VARIABLE TRANSMISSION SYSTEM CATHODE RAY TUBE

Filed March 11, 1966

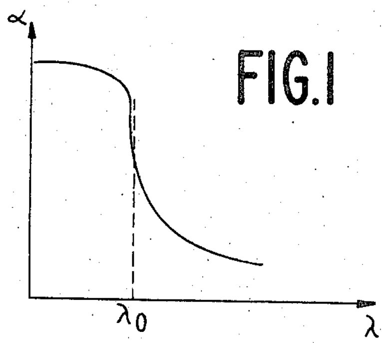


FIG.1

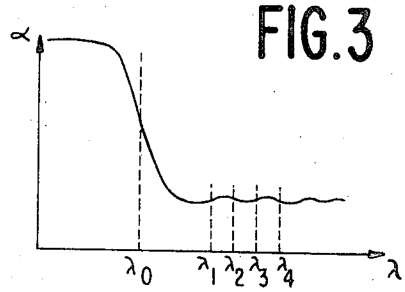


FIG.3

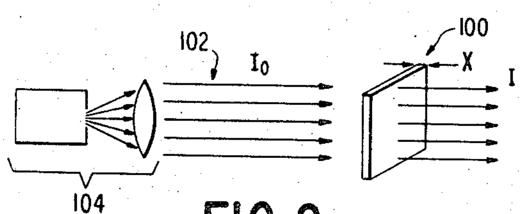


FIG.2

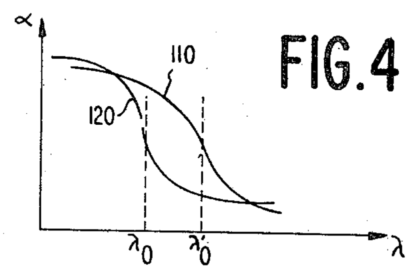


FIG.4

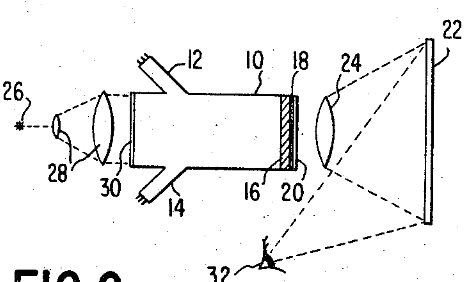


FIG.6

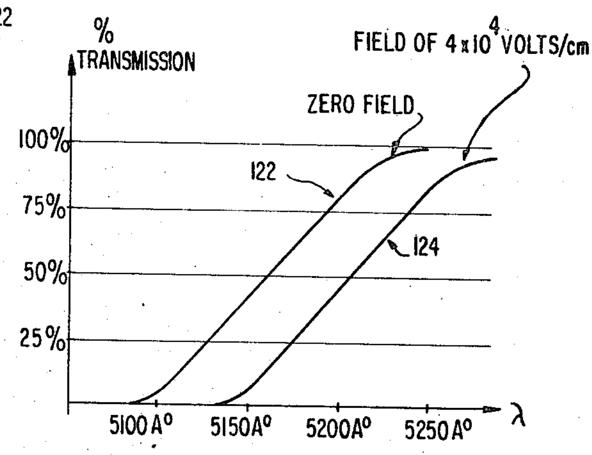
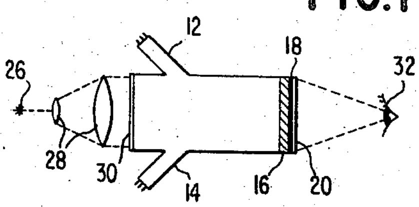


FIG.5

FIG.7



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VARIABLE TRANSMISSION SYSTEM CATHODE RAY TUBE

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ABSTRACT OF THE DISCLOSURE

Information in the form of an electrical signal is converted into visual information by selectively applying potentials proportional to the electrical information to selected areas of an electric field dependent variable transmission layer having an optical absorption edge in the visible region. A source of light floods the variable transmission layer and the amount of light passed through the layer at any point thereon is dependent upon the field strength through the layer at that point. The potential or field strength is varied by placing a common transparent electrode on one surface of the layer and creating potential differences at selected areas on the other surface of the layer by means of an electron beam which creates secondary emission at the latter surface.

The present invention relates to cathode ray tubes having target layers which are variable transmission layers.

In a typical cathode ray tube, a stream of electrons is produced by an electron gun and is directed to certain points on a target layer by a deflecting means having deflecting voltages or currents applied thereto. The target layer typically consists of a material which responds to the electron beam to give off light. For example, in a television system, proper voltages are applied to the deflecting means to produce a raster type scan and the pattern of light and dark spots produced on the target layer is controlled by the amplitude of the signal applied to the grid of the electron gun. In other words, the CRT selectively varies the light intensity in spot-sized areas of the CRT phosphor.

In the present invention, instead of using as the target material a layer of material which responds to bombardment by an electron beam to give off light of varying degrees of luminescence, the target layer is a layer of variable transmission material. The term "variable transmission layer" or "variable transmission material" is used herein to describe a material with an optical absorption edge in the visible light region of the spectrum wherein the transmisison of light in the vicinity of the absorption edge is strongly electric field dependent. In other words, for a given VTL (variable transmission layer) having a given optical absorption edge, there is a certain spectrum of visible light frequencies whose transmission through said VTL is strongly dependent upon the electric field across the VTL. Large numbers of such material exist, for example, cadmium sulphide, cadmium selenide, zinc cadmium sulphide mixed crystals in various proportions to yield optical absorption edges from the ultra-violet absorption edge of zinc sulphide to the cadmium sulphide absorption edge at approximately 5200 angstroms, and mixed crystals of cadmium sulphide-cadmium selenide in various proportions to yield optical absorption edges from the cadmium sulphide edge at 5200 angstroms to the cadmium selenide edge at approximately 7200 angstroms.

The variable tranmsission system cathode ray tube has many functions which cannot be performed by the prior art cathode ray tubes, but a basic difference between the prior art cathode ray tubes and the present invention can

be readily understood by noting the fact that in the prior art cathode ray tubes, the combination of the target material, the electron gun and the proper control and deflection voltages produces a picture such as seen on a TV screen, whereas in the present invention, the combination of the target material, the electron gun, and the proper control and deflection voltages produces a transparency.

By using a source of incoherent light as the light source to which the VTL provides variable transmission, a television image may be projected onto a very large viewing screen. Also, if a coherent light source, such as a laser beam, is used as the light to which the VTL has a field dependent transmission pattern, and further if the electron beam is controlled to cause the VTL to be a holographic transparency of an object or scene, a super-three-dimensional picture of the object or scene can be observed. (The suject of holograms and the use of holograms to reconstruct visual information about an object or a scene is thoroughly discussed in the literature. One particular article which may be of interset because it discusses in general terms the formation of holographic transparencies is, "Photography by Laser," by Leith and Upatnieks, Scientific American, June 1965, vol. 212, No. 6, page 24.)

It is, therefore, an object of the present invention to provide a cathode ray tube having a target material which is responsive to the electric fiield thereacross to vary its transmission to certain frequency spectrum of light.

It is an object of the present invention to provide a display apparatus which is capable of projecting information onto a viewing screen.

A further object of the present invention is to provide a display apparatus capable of providing a real three-dimensional view of a distant or no longer existing scene.

A still further object of the present invention is to provide a device which converts a layer of material having an optical absorption edge in the visible light spectrum into a transparency having a desired pattern.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings, wherein:

FIG. 1 is an idealized graph of absorption coefficient versus wavelength for a typical material which may be used as the target layer in the present invention;

FIG. 2 is a diagram illustratng an example of how the graph of FIG. 1 is determined;

FIG. 3 is also a graph of absorption coefficient versus wavelength for a typical material which may be used as the target layer in the present invention;

FIG. 4 is graph illustrating the effect of electric field on the optical absorption edge;

FIG. 5 is a graph of transmission versus wavelength for cadmium sulphide;

FIG. 6 is a side view of a preferred embodiment of the invention capable of use in the projection mode; and

FIG. 7 is a side view of a preferred embodiment of the invention capable of use in the direct observation mode.

A typical absorption versus wavelength diagram is shown in FIG. 1 where α is the coefficient of absorption and is defined by the following equation:

$$I=I_0e^{-\alpha x} \quad (1)$$

The curve shown in FIG. 1 is developed from the experiment illustrated in FIG. 2.

A plate of material **100** of uniform thickness is set in a manner that allows it to intersect a parallel light beam **102** on its face. The intensity of the incident light on the surface is defined as I_0, the light leaving the back face as

I. The wavelength of the parallel light beam is varied by variable light source **104** and I and I_o are measured at every wavelength of the incident light.

Equation 1 may be rewritten as

$$\ln\left[\frac{I_o}{I}\right]=\alpha_x \quad (2)$$

where the natural log of Equation 1 has been taken. Since x represents the thickness of the plate of material, it may be replaced by the actual value δ. Thus

$$\alpha=\frac{I}{\delta}\ln\left[\frac{I_o}{I}\right] \quad (3)$$

I_o, I and δ are measured values and α is calculated directly from Equation 3. Note large α implies low transmission, small α implies high transmission.

As the wavelength of the incident light is varied, α changes as shown in FIG. 1. For λ less than λ_o, α is large; for λ greater than λ_o, α is small. The region around λ_o where α is rapidly varying with changing wavelength is defined as the absorption edge region. Although there are several accepted definitions of absorption edge, for the purpose of this specification the term "absorption edge" is defined as the "point of inflection" of the curve shown in FIG. 1. This is the wavelength at which the second derivative of α with respect to λ goes to zero and is depicted as λ_o in FIG. 1, i.e.

$$\frac{\partial^2\alpha}{\partial\lambda^2}=0 \quad (4)$$

defines λ_o, the absorption edge.

It should be noted that FIG. 1 is an idealized picture of what actually occurs. There may in fact be other local variations in α as is shown in FIG. 3.

Thus there will be other values of λ where Equation 4 is satisfied, as shown by λ_1, λ_2, λ_3, and λ_4 in the figure. One type of effect which brings about electric field dependent optical absorption is associated with the band gap energy of the crystal. That is, the difference in energy between the lowest energy of the conduction band and the highest energy of the valence band. The effect at λ_o as seen in FIG. 3 is very different than at $\lambda_1 \ldots \lambda_4$, since it separates a general area of high α from one of low α.

FIG. 4 depicts the change in the absorption edge due to the application of an electric field to the material under investigation.

Curve **110** represents the characteristic of the material when an electric field is applied thereto, and curve **120** represents the zero field characteristic. The shift of absorption edge from λ_o to λ_o^1 permits the construction of a variable transmission layer. For purposes of definition, λ_o is defined as the zero field absorption edge. As the electric field is applied to the material, light having wavelengths slightly longer than λ_o will no longer be transmitted through the material. By varying the electric field and flooding the material (VTL) with light of wavelengths slightly longer than the zero field absorption edge, the output light intensity, I, may be varied.

In its simplest form as shown in FIG. 6, the invention provides a two-dimensional two-color image capable of being projected onto a viewing screen, wherein the two colors are black and a color corresponding to the frequency of light which is used. The cathode ray tube housing **10** includes a first and second electron gun and deflection circuitry arrangements indicated generally by the numerals **12** and **14**, a target layer of VTL material **16**, a thin layer of electrically conductive material **18**, and two transparent glass windows **20** and **30**. A projection lens system indicated generally by lens **24** is provided to direct the light passing through the window **20** onto a viewing screen **22**, whereby the image thereon may be viewed by an observer **32**. An incoherent light source **26** is placed with respect to collimating lens system **28** and glass window **30** to flood the VTL target layer **16**.

As stated previously, the VTL material may be any material having an optical absorption edge in the visible light region of the spectrum, wherein the transmission of light in the vicinity of the absorption edge is strongly electric field dependent. The entire screen may be formed by first depositing a transparent uniformly-thick conducting layer **18** on the inner face of the transparent window **20** of cathode ray tube **10**. Such layers are well-known in the art and usually consist of tin oxide with dopants to produce the desired transparency and conductivity. The VTL is then deposited onto the conducting layer **18** by vacuum deposition, as is well known in the art, or by any other means that results in a controlled thickness layer of the VTL material that is transparent to light of longer wavelength than the absorption edge. The desired thickness of the layer depends upon the specific material and the light source used.

The requirements for light source **26** are primarily associated with its wavelengths spectrum. The spectrum must be confined to a narrow region starting with wavelengths slightly longer than the absorption edge. This can be readily accomplished with a tungsten light source and appropriate filters. Other examples of light sources which may be used, although it is to be understood that the invention is not to be limited to their use, are a suitably filtered mercury arc and a suitably pulsed and filtered xenon flash tube. The lens system **28** is provided to collimate the light from light source **26** so that the VTL is uniformly illuminated.

With reference to the embodiment described in FIG. 1, the light source **26** chosen to illuminate the VTL is filtered so that only radiation of longer wavelength than the absorption edge is used. Under application of an electric field the absorption edge shifts, as indicated in FIG. 4, to longer wavelengths reducing the amount of transmitted light. For example, referring again to FIG. 4, assume the combination of light source and filters floods the VTL **16** with light having a spectrum from $\lambda_o+\Delta$ to $\lambda^1_o-\Delta$ where Δ is some small wavelength increment. Also assume that λ^1_o is the absorption edge of the VTL for an applied electric field strength of E. If zero field is applied to the VTL substantially all of the light would be transmitted; if E field is applied to the VTL substantially all of the light would be absorbed; for a varying electric field between E and zero, corresponding varying amounts of light would be transmitted through the VTL.

In operation, the first of the two electron guns, for example, electron gun **12**, is set to spray electrons uniformly onto the entire VTL **16**. Gun **12** is adjusted to spray electrons of the proper energy to effect secondary emission from the inner surface of the VTL and, therefore, positive charging of that surface results. The tin oxide conducting layer **18** is electrically grounded, so that the positive surface charge produces a uniform strong electric field across the entire VTL surface directed across the thickness of the VTL. Since the wavelength of the light which floods the VTL is slightly longer than the absorption edge of the material used for the VTL and, further, since the transmission of the VTL decreases for wavelengths longer than the absorption edge in response to an electric field, none of the light flooding the VTL passes therethrough and thus the viewing screen is darkened.

The second electron gun, for example gun **14**, provides focused stream of electrons which scans the VTL in a pattern dictated by the deflection circuity as is well known in the CRT art. The spray of electrons by the second gun onto different spots on the surface of the VTL tends to neutralize the positive charge on the VTL at those spots thereby making the VTL at those spots transparent to the light from source **26**. Thus, the picture information, or video amplitude information is substantially the same as in ordinary TV displays and is applied to the grid electrode of the electron gun. However, in the present invention, the amplitude of the signal applied to the grid electron gun varies the transparency of the VTL rather than the luminescence of a phosphor layer.

The energy of the second electron beam is adjusted so that the electrons sprayed onto the surface of the VTL stick to that surface, thereby neutralizing the surface charge developed by the first gun. As the second gun scans the VTL, the first gun is continually spraying the surface, causing a rebuild-up of the strong electric field and a reduction in the intensity of the light transmitted therethrough. The rate of build-up of this electric field is adjusted to accommodate the rate at which the second gun scans the screen. Thus, when the second gun starts its second scan of the screen, it traverses that portion of the screen which has been completely recharged and is opaque to the light source.

No particular electron beam gun and deflection means are described in this specification because such components are well known in the prior art and it is not intended that the invention be limited to any particular type of electron gun and/or deflection circuitry.

In constructing the cathode ray tube of the present invention the light source **26** and the collimating lens may be suitably positioned inside the housing **10**, or they may be positioned outside the housing as indicated in the drawing.

A variation of the two-dimensional image producing embodiment of FIG. 6 is to use a single electron gun wherein the electron beam emanating from the single gun is focused, deflected and modulated, so that it only charges areas of the VTL which are to be made opaque. There will be a natural discharge (due to the finite conductivity of the VTL) through the thickness of the VTL. The conductivity, and hence the characteristic discharge time of the VTL may be adjusted by suitable doping to match the scan rate of the electron beam.

Another alternative is to use two electron guns but instead of continuously spraying the entire surface of the VTL with electrons from the bias gun, deflection and focusing means for the bias gun are provided so that a second electron beam is formed and scans the VTL. In this embodiment, the modulated beam trails the bias beam in the scan process by a predetermined time increment. The leading beam is adjusted to charge the VTL, resulting in a loss of transmission, and the trailing beam, which is the modulated beam, restores the transmission selectively to produce the desired transmission pattern. In this manner, the average light output on the viewing screen is greater than that produced by the first described embodiment without changing the light source or the optics.

A further alternative, using the two electron guns, is to operate the gun which sprays electrons onto the entire screen such that the screen is sprayed and thereby totally charged only for a short interval after each completed scan of the focused and modulated beam.

It should also be noted that in all embodiments, increased resolution on the screen may be achieved by providing a third layer of material, consisting of a thin transparent insulating material coextensive with the VTL and located closest to the electron beam. This layer would be designed to have an extremely low surface conductivity and would, therefore, prevent the spread of surface charges on the VTL.

As a specific example, CdS having a thickness of one micron would produce a curve of transmission

$$(I/I_0 \times 100\%)$$

versus wavelength under zero field conditions as indicated by curve **122** in FIG. 5. With an electron beam adjusted to charge the CdS film from 0 to 4 volts, thereby producing a maximum field strength of

$$4 \text{ volts}/1 \text{ micron} = 4 \times 10^4 \text{ volts/cm.}$$

the curve of transmission versus wavelength under the greatest field conditions (4×10^4 volts/cm.) would resemble curve **124** of FIG. 5. For a light source, a xenon arc lamp having its output filtered by a narrow band pass filter to produce a peak wavelength of 5135 A. and

a half bandwidth of 20 A. may be used. Under the above conditions, the device would have contrast ratios of 5/1 or higher with zero volts across the CdS film causing it to be transparent and with 4 volts causing it to be substantially opaque.

The specific example given above is inserted only by way of example and it is not intended that it is in any way limiting. Given the teachings of this invention, the selection of particular VTL matreials, light sources and voltages applied thereto rests with an individual manufacturer and is well within the skill of the art.

It is also possible to provide a full-color two dimensional image by using two narrow band incoherent light sources optically adjusted to result in completely overlapping parallel beams which simultaneously illuminate the VTL, rather than a single incoherent light source **26**. In the full-color two-dimensional embodiment, both light sources radiate in narrow wavelength ranges of slightly longer wavelength than the variable transmission layer absorption edge. Both are within wavelength range of having their transmission through the VTL blocked by absorption edge shifts caused by the electrical charging of the VTL. This embodiment takes advantage of the "Land effect" as described in Scientific American, pages 84–94, May 1959, wherein only two colors plus black (absence of color) are used to produce a visual full-color image. In this embodiment both electron guns are focused and scanned, and one is modulated. The electron beams are adjusted so that they scan the screen, the second following the first by a short time delay. The first beam is not modulated and has its electron energy adjusted to produce a positive charging of the VTL by causing secondary emission from the VTL surface. The second beam is modulated by the incoming signal to either completely neutralize, partially neutralize, or uneffect the VTL surface charge. The light source intensities are adjusted so that when the VTL is fully charged, little light from either source is transmitted; when the VTL is uncharged the reverse occurs, that is, a predetermined amount of light from both sources will be transmitted. Partial charging allows a portion of the longer wavelength source, or all of the longer wavelength source and a portion of the shorter wavelength source to be transmitted.

The method for providing the proper modulating signal information to the grid of the scanning electron gun forms no part of the present invention, since the invention is concerned only with a system for converting such information into a visual display. However, it should be noted that if the "Land effect" is used to produce a full color image in the present invention the modulating information could be derived from the multiplexing of video information from two image orthicon tubes wherein each tube is provided with a suitable color filter so that one tube responds only to the varying degrees of intensity of a first color and black, and the second tube responds only to varying degrees of intensity of a second color and black. The multiplexing could be arranged so that the orthicon tubes transmit frames alternately or it could be arranged so that they alternately transmit information derived from alternate spot-sized areas of the scene being scanned by the tubes. In both cases the receiver would effectively produce two transparencies; one being controlled by the video output of the first image orthicon tube and the second being controlled by the video output of the second orthicon tube. In the first case the two transparencies would be displayed in alternate frames whereas in the second case the two transparencies would be superimposed. It should be noted that the time between frames and/or the spacing between alternate spots are such that the human eye cannot distinguish between the two transparencies and, therefore, the viewer sees a "Land effect" full-color image.

The above described embodiment and variations thereof relate to the production of a two-dimensional image. In the use of such an embodiment, the information content of a conventional TV signal may be presented to the deflection and control circuity of the VTSCRT (variable transmission system cathode ray tube) and cause a positive transparency, corresponding to the scene which is to be displayed, to be written on the VTL. If a diffuse, incoherent light source is located behind the VTSCRT, the VTL may be viewed directly and a likeness of the original scene observed. If a beamed incoherent light source is projected through the VTL with appropriate optics, an image of the scene being displayed is formed on a suitable distant viewing surface, or screen, analogous to a slide or movie projector. For example, a theatre could employ a video tape recorder to supply the modulation signal and the sweeping voltages to the drive circuitry of the VTSCRT, and with a light source of suitable intensity, reproduction of prerecorded still or motion pictures may be obtained. The system may be scaled down for home projection TV or scaled up for military or industrial displays. It should also be noted that the VTSCRT of the present invention is suitable for use in a projection oscilloscope or a closed circuit TV system for group viewing.

The second major preferred embodiment of the present invention is the super-3-D embodiment as shown in FIG. 7. Before proceeding with an explanation of FIG. 7, it should be noted that the term "super-3-D" is used herein to distinguish between a 3-D effect as in panoramic movie displays and a real 3-D display, such as that produced by holographic reconstruction. Structurally, the embodiment of FIG. 7 differs from that of FIG. 6 only in that no projecting lens and viewing screen are necessary and light source **26** is a source of coherent rather than incoherent light.

In FIG. 7, a source of coherent light **26**, such as a laser beam, floods the inner surface of VTL **16**. As in the two-dimensional embodiment, the frequency of the light used depends upon the absorption edge of the VTL material. Scanning of the electron beam or electron beams takes place in any of the manners described above with reference to the two-dimensional image producing embodiment. The viewer, indicated generally at **32**, observes a holographic reconstruction (super-3-D image) by direct observation of the light passing through the VTL.

In order to realize three-dimensional reproductions with this embodiment, the transparencies which are formed by the action of the electron beams and the VTL are replicas of Fresnel holograms of the original objects. In general, the proper modulating signal applied to the electron gun control circuitry to produce a holographic transparency of an object may be provided by an image orthicon tube whose face is positioned in the plane normally occupied by the film in the method of producing holographic transparencies as described in the article "Laser Photography" cited above. In other words, the output of the image orthicon tube would correspond to a video scan of a holographic transparency and would be applied to the control circuitry of the VTSCRT to modulate the electron beam. It should be noted that the present invention is not concerned with the method for producing the control signal, but is concerned with a system that is adapted to receive the control signal once it is produced, and to provide a transparency having a pattern which is controlled by the control signal.

When coherent light of wavelength in the vicinity of the absorption edge is projected through the VTL (which is now a hologram replica) the wave front which emanated from the original scene is actually reconstructed (holographic reconstruction) and hence the scene is reproduced in full 3-D.

This type of holographic display may be extended to full-color reproduction by replacing the two light sources in the full-color two-dimensional embodiment with two coherent light sources having similar restrictions on wavelength range. The focusing optics for viewing on a viewing screen are eliminated and the viewer in this embodiment sees a full-color three-dimensional image by direct observation of the light passing through the VTL. The input information to program the electron beam as in the previous embodiment for the three-dimensional reproduction, results in the formation of hologram replicas on the VTL. However, in a like manner to that for producing two-dimensional full-color viewing, the system produces two transparencies; one controlled by video information from a first color filtered image orthicon tube and the second controlled by video information from a second color filtered image orthicon tube. Both tubes are, of course, positioned as described above, to provide holographic video information so that the two transparencies produced by the VTSCRT are holographic transparencies. In this embodiment, two holograms are simultaneously reproduced, one for each light source. The holograms are completely interwoven and are only decipherable by the holographic reconstruction process. Typical uses for the holographis displays include home "super-3-D TV," "super 3-D movies" (from video tape not filmed) and holographic 3-D microscopes.

Another use of the VTSCRT of the present invention is as a primary display for electro-optical computers. Such computers conventionally utilize a transparent object through which light is allowed to pass. Mathematical operations are performed on the object by means of performing optical operations on the light beam which is defracted by the object, as discussed in "Optical Data Processing and Filtering Systems," IRE Transactions on Information Theory, pages 386–400, June 1960, by Cutrona, Leith, Palermo and Porcello. A display system built around the VTSCRT of the present invention will interface easily with such computing systems and will greatly improve them because suitable driving circuitry will allow the rapid and accurate display of objects to be operated upon. Furthermore, objects may be designed in a continuous fashion, wherein the operator merely changes some parameter of the object display in an effort to maximize by visual or photoelectric observations some feature of the output.

The invention also has use in servo control systems. For example, an object to be accurately positioned could be painted entirely black except for three point mirrors oriented (for the sake of convenience of description) at the endpoints of three principal rotation axes. The object would then be continuously halographed and the "moving picture" hologram which results would be monitored by an image orthicon tube. The output from the image orthicon tube would be applied to the control circuitry of the VTSCRT and a coherent radiation source would be allowed to impinge on the VTL thereby producing both the real and virtual object reconstruction. In this particular use, the real image rather than the virtual image would be used. Three photodetectors could be placed in the vicinity of the real image at positions in space which are conjugate to those where the point mirror reference points located on the object are to be oriented. A single mechanism with feedback control positions the object until a maximized signal from the three sensing photodetectors indicates that the object has been properly oriented.

It should be apparent from the above description and drawings that the present invention has a great many uses, in the field of electro-optics. However, the uses which are described herein are given only by way of example and it is not intended that the invention be limited thereto. While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. The combination of a layer of electric field dependent variable transmission material having a zero field absorption edge in the optical spectrum, said layer having a thickness such that it is transparent to light having wavelengths longer than the absorption edge of the material, and a first means for applying a reference potential to one surface of said layer and second means for selectively applying potentials to selected areas on a second surface of said layer opposite said one surface for selectively shifting the absorption edge of said layer in said areas.

2. The system as claimed in claim **1** wherein said means for selectively shifting comprises a transparent electrode placed on one surface of said layer, means for producing a secondary emission of electrons at the second surface of said layer, and means for neutralizing the charge, created by secondary emission, on selected areas of said second surface.

3. The system as claimed in claim **1** wherein said means for applying a reference potential comprises a transparent electrode on said one surface of said layer and connected to a reference potential.

4. The system as claimed in claim **2** wherein said means for producing and means for neutralizing comprise respectively first and second electron producing means for producing and directing electrons toward said one surface.

5. The system as claimed in claim **3** wherein said means for selectively applying potentials comprises at least one electron gun and means for focusing, deflecting and modulating an electron beam produced by said electron gun.

6. The system as claimed in claim **5** wherein said means for selectively applying potentials further comprises a second electron gun and means directing the electrons from said second electron gun at said one surface whereby said second electron gun positively charges said one surface.

7. The system as claimed in claim **5** wherein said means for flooding comprises a source of incoherent visible light, and means for directing said visible incoherent light at a surface of said layer.

8. The system as claimed in claim **5** wherein said means for flooding comprises a source of coherent visible light and means for directing said coherent visible light at a surface of said layer.

9. The system as claimed in claim **9** wherein said visible light includes wavelengths of light which are greater than zero field absorption edge and less than the maximum absorption edge obtained by shifting said absorption edge.

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U.S. DEPARTMENT OF COMMERCE

PATENT OFFICE

Washington, D.C. 20231

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,403,283 September 24, 196[illegible]

Fred Chernow et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 48, "illustratng" should read -- illustratin[illegible] --; line 65, the equation should appear as shown below:

$$I=I_0e^{-\alpha x}$$

Column 3, line 5, "α_x" should read -- αx --. Column 10, line 12, "claim 9" should read -- claim 7 --.

Signed and sealed this 27th day of January 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr. WILLIAM E. SCHUYLER, JR.
Attesting Officer Commissioner of Patents