Sept. 26, 1950 H. F. KAISER ET AL 2,523,306

APPLICATION OF RADIOGRAPHY TO INFRARED PHOSPHORS

Filed Sept. 23, 1947

FIG. 1

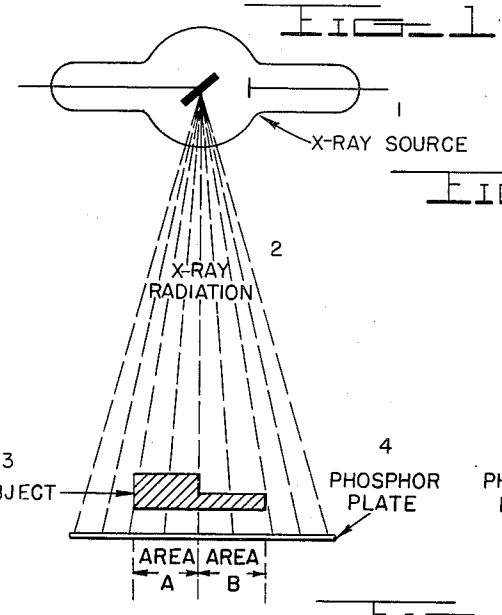


FIG. 2

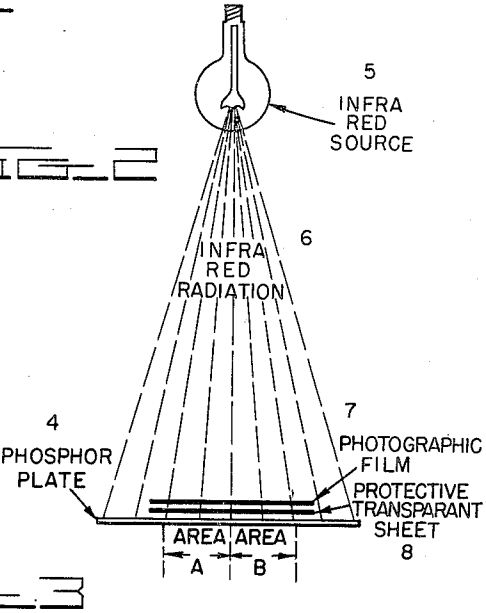


FIG. 3

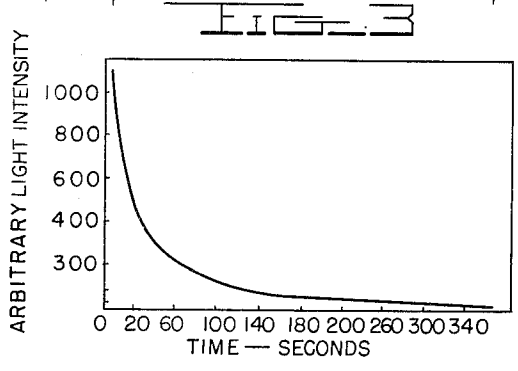


FIG. 4

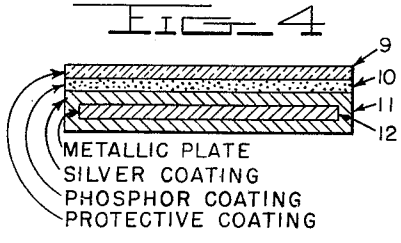
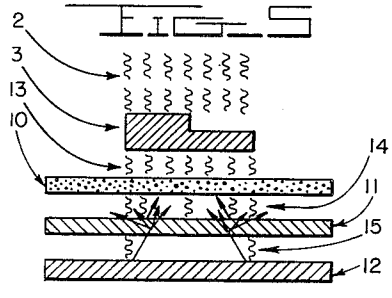


FIG. 5



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APPLICATION OF RADIOGRAPHY TO INFRARED PHOSPHORS

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This invention relates in general to the art of radiography and in particular to methods and means for employing infrared sensitive phosphor as a sensitized recording element on which radiant energy shadowgraphs may first be recorded and thereafter visibly reproduced and recorded on standard photographic film or paper.

In general, we have discovered that numerous phosphor compositions, and especially those known to the art as infra-red sensitive phosphors, possess the ability to store radiant energy for indefinite periods of time and particularly energy from X rays and gamma rays. This property of infra-red sensitive phosphors renders them excellently suited to the art of radiography.

Very briefly and in accordance with the spirit of our invention an infra-red sensitive phosphor plate is first placed beneath the subject to be radiographed, then a source of penetrating radiant energy is arranged to pass its radiation through the subject into the phosphor plate. The amount of energy impinging on the infra-red sensitive phosphor, and hence the energy stored thereby, is related exponentially to the thickness of the subject traversed. Thereafter and at the convenience of the operator the phosphor plate is irradiated with infra-red radiation which acts to release the stored energy in the form of light visible to the eye. The color of the light may be controlled by the composition of the phosphor and its intensity by the intensity of the infra-red radiation. If a permanent record of the latent image is desired, the infra-red radiation is passed through a standard sensitized photographic film or paper onto the infra-red sensitive phosphor plate whereby the released latent image is recorded in detail on the sensitized film.

An object of this invention is to provide a new system of radiography, whereby subjects opaque to light may first be recorded as latent images on a phosphor screen and thereafter rendered visible by subjecting such phosphor screen to infra-red radiation.

A further object of this invention is to provide a new phosphor screen suitable for use in the system of radiography taught by the invention.

Another object of this invention is to provide a method and means of making a plurality of permanent photographic records from a single latent image stored on a phosphor screen in the foregoing manner.

Other objects and features of the present invention will become apparent upon a careful consideration of the following detailed description when read in conjunction with the accompanying drawings, in which:

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Fig. 1 is a simplified diagram showing the organization of the radiographic recording equipment employed in the invention,

Fig. 2 is a simplified diagram showing the organization of the reproducing equipment employed by the invention,

Fig. 3 is a simple graph showing the intensity of the released light as a function of time and intensity of the infra-red source,

Fig. 4 is a cross sectional view of silver coated phosphor plate constructed in accordance with the teachings of the invention,

Fig. 5 is an exploded sectional view of Fig. 4, taken to illustrate the electron emission of the phosphor plate shown in Fig. 4.

Referring now in particular to Fig. 1, X-rays or other penetrating radiation 2 produced by a point source indicated at 1 are passed through a subject 3 either opaque or otherwise impervious to visible light into an infra-red sensitive phosphor screen 4, and stored in the phosphor crystals in the form of a latent image. The intensity of the X radiation and time of exposure is similar to that employed in standard X ray techniques. The subject 3 may be mechanically supported by suitable means, not illustrated, between the source of radiant energy and the phosphor screen, or alternately it may be supported directly by the plate 4. The loss of intensity of the radiant energy, passing through the subject and impinging on the infra-red sensitive phosphor, is related to the thickness of the subject traversed. For example, the area A, of the infra-red sensitive phosphor, will have absorbed or stored less energy than area B, as the intensity of the radiant energy on area A is less than on area B. The energy stored in the crystals of the infra-red sensitive phosphor, is in the form of electrons that have absorbed enough energy to pass them to the metastable energy level, and these electrons are stored until the crystals are irradiated with infra-red.

In Fig. 2 there is shown a method and apparatus for visibly reproducing an energy pattern stored on a phosphor screen, such as for example the latent image recorded by the apparatus and method of Fig. 1. In particular there is here provided a suitable source of infra-red radiation 5 arranged to, as herein exemplified, direct its radiation flux 6, uniformly intense through a sensitized photographic film 7, into the phosphor screen 4. The electrons stored in the metastable energy levels are released to move

to stable levels and in transition emit energy in the form of visible light. The latent image thus visibly reproduced is recorded in detail on the sensitized film, eliminating the process of exposing a photographic plate as an intermediate means of recording a radiograph image. The intensity of the phosphorescence will be proportional to the stored energy. Thus area A will glow less brightly than area B and will record itself on the film in corresponding differential intensity. A negative may be used instead of the sensitized film 7 whereby the latent image may be recorded using standard photographic techniques. The emulsion side of the sensitized film 7 is on the bottom side or the side adjacent to the phosphor 4. The sensitized film may be supported directly by the phosphor plate 4, or alternatively, separated at 8 by a protective transparent sheet, such as clear cellophane.

If the entire area of the subject is not desired to be recorded, a particular area of the image may be exposed separately using an infra-red spotlight for example, or by employing photographic masking technique, with the procedure just described in relation to Fig. 2, enabling the recording on film of the particular area desired. The same process can also be employed without the film for the intensification of an area of particular interest.

If no permanent record of the image is desired the same procedure outlined in relation to Figure 2 is followed, omitting the photographic film 7 and the protective paper. In this instance, the stored latent image may be viewed directly from the infra-red sensitive phosphor plate 4.

The energy decay rate of the latent image with exposure to infra-red radiation is given in Fig. 3 to which reference is now had. As will be observed from this figure, the energy of the latent image decays exponentially with time. Thus when an infra-red sensitive phosphor plate is first exposed to infra-red radiation in the process of recording the image on a photographic emulsion, each successive exposure requires increased exposure time. For instance assume the first exposure requires approximately 5 seconds, which referring to the graph Fig. 3 shows the 5 second exposure leaving approximately 1500 arbitrary light intensity units, thereby affording a second recording of the same image stored on the phosphor plate. The second exposure due to the decreased intensity of stored radiant energy will require approximately 10 seconds, which referring to the graph Fig. 3 will show approximately 700 arbitrary light intensity units remaining; thereby affording a 3rd recording of the image impinged on the same phosphor plate. The 3rd exposure due to decreased intensity of stored radiant energy will require approximately 20 seconds. Further recording is impractical but the latent image will remain visible according to the graph of the particular infra-red sensitive phosphor and the intensity of the infra-red lamp employed.

Another feature of this invention is the recording of a subject that is not stationary but moving with high velocity such as a bullet emerging from the muzzle of a gun or a detonator discharging. In this process the same procedure is followed as described in relation to Fig. 1 except, a high current condenser-discharge X-ray tube with a device for instantaneous triggering is employed as the source in 1 of Fig. 1. The X-ray tube's discharge is triggered as the subject passes over the infra-red sensitive phosphor

plate 4 thereby storing on the infra-red sensitive phosphor the latent image of the subject. The subject may then be viewed upon infra-red irradiation or recorded on film as previously described in relation to Fig. 2.

Although the construction of the phosphor screen employed by the apparatus of Figs. 1 and 2 is not critical, we have found the construction of Fig. 4 to which reference is now had, to have certain advantages and features which renders it well suited to this invention. In particular we employ a metallic base plate 12 coated on both sides and edges with silver 11. The phosphor composition, in a specific example, comprised proportions of 12 grams of phosphor, such as lanthanum oxy-sulfide; calcium selenide or strontium selenide; 200 cc. ethylene dichloride; and 1.6 grams of jasonite or any other suitable binder, thoroughly mixed and applied with an artist's small spray gun and fired at 850° C. to remove the excess binder and to render the infra-red sensitive phosphor active. A .020'' coating of the infra-red sensitive phosphor 10 was found to be sufficiently thick to produce peak luminescence. Another coating 9 of methyl methacrylate resin or acrylate and methacrylate resin .010'' thick is applied on the infra-red sensitive phosphor to protect the same when the subject is placed upon it. The metallic plate 12 can be either steel, iron alloy, bronze, or any suitable metallic material with a thickness of say $\frac{1}{32}$'' and an area suitably large for the subject to be viewed. An electron emitting coating 11, such as silver, gold, lead, or metallic oxides, is applied on both sides and all edges of the metallic plate to prevent oxidation during the processing of the infra-red sensitive phosphor. The electron emitting plating acts as a tenacious base for the infra-red sensitive phosphor coating to prevent the phosphor from chipping or peeling while cooling or during usage.

The electron emitting plated metallic plate as illustrated in Fig. 4 is also an intensifier for the infra-red sensitive phosphor, as Fig. 5 illustrates. The X radiation or other penetrating radiation 2 traverses the subject 3 and the amount of radiation 13 absorbed by the infra-red sensitive phosphor 10 is dependent upon the storage characteristics of the phosphor used. The major fraction of the X radiation or penetrating radiation passes through the infra-red sensitive phosphor at 14 and into the silver 11, where the radiation releases electrons from the silver atoms. These electrons shoot out from silver atoms at 14 and a fraction are emitted into the infra-red sensitive phosphor, where the electron energy is absorbed. The major fraction of the X radiation or other penetrating radiation passes through the silver 11 as well as the phosphor 10 and into the metal plate 12. The radiant energy releases electrons from the metal atoms at 15, while in turn each metal electron releases several silver electrons at 14. These silver electrons are emitted into the infra-red sensitive phosphor where the electron energy is absorbed. The infra-red sensitive phosphor plate is, thereby, not only activated by the direct radiation of X rays or penetrating rays, but also by the emission of electrons from the silver and the metal plate.

The electron emitting plated metallic plate also serves as an absorbing medium for excessive radiation after the radiant energy from source 1 has traversed the subject and the phosphor, thereby reducing scattered radiation that has a blurring effect on films or infra-red sensitive

phosphor screens. The metallic base also affords a rigid and protective foundation for the infra-red sensitive phosphor coating to prevent the phosphor from being easily damaged when placing heavy subjects on the phosphor.

Although we have shown and described only a certain and preferred embodiment of this invention it must be understood that the description is only to be taken as illustrative and not as a limitation on the scope of the invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. In an apparatus for making a radiographic image of an opaque object, the combination of, an infra-red sensitive phosphor screen, and a source of radiant energy having a wavelength less than 1.2×10^{-6} cm. for projecting an invisible shadowgraph in accordance with the varying opacity of said object onto said phosphor screen.

2. In a system for producing a radiographic image in accordance with the varying opacity of an opaque object; the combination of, an infra-red sensitive phosphor screen, means including a source of radiant energy having a wave length of less than 1.2×10^{-6} cm. for projecting a shadowgraph in accordance with the varying opacity of said opaque object invisible to the eye onto said phosphor screen, and means including a source of infra-red radiation for thereafter illuminating said screen whereby said shadowgraph is rendered visible to the eye.

3. In a system for producing a radiographic image in accordance with the varying opacity of an opaque object, the combination of an infra-red sensitive phosphor screen, means including a source of radiant energy having a wave length of less than 1.2×10^{-6} cm. for projecting a shadowgraph in accordance with the varying opacity of said opaque object invisible to the eye onto said phosphor screen, and means including a sensitized film and a source of infra-red radiation for thereafter illuminating said infra-red sensitive phosphor screen through said sensitized film whereby said shadowgraph is recorded as a visible image on said sensitized film.

4. In a system utilizing an infra-red sensitive phosphor screen, for producing a radiographic image of an opaque object the method which comprises, placing said object in superposed relation to said phosphor screen, illuminating said object with radiant energy having a wave length of less than 1.2×10^{-6} cm. whereby there is produced on said screen a latent image in accordance with the varying opacity of said object, and thereafter irradiating said screen with infra-red radiation thereby to release said image in the form of light visible to the eye.

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