as one step of its operation, it amplifies the intensity of an optical image produced from the electron image at the face of screen 8, the method is applicable to producing intensified optical images from electron images generally.

Among the reasons that increasing intensity on a fluorescent screen in the way made possible by applying the principles of our invention are:

(1) An increase of intensity will do away with the need for dark adaptation.

(2) At present the resolving power of the fluorescent screen system is limited by the eye as we do not use the color vision apparatus of our eye at the intensities of present screen operation. The intrinsic resolving power of the screen itself is much better than that at which it is used. A great increase in brightness would therefore permit an operator to see much finer detail in a fluoroscope screen.

We claim as our invention:

1. An electronic system adapted to be aligned with a source of X-rays, said system including a first fluorescent screen, then in order, a photoelectric screen and a second fluorescent screen spaced from said first fluorescent screen, a condensing electronic lens adjacent said screens for projecting an image from said photoelectric screen of contracted size and increased brilliancy upon said second fluorescent screen and a magnifying optical system adjacent said second fluorescent screen for magnifying the image on said second fluorescent screen.

2. In combination with a source for projecting a beam of X-rays, an electronic system adapted to be aligned therewith and including a first fluorescent screen, then in order, a photoelectric screen and a second fluorescent screen spaced from said first fluorescent screen, a condensing electronic lens adjacent said screens for projecting an image from said photoelectric screen of contracted size and increased brilliancy upon said second fluorescent screen and a magnifying optical system adjacent said second fluorescent screen for magnifying the image on said second fluorescent screen.

3. An electronic system adapted to be aligned with a source of X-rays, said system including a first fluorescent screen, then in order, a photoelectric screen closely adjacent and parallel with said first fluorescent screen and a second fluorescent screen spaced from said first fluorescent screen, a condensing electronic lens adjacent said screens for projecting an image from said photoelectric screen of contracted size and increased brilliancy upon said second fluorescent screen and a magnifying optical system adjacent said second fluorescent screen for magnifying the image on said second fluorescent screen.

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