

[54] **RESOLUTION ENHANCEMENT OF
IMAGE INTENSIFICATION SYSTEMS**

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[58] Field of Search **250/213 VT, 225**

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Primary Examiner—Archie R. Borchelt

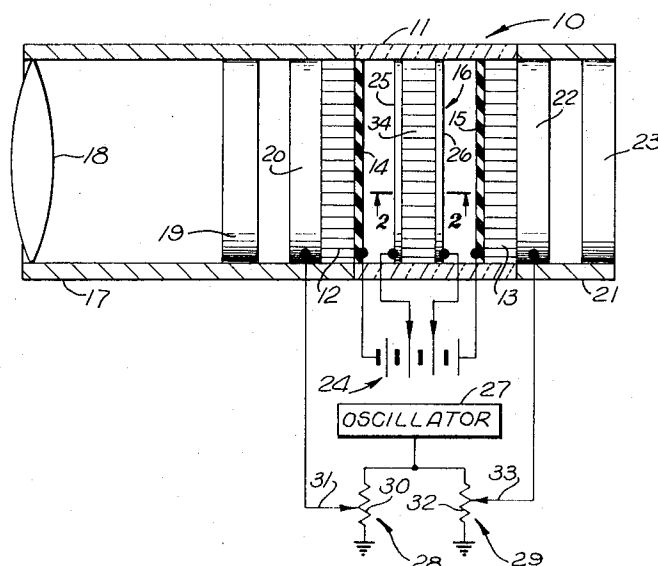
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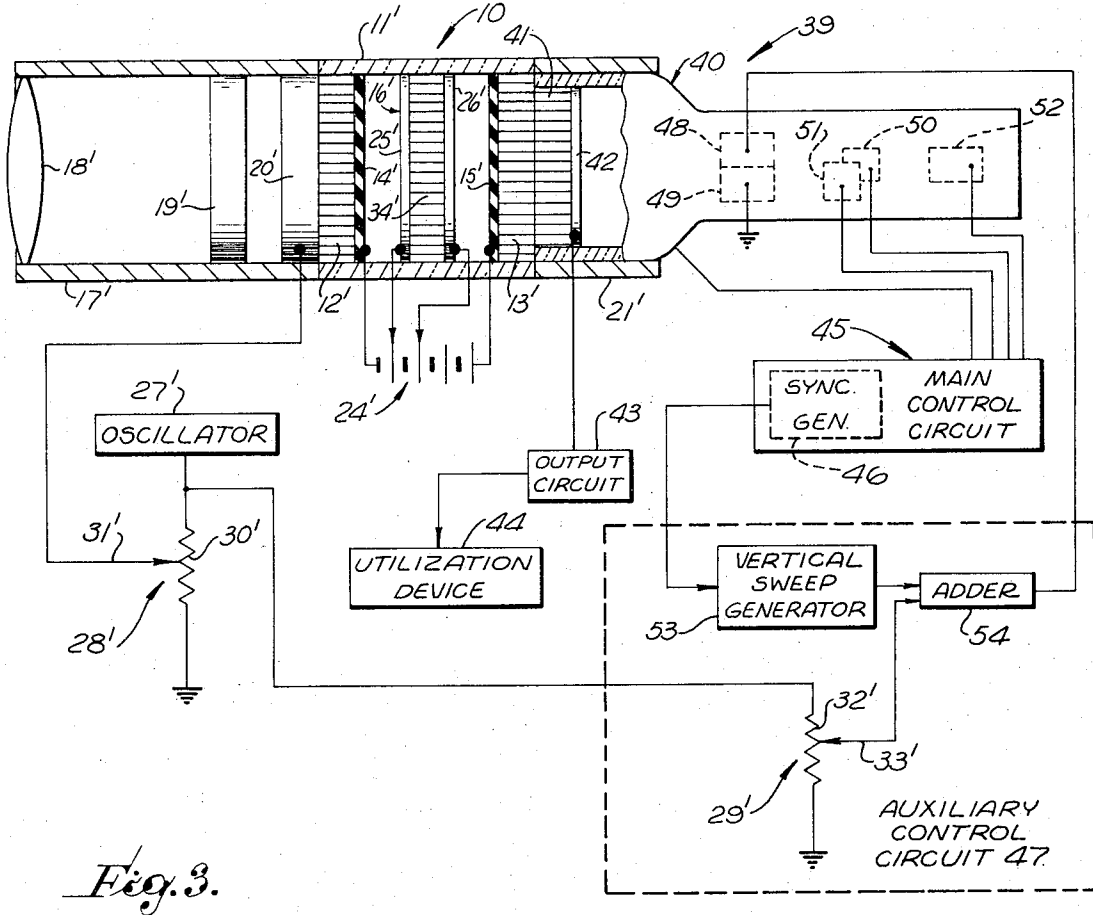
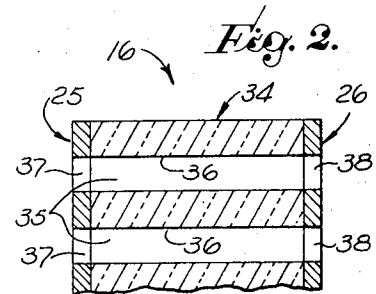
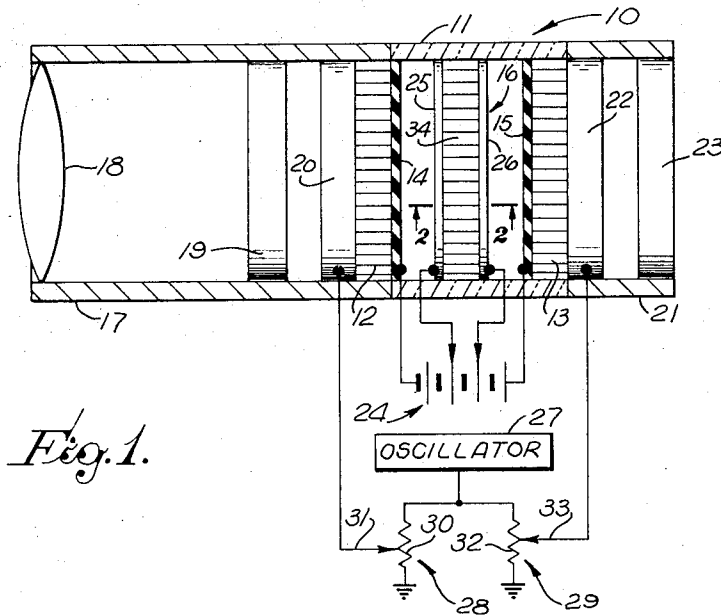
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[57] **ABSTRACT**

An image intensification system utilizing an image intensifier having a channel type electron multiplier. The light input to the intensifier is oscillated vertically up and down by an electrically active double refracting input crystal. An oscillator provides an A.C. voltage for the crystal. The light output of the intensifier is unscrambled by another such crystal at the intensifier output, which crystal also receives an input from the oscillator. That is, the intensifier oscillating output image is made to appear stationary by operation of the output crystal. Another embodiment employs a vidicon at the intensifier output, the vidicon vertical sweep being amplitude modulated in synchronism with the oscillator output. Although completely unexpected, the intensifier resolution is substantially improved.

25 Claims, 3 Drawing Figures





RESOLUTION ENHANCEMENT OF IMAGE INTENSIFICATION SYSTEMS

BACKGROUND OF THE INVENTION

This invention relates to tubes employing channel type electron multipliers, and more particularly, to an image intensification system for producing an image or image data having an unusually high resolution.

In the past, a system was previously derived to improve the resolution of an image intensifier employing a channel type electron multiplier. See copending application Ser. No. 797,372 filed Jan. 30, 1969, by R. K. Orthuber for MULTICOLOR DIRECT VIEW DEVICE. This system includes means for oscillating the intensifier. The improvement in resolution in this case is very substantial and unexpected. However, damage to intensifier component parts is possible. A more rugged and more expensive tube can, therefore, be required. Further, reliability can be a problem and the system has all the other complexity, expense, repair and other disadvantages of an electromechanical arrangement which the prior art system incorporates.

SUMMARY OF THE INVENTION

In accordance with the system of the present invention, the above-described and other disadvantages of the prior art are overcome by connecting the output of an oscillator to input and output crystals located at the input and output, respectively, of an image intensifier, or by employing a vidicon or other device at the intensifier output and modulating the amplitude of at least one deflection signal in synchronism with the oscillator output.

In either case, the image intensifier is of the type which employs a channel type electron multiplier.

Both crystals need not be employed when a vidicon is used. In any event, all of the crystals may be electrically active double refracting or birefringent crystals. Such crystals are, by themselves and not in the system of the present invention, entirely conventional. Such crystals and their uses are described in many places in the prior art, one such place being in Volume 9, No. 6, November 1966, IBM Technical Disclosure Bulletin. See also copending application Ser. No. 65,614, now U.S. Pat. No. 3,639,684 filed Aug. 20, 1970, by A. M. Levine for FIELD SEQUENTIAL LASER SCAN FOR NIGHT COLOR TELEVISION.

In accordance with the present invention, it is an outstanding advantage that the image intensifier employed in the system of the present invention has much improved resolution. Although this is completely unexpected, it is believed that a mechanism must be at work, which mechanism may be, in a few respects, similar to that by which resolution is improved by actually gyrating or moving the intensifier by the means previously described.

It is also substantially unexpected that the linear light oscillation or image oscillation produced by the input crystals alternately in two opposite directions would improve resolution.

The above-described and other advantages of the present invention will be better understood from the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which are to be regarded as merely illustrative:

FIG. 1 is a longitudinal sectional view of an image intensification system, partly in elevation, constructed in accordance with the present invention;

FIG. 2 is a transverse sectional view of a channel type electron multiplier shown in FIG. 1; and

FIG. 3 is a longitudinal elevational view, partly in section, of another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, an evacuated envelope is indicated at 10 including a glass cylinder 11, and fiber optics input and output windows 12 and 13, respectively. By themselves, windows 12 and 13 may be entirely conventional as may be all other fiber optics windows disclosed herein.

A photocathode layer 14 is fixed to the interior surface of window 12. A phosphor screen layer 15 is fixed to the internal surface of window 13. A channel type electron multiplier 16 is fixed relative to envelope 10 inside thereof between and in spaced relation to layers 14 and 15 on the input and output sides thereof, respectively. A cylinder 17 is fixed relative to envelope 10 on the left end thereof. Cylinder 17 supports a lens 18 at the left end thereof, a polarizer 19 and an electrically active double refracting input crystal 20.

Polarizer 19 is located between and spaced from each of lens 18 and crystal 20.

Crystal 20 is supported in a position which may be in contact with window 12.

At the right end of the assembly of FIG. 1, a cylinder 21 is fixed relative to envelope 10 and carries a crystal 22 which may be or may not be identical to crystal 20, as desired. Cylinder 21 also supports an analyzer 23 which may, in fact, be a polarizer, depending upon definition. That is, for example, analyzer 23 may or may not be precisely identical to polarizer 19, as desired.

Again, crystal 22 may abut the face of window 13.

Envelope 10 and the structures contained therein may be defined as an image intensifier. The image intensifier may be operated, as is conventional, by a source of potential 24, whereby layer 14 is maintained at the lowest potential; the potential of an input electrode 25 of multiplier 16 is maintained at a potential higher than that of layer 14; the potential of an output electrode 26 of multiplier 16 is maintained at a potential higher than that of electrode 25; and layer 15 is maintained at a potential higher than that of electrode 26.

An oscillator 27 is provided to operate crystals 20 and 22. Oscillator 27 may produce an output signal which is an alternating voltage having a sawtooth, a triangular wave, a sine wave or another shape.

Sometimes it may be desirable to adjust the amplitudes of the signals applied to crystals 20 and 22, which adjustment may or may not be employed or provided, as desired. However, as shown in FIG. 1, one or more potentiometers 28 and 29 may be connected from oscillator 27 to ground, if desired. Potentiometer

28 has a winding 30 and a wiper 31. Potentiometer 29 has a winding 32 and a wiper 33. Wiper 31 is connected to crystal 20, and wiper 33 is connected to crystal 22.

Channel type electron multipliers are old in the art, by themselves. For example, see U.S. Pat. No. 3,541,254. However, the section of FIG. 2 shows multiplier 16 in somewhat greater detail. Multiplier 16 has a dielectric plate 34 upon which conductive layers are evaporated to form electrodes 25 and 26. Plate 34 has a multitude of holes 35 extending completely therethrough. Plate 34 thus has cylindrical internal surfaces 36 at least partially defining holes 35, surfaces 36 being secondary emissive.

As shown in FIG. 2, input electrode 25 has holes 37 extending completely therethrough in registration with holes 35 of plate 34.

Output electrode 26 also has holes 38 which lie in registration with the plate holes 35.

When electrons enter multiplier 16 through holes 37 in input electrode 25, such electrons impact the surface 36 near input electrode 25. Secondary electrons are then released. Electron multiplication then occurs so that the current output in the vicinity of one output electrode hole 38 is a great many times larger than the input current through the corresponding input electrode hole 37.

In the operation of the invention of FIG. 1, oscillator 27, for example, applies a sine wave signal to crystal 20. Crystal 20, at all times, passes an image to window 12 which is an image of the field of view. However, the application of the output signal of oscillator 27 to crystal 20 causes the image on window 12 to be shifted back and forth alternately in two opposite directions.

The frequency of oscillator 27 is by no means critical. The frequency of oscillator 27 may be, if desired, sufficiently high so as to obtain all substantial resolution improvement, if desired. However, it may be convenient to keep the frequency of oscillator 27 relatively low. No substantial disadvantages are attendant upon the use of a low frequency oscillator 27. Since, as will be described, there is a certain synchronism, the frame rate relative to the naked eye is not important. That is, the frequency of oscillator 27 is wholly independent of the persistence of vision. However, at a relatively low oscillator frequency, it will be understood that electron transit time problems do not exist. If the oscillator frequency is too low, insufficient resolution improvement may result. A typical, although not critical, frequency for oscillator 27 might be 16 Hz. However, a range lower or higher than 10 Hz to 20 Hz is possible.

Note will be taken that in order for crystal 20 to be operated in a manner to shift the image on window 12 coherently, light must be linearly polarized by polarizer 19 when crystal 20, for example, oscillates the image on window 12 vertically up and down. Similarly, polarizer 23 must be positioned so as to provide polarized light polarized in the same direction as light emitted from the right side of polarizer 19.

OPERATION OF THE EMBODIMENT OF FIG. 1

In the operation of the system of FIG. 1, polarizer 19 polarizes the light output of lens 18. Oscillator 27 then causes the image on window 12 provided through crystal 20 to oscillate up and down. Since multiplier 16 is fixed relative to the moving image on window 12, it is

true that current multiplication takes place in different holes 35 for the same image spot or elemental area, but the result is only that the image produced on the right face of window 13 also oscillates. Phosphor layer 15, which is a luminescent screen, contains phosphors which are sufficiently fast to follow the motion produced at the frequency of oscillator 27.

Crystal 22 is controlled so as to effectively follow the moving image on the right face of window 13. The result then is, at the right hand surface of polarizer 23, a stationary image of improved resolution.

THE ALTERNATIVE EMBODIMENT OF FIG. 3

All the structures shown in FIG. 1 may be employed in the embodiment of FIG. 3 with the exception of crystal 22 and polarizer 23. Parts 10' to 34', inclusive, in FIG. 3 may be identical to parts 10 to 34, inclusive, respectively, except for parts 22 and 23, as aforesaid. However, there is one other exception. Since crystal 22 is missing in FIG. 3, potentiometer wiper 33' in FIG. 3 is not connected to any crystal, whereas potentiometer wiper 33 in FIG. 1 is connected to crystal 22. In FIG. 3, a number of other structures are shown in addition to the structure of FIG. 1.

In FIG. 3, a vidicon is shown at 39 including an evacuated envelope 40 closed at its left end by a fiber optics window 41. The left end of envelope 40 including window 41 abuts window 13'. A photoconductive layer 42 is fixed to window 41 inside envelope 40. Envelope 40 is fixed relative to cylinder 21'. Layer 42 is connected to an output circuit 43. Output circuit 43 may be connected to any kind of utilization device 44 such as a kinescope for closed circuit television or a television transmitter.

The system of the present invention is by no means limited to either electrostatic or magnetic deflection of the vidicon electron beam. Although magnetic deflection is most commonly used, electrostatic deflection has been illustrated as the simplest mode of practicing the invention.

A main control circuit 45 is connected from tube 39. Circuit 45 has a sync generator 46. An auxiliary control circuit 47 is connected from circuit 45 to a vertical deflection plate 48. The other vertical deflection plate 49 is connected to ground.

Tube 39 has horizontal deflection plates 50 and 51. Tube 39 also has an electron gun 52. Circuit 47 includes a vertical sweep generator 53 and an analog adder 54. Circuit 47 also includes the potentiometer 29', the wiper 33' of which is connected to one input of adder 54. Adder 54 has a second input from the output of vertical sweep generator 53. The output of sync generator 46 is connected to the input of vertical sweep generator 53. The output of adder 54 is connected to the vertical deflection plate 48.

OPERATION OF THE EMBODIMENT OF FIG. 3

In the operation of the embodiment of FIG. 3, the image on the left hand face of window 12' is oscillated up and down by the control of crystal 20' through oscillator 27', as before. An oscillating image then appears on the right hand face of window 13'. Light emanating from layer 15' thus passes through window 13' and still appears as an oscillating image on the left hand face of vidicon window 41.

Tube 39 may be entirely conventional. However, if auxiliary control circuit 47, or some other means were not provided, the video output of vidicon 39 would represent an oscillating image. Thus, what circuit 47 does is to obtain a video output which is exactly the same as it would do so if the image displayed on the left hand face of the vidicon window 41 were stationary. This is done by modulating the vertical position of the electron beam of vidicon 39 in synchronism with the oscillation of the image on the left hand face of the vidicon window 41. Modulation is performed simply by adding to the conventional output of a conventional vertical sweep generator, a signal which is directly proportional to the output voltage of oscillator 27'.

From the foregoing, it will be appreciated that vidicon 39 may be entirely conventional. The same is true of circuit 45 including sync generator 46, output circuit 43, utilization device 44 and vertical sweep generator 53. However, it is only vertical sweep generator 53, by itself, that is conventional. It is not the connection thereof in circuit 47. The same is true of adder 54 and potentiometer 29'.

The phrase "means to maintain at a potential" is hereby defined for use herein and in the claims to mean source 24, only the conductive leads connected from source 24, or neither.

Although oscillation up and down of images has been described in a vertical direction, it is to be understood that such oscillation may take place in any direction as long as the invention is practiced as taught hereinabove.

The phrase "electrically active double refracting crystal" is hereby defined for use herein and in the claims to mean any device which is transparent to light and will shift the position thereof at the output from that at the input as a function of the magnitude of a signal applied thereto. Thus, the phrase "electrically active double refracting crystal" includes a birefringent crystal.

In FIG. 3, polarizer 19' may be oriented to vertically polarize light passing therethrough.

What is claimed is:

1. In an image intensification system, the combination comprising: intensifier means, an evacuated envelope having spaced front and rear transparent windows; a photocathode layer fixed relative to said front window contiguous thereto inside said envelope; a luminescent screen layer fixed relative to said rear window contiguous thereto inside said envelope; a channel type electron multiplier fixed relative to said envelope inside thereof between said windows; a first light polarizer; means to support said first polarizer in a position adjacent to said front window to polarize light directed theretoward; a second light polarizer; means to support said second polarizer in a position adjacent said rear window at least a first transparent device, said device being actuable to shift light passing therethrough in a predetermined direction an amount which is a function of the magnitude of a signal applied thereto; means to support said first device in a position adjacent to said front window and actuable to shift the position of light falling on said front window relative to its corresponding position on the opposite side of said first device; utilization means fixed relative to said second polarizer to receive the light passing

therethrough which emanates from said rear window; and oscillator control means connected to said first device and to said utilization means to operate them synchronously, said control means causing said first device to oscillate the image at said rear window via said intensifier means, said control means synchronous operation of said utilization means with said first device causing said utilization means to follow synchronously the said oscillating rear window image.

2. The invention as defined in claim 1, wherein said utilization means includes a second transparent device actuable to shift light passing therethrough an amount which is a function of the magnitude of a signal applied thereto, and means to support said second device in a position adjacent to said rear window and actuable to shift the position of light emanating, a second polarizer fixed relative to said second device on the side thereof opposite that on which said rear window is positioned, both of said polarizers being positioned to polarize light in the same direction.

3. The invention as defined in claim 2, wherein said first and second devices include electrically active double refracting crystals, said control means including an oscillator connected to both of said first and second devices to cause light passing therethrough to be shifted in an oscillatory manner in one of two opposite directions and in synchronism, the amplitudes of the light shifts through said devices being in accordance with the amplitude of the alternating output signal of said oscillator, said oscillator being connected to said first and second devices and both of said first and second devices being mounted in a manner such that they shift light passing therethrough in synchronism in the same direction, said second device having a shift amplitude the same as the image on said luminescent screen layer.

4. The invention as defined in claim 3, wherein said first device is positioned contiguous to said first window, said first device being positioned between said first polarizer and said front window, said first polarizer being spaced from said first device, lens means, means to support said lens means adjacent said first polarizer on the side thereof opposite the side on which said first device is positioned, said second device being positioned contiguous to said rear window, said second device being positioned between said rear window and said second polarizer.

5. The invention as defined in claim 4, wherein said multiplier includes a dielectric plate having holes therethrough extending approximately in a direction from said front window to said rear window, said plate having internal surfaces at least partially defining said holes, said internal surfaces being secondary emissive, a front conductive electrode fixed relative to said plate on the front window side thereof, a rear conductive electrode fixed relative to said plate on the rear window side thereof, both of said electrodes having holes therethrough which lie in registration with said plate holes.

6. The invention as defined in claim 5, wherein said electrodes are layers evaporated onto opposite sides of said plate, and means to apply successively higher potentials to said layers, said front electrode potential being greater than that of said photocathode layer and less than that of said rear electrode potential, said lu-

minescent screen layer having a potential greater than that of said rear electrode.

7. The invention as defined in claim 1, wherein said utilization means includes an image tube having scanning means connected from said control means to modulate the scan thereof in synchronism with the shift of light produced by actuation of said first device and to compensate for the image movement on said luminescent screen produced by said first device actuation.

8. The invention as defined in claim 7, wherein said image tube is a vidicon having a main control circuit connected therefrom, said main control circuit including a sync generator, said control means including an oscillator having its output connected to said first device, and an auxiliary control circuit connected from said oscillator output and from the output of said sync generator, said vidicon having means to produce an electron beam and vertical and horizontal deflection means to deflect said beam, said auxiliary control circuit including means to supply a signal to at least one of said deflection means to cause modulation of the position of said beam in synchronism with and in the same direction and amplitude as the shift in the image on said luminescent screen layer produced by the shift of light through said first device, said shift of light through said first device being oscillatory in nature in one of two opposite directions and of an amplitude which is a function of the amplitude of the alternating output signal of said oscillator.

9. The invention as defined in claim 8, wherein said first device includes an electrically active double refracting crystal.

10. The invention as defined in claim 9, wherein said auxiliary control circuit means includes a vertical sweep generator connected from said sync generator, and an adder connected from said vertical sweep generator and said oscillator to said vertical deflection means, said oscillator being connected to said first device and said first device being positioned in a manner to shift light in a vertical direction.

11. The invention as defined in claim 10, wherein said first device is positioned contiguous to said first window, said first device being positioned between said first polarizer and said front window, said first polarizer being spaced from said first device, lens means, means to support said lens means adjacent said first polarizer on the side thereof opposite the side on which said first device is positioned.

12. The invention as defined in claim 11, wherein said multiplier includes a dielectric plate having holes therethrough extending approximately in a direction from said front window to said rear window, said plate having internal surfaces at least partially defining said holes, said internal surfaces being secondary emissive, a front conductive electrode fixed relative to said plate on the front window side thereof, a rear conductive electrode fixed relative to said plate on the rear window side thereof, both of said electrodes having holes therethrough which lie in registration with said plate holes.

13. The invention as defined in claim 12, wherein said electrodes are layers evaporated onto opposite sides of said plate, and means to apply successively higher potentials to said layers, said front electrode

potential being greater than that of said photocathode layer and less than that of said rear electrode potential, said luminescent screen layer having a potential greater than that of said rear electrode.

14. The invention as defined in claim 1, wherein said windows are both fiber optics windows.

15. The invention as defined in claim 3, wherein both of said windows are fiber optics windows.

16. The invention as defined in claim 7, wherein both of said windows are fiber optics windows, said image tube including an evacuated envelope having a fiber optics image receiving window positioned adjacent said rear window outside said envelope.

17. The invention as defined in claim 16, wherein said image tube window is positioned contiguous to said rear window.

18. The invention as defined in claim 8, wherein both of said windows are fiber optics windows, said image tube including an evacuated envelope having a fiber optics image receiving window positioned adjacent said rear window outside said envelope.

19. The invention as defined in claim 18, wherein said second image tube window is positioned contiguous to said rear window.

20. In an image intensification system, the combination comprising: an evacuated envelope having a light input window and a light output window; input means including an input device mounted in front of said input window and adjacent thereto and actuable to oscillate a beam of light thereon; an oscillator; and output means mounted to the rear of said output window and adjacent thereto, said oscillator being connected to said device and said input device being connected and positioned in a manner such that the image on said input window produced by the passage of light to said input window oscillates in synchronism with the output signal of said oscillator, the oscillation of the image on said input window causing the image on said output window to oscillate synchronously therewith, said output means including compensation means connected from said oscillator to follow said output window image in synchronism therewith in a manner to unscramble the same and to produce a sensed output as though said output window image were stationary.

21. The invention as defined in claim 20, wherein said compensation means is an output device mounted to the rear of said output window and adjacent thereto and actuable to oscillate a beam of light emanating therefrom, and a channel type electron multiplier fixed relative to said envelope inside thereof between said windows.

22. The invention as defined in claim 21, wherein each of said devices includes a birefringent crystal.

23. The invention as defined in claim 20, wherein said compensation means includes a vidicon including an evacuated envelope having a light input window, a photoconductive layer fixed relative to said vidicon envelope inside thereof contiguous to said window thereof, said vidicon envelope window being fixed adjacent said output window, an electron gun fixed relative to said vidicon envelope inside thereof to produce an electron beam to scan said photoconductive layer, a main control circuit including a sync generator, a vertical sweep generator connected from said sync generator, vertical sweep deflection means for said vidicon,

and means connected from said oscillator and said vertical sweep generator to said vertical sweep deflection means to oscillate said electron beam vertically up and down in synchronism with the oscillation of the image on said input window, said input device being actuated to oscillate the image on said input window vertically up and down.

24. The invention as defined in claim 23, including a channel type electron multiplier fixed relative to said envelope inside thereof between said windows.

25. The invention as defined in claim 23, wherein said input device includes a birefringent crystal.

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