

Nov. 4, 1952

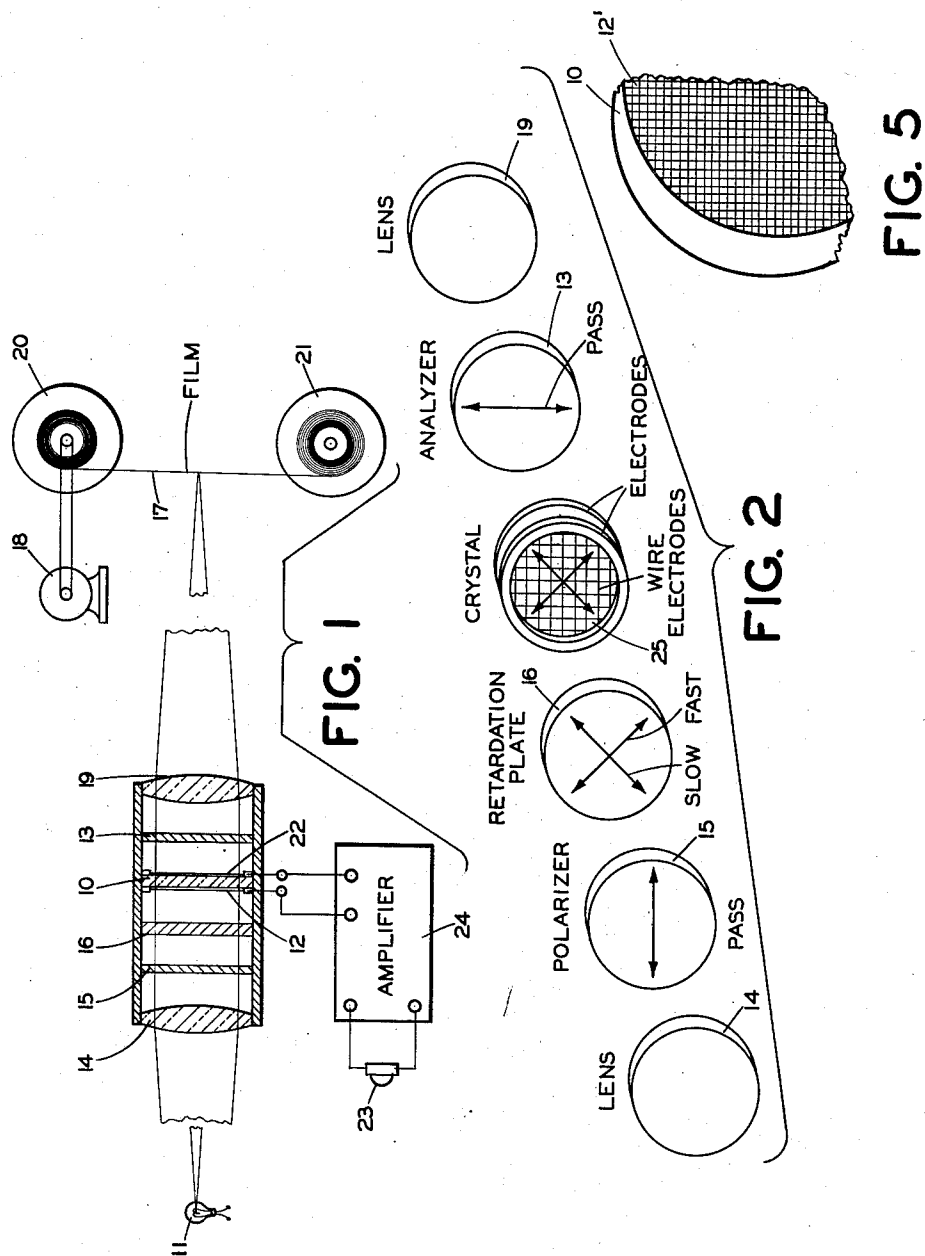
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2,616,962

ELECTRICAL LIGHT-TRANSMISSION CONTROLLING ARRANGEMENT

Filed Oct. 15, 1947

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

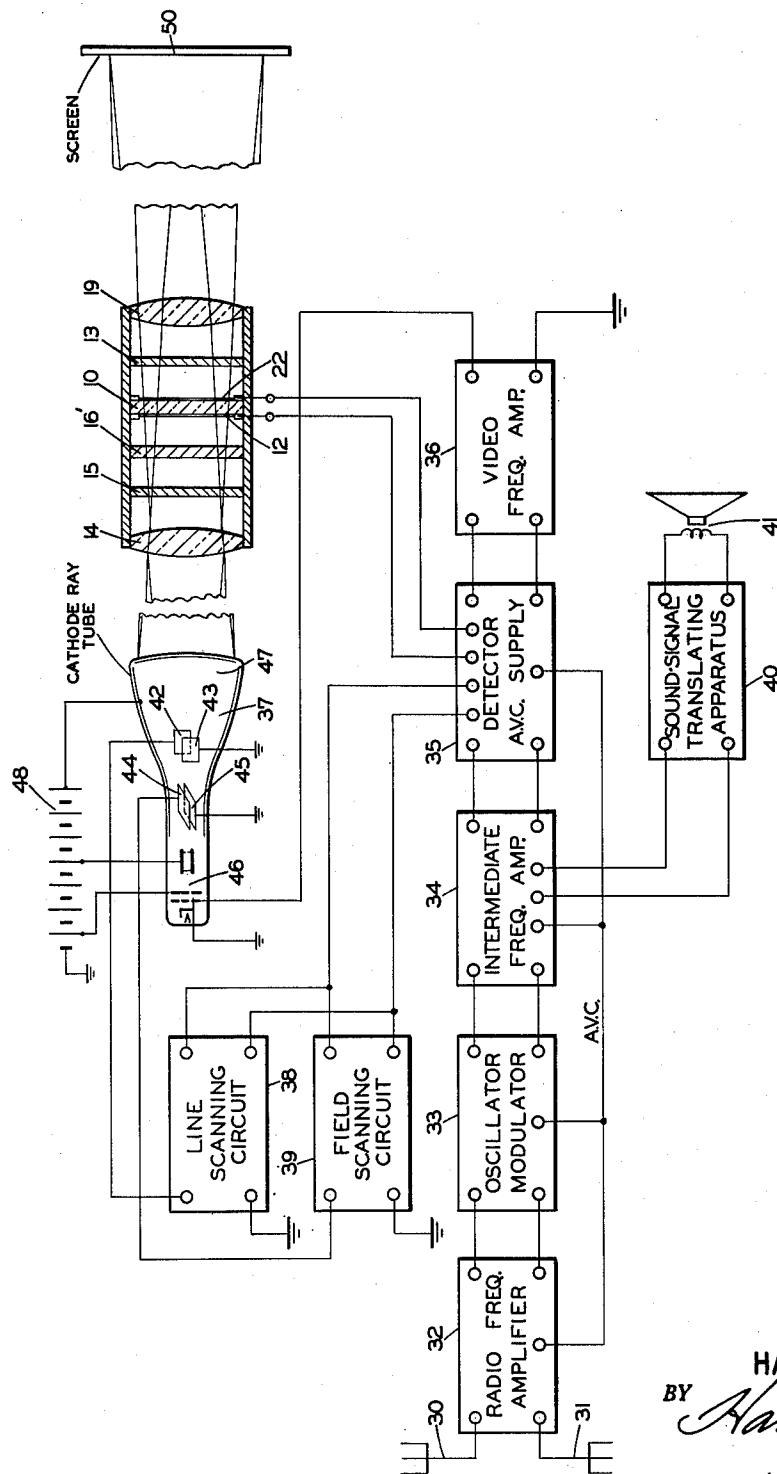


FIG. 3

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3 Sheets-Sheet 3

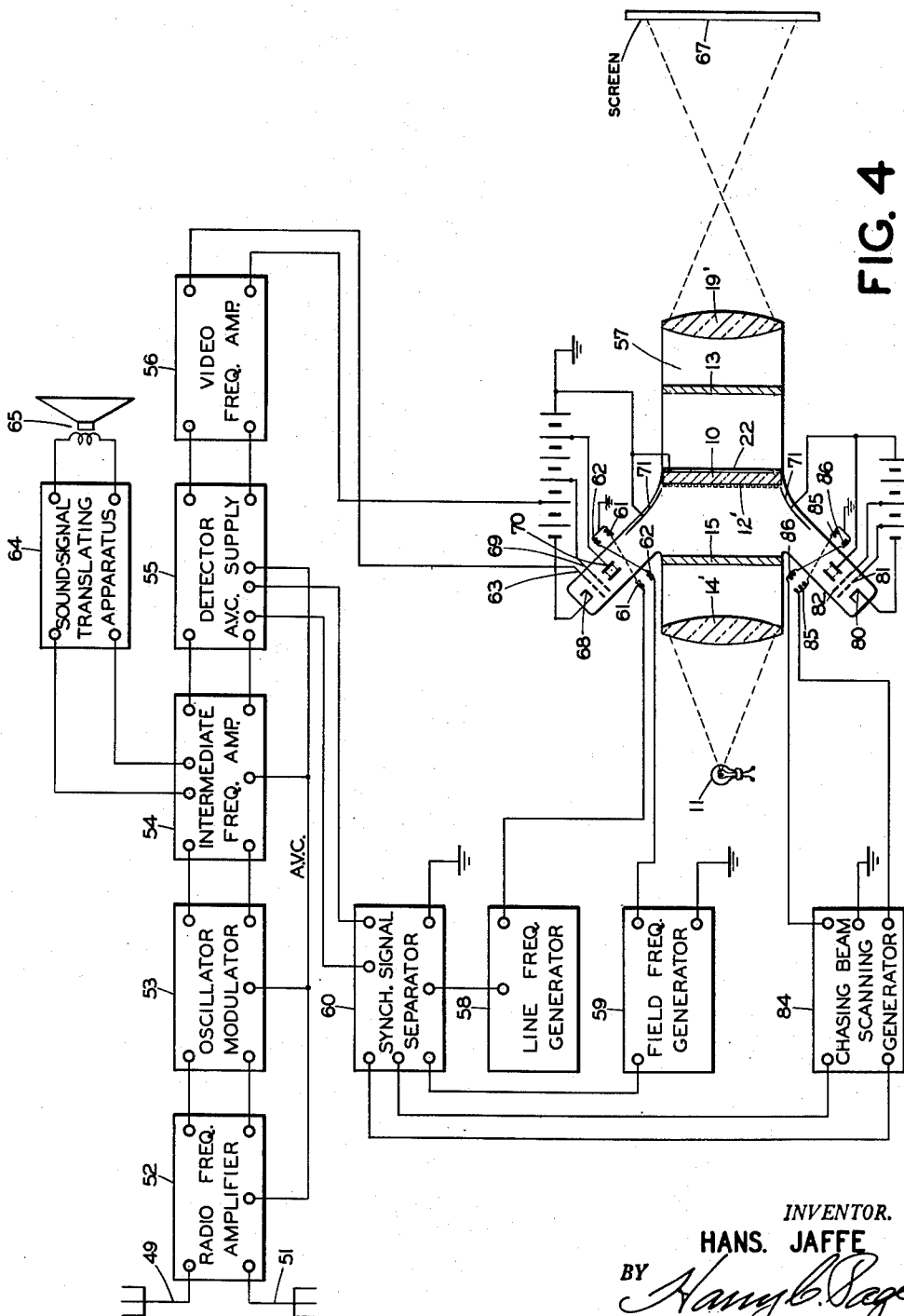


FIG. 4

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2,616,962

ELECTRICAL LIGHT-TRANSMISSION CONTROLLING ARRANGEMENT

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Application October 15, 1947, Serial No. 780,022

12 Claims. (Cl. 178-5.4)

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The subject matter of this invention relates to arrangements for controlling the transmission of light and, while the invention is of general utility, it is of particular utility in arrangements for electrically controlling the intensity of light transmitted or for electrically controlling the color of light transmitted.

This application is a continuation-in-part of application for United States Letters Patent Serial No. 539,312, filed June 8, 1944, now Patent No. 2,463,109, issued March 1, 1949, in the name of Hans Jaffe and assigned to the same assignee as the present application.

There is a wide variety of applications for an arrangement for controlling the intensity of transmitted light or for controlling the color of the light transmitted. Light-controlling arrangements of the general type under consideration may have many possible applications in photography, recording of sound on film, etc. Arrangements of the general type under consideration which have previously been available have been entirely unsuitable for many commercial applications. Such prior devices have been characterized by one or more of the following deficiencies:

- (a) A very low cross-section in the light path at the point of control
- (b) High attenuation of light
- (c) An insufficient range of light variation
- (d) An inability to respond to high-frequency variations of a control signal

Thus, in the reproduction of television signals, it has been heretofore proposed that a light valve, together with a local source of illumination, be utilized to reproduce the televised picture, the light valve being controlled by the television video signals. Such arrangements have not, however, been accepted commercially because of one or more of the above-mentioned defects which has been present in all such prior systems.

It has been proposed to provide a light valve using a crystal substance which is piezoelectric and in which the controlling potentials applied thereto are applied to provide an electric field parallel to the optic axis of the system. Thus, in United States Letters Patent 2,277,007, granted on March 17, 1942, on the application of M. Von Ardenne there is disclosed a television system in which such a crystal substance is utilized. The crystal substance which is proposed in this patent is zinc blende or zinc sulphide. While arrangements of the type of the patent, in which the electric field applied to the crystal to control the

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light transmitted by the system is parallel to the optic axis of the system, are not subject to one of the above-mentioned defects, namely, to the defect of a small cross-section, there are several other disadvantages associated with the use of crystals of zinc blende in a system of the type under consideration. Specifically, only quite small crystals of zinc blende are available commercially. Also, the transparency of zinc blende is quite deficient for use in an optical system where a relatively wide range of wave lengths of light are to be transmitted. Zinc blende has the property of highly attenuating signals at the short-wave end of the visible spectrum so that the crystal is generally colored when viewed in ordinary light. It would be desirable, therefore, to provide an arrangement for controlling the transmission of light which is not subject to one or more of the deficiencies of the above-mentioned prior devices.

It is an object of the invention to provide an improved arrangement for controlling the transmission of light.

It is another object of the invention to provide an arrangement for controlling the transmission of light which is not subject to one or more of the above-mentioned deficiencies of prior devices.

It is specifically an object of the invention to provide an arrangement, for controlling the transmission of light, which has a large cross section in the light path at the point of control, low light attenuation, and a high range of light control.

In accordance with the invention, an arrangement for controlling the transmission of polarized light comprises a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of the light and which is at least partially transparent to the light. Means are also provided, including electrode means disposed adjacent to at least one of the major surfaces of the plate, for applying variable potentials across the plate of crystal material in the direction of light travel, and, in a preferred embodiment of the invention, this last-named means includes an electrode portion in the light path which is at least partially transparent to the light to permit it to enter the crystal plate. An analyzer is provided for light emerging from the plate.

As used in this specification and in the appended claims, the expression "P-type crystal material" is intended to mean primary ammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$), primary potassium phosphate, primary rubidium phosphate,

the primary arsenates of ammonium, potassium and rubidium, isomorphous mixtures of any of these named compounds, and all other piezoelectrically active crystal materials isomorphous therewith.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

Fig. 1 of the drawing is a circuit diagram, partially schematic, of an arrangement in accordance with the invention for controlling the transmission of light in accordance with sound waves to be recorded upon a film; Fig. 2 is an exploded view of the crystal element and lens assembly of Fig. 1; Fig. 3 illustrates an embodiment of the invention utilized to control the color of the picture reproduced in a television system; Fig. 4 illustrates an embodiment of the invention in which the arrangement is utilized as the light-controlling device in a television-picture reproducing system; and Fig. 5 illustrates a portion of the crystal plate of the Fig. 4 embodiment of the invention.

The P-type crystal materials to which this invention relates are all such that electro-optical properties are present for an electric field applied parallel to the optic axis of the crystal. This permits an arrangement of the light beam approximately parallel to the optic axis and the latter parallel to the applied electric field resulting in comparative freedom from interference due to the nature birefringence of the crystal and enabling a large cross section in the light path at the point of control to be readily obtained. Also, these crystal materials as a class have very desirable light-transmitting properties in the visible portion of the frequency spectrum and certain of them, as will be pointed out hereinafter, have high light-transmitting properties. Primary ammonium phosphate has its melting point near 190° C. and is absolutely stable up to 120° C. Since this crystal has no water of crystallization it may be subjected to a high vacuum for long periods of time without detrimental effects.

All crystals which, by their symmetry, are piezoelectric can be expected to show a linear electro-optic effect. A part of the electro-optic effect is contributed by the elasto-optical effect due to the piezoelectric deformation. In addition, however, there is a direct electro-optic effect which persists even if the piezoelectric deformation is suppressed. The direct electro-optic effect is of particular interest inasmuch as it can be expected to be substantially independent of frequency up into the ultra-short wave range of vibrations. Its value, however, cannot be predicted from the piezoelectric effect.

Certain of the P-type crystal materials have an amazingly high direct electro-optic effect and this fact was not known prior to my invention. Particularly efficacious arrangements involving plates of P-type primary-phosphate crystal material are described and claimed in my copending application for United States Letters Patent Serial No. 780,021, filed October 15, 1947, and assigned to the same assignee as the instant application.

The nature of the electro-optic effect of an electric field applied parallel to the optic axis of a P-type crystal material is such that the crystal becomes optically bi-axial; that is, the propagation velocity of a beam traveling par-

allel to the original optic axis is no longer independent of the state of polarization. Thus light traveling parallel to the optic axis of P-type crystal materials is split up into two components having planes of polarization at 90° in respect to each other. After leaving the crystal material, these components again combine with a phase shift which is proportional to the voltage applied parallel to the optic axis but which is independent of the thickness of the plate.

I have found the electro-optic effect of an electric field parallel to the optic axis in primary ammonium phosphate crystals to produce a phase shift of one-fourth wave-length at 4,500 volts for green mercury light and have determined that the high value of about two-thirds of this effect is a direct electro-optic effect. The electro-optic effect in Z-cut plates, that is, plates cut from a crystal material and having faces oriented substantially perpendicular to the optic axis of the crystal material, permit the construction of a light valve of large cross section in the light path at the point of control and small thickness with no need to compensate for the natural birefringence of the crystal. I have also found the direct electro-optic effect of a field parallel to the optic axis of a primary potassium phosphate crystal to be even higher, specifically approximately 50% higher, than for primary ammonium phosphate which also makes primary potassium phosphate eminently suitable for electro-optic purposes. The type of electro-optic effect found in Z-cuts of P-type crystals thus makes them particularly useful for various devices for modulating the intensity of light beams.

Referring now to Fig. 1 there is shown an arrangement for controlling the transmission of polarized light which includes a Z-cut plate 10 of P-type crystal material in the path of the light and which is at least partially transparent to the light of a source 11. It is evident that the thickness direction, or Z-axis direction, of the plate 10 is at least approximately coincident with the direction of the light path. The plate 10 will be seen to have the shape of a slice cut from a single crystal of the P-type crystal material. It will appear from the discussion hereinabove that a slice of primary ammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$) crystal, otherwise called ammonium dihydrogen phosphate crystal, is a P-type crystal material well suited for this purpose in many cases; light valves and similar arrangements or devices comprising more specifically such crystal slices are disclosed and claimed in the aforementioned application Serial No. 780,021, which issued as Patent No. 2,591,701 on April 8, 1952. The Fig. 1 arrangement also includes means for applying variable potentials across the plate in the direction of light travel, this last-named means including an electrode portion 12 in the light path which is at least partially transparent to light from the light source 11 to permit light to enter the plate 10. An analyzer 13 is provided for light emerging from the plate 10. While it is possible to utilize the plate 10 to control light in a system in which light enters the plate from one side, is reflected from a reflecting surface at the opposite side of the plate, and again leaves the plate at the same face at which the light originally entered, a preferred embodiment of the invention, as illustrated in Fig. 1, is one in which the light enters one face of the plate and leaves the opposite face of the plate. However, it is to be understood that the invention is not limited to

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this illustrated type of action. Thus, the analyzer 13 is on the opposite side of the plate 10 from source 11 and a collimating lens 14 is provided for forming a beam having substantially parallel rays which is thereafter polarized by means of a polarizing screen 15 and caused to be incident upon the plate 10. A retarding plate 16 may also be utilized in the system.

A lens 19 is provided for focusing the light transmitted by the system upon a film 17 which is driven past the focal point by means of a motor 18 driving one of the two reels 20, 21 upon which the film is wound. The above-mentioned means for applying variable potentials across the plate 10 comprises the light-transparent electrode 12, upon one face of the plate 10, and a light-transparent electrode 22 on the other face thereof, together with a microphone 23, connected to the input circuit of an amplifier 24, the output circuit of which is, in turn, coupled to electrodes 12, 22.

One possible optic orientation of the various elements of the Fig. 1 arrangement is illustrated in Fig. 2. This shows the polarizer 15 and analyzer 13 in crossed position with the X axis of the crystal plate 10 at 45° to the analyzer position. In terms of the X, Y, Z coordinate system, a field parallel to the Z-axis will produce an expansion or contraction along the X-axis and the opposite action, as the case may be along the Y-axis, as explained in more detail in the above-mentioned parent application. Fig. 2 also illustrates a retardation plate 16 with the orientation of the slow ray parallel to the X-direction of the crystal 10.

In considering the operation of the arrangement of Fig. 1, it will be seen that, in the absence of an applied voltage to electrodes 12, 22 and in the absence of retardation plate 16, the system does not transmit any light. On the other hand, if potentials are applied to electrodes 12, 22 sufficient to produce $\frac{1}{2}$ wave phase difference in the two optical components of polarized light transmitted by the plate 10, maximum light intensity is passed by the system and is incident upon the film 17. This is true regardless of the polarity of the potential applied to the electrodes 12, 22 and, for this reason, an AC signal applied to the system would produce frequency doubling. It is to prevent this frequency-doubling effect that the retardation plate 16 is provided. The retardation is in the nature of an optic bias and preferably a retardation of $\frac{1}{4}$ wave-length is utilized as it provides a symmetrical increase and decrease of transmitted light intensity with the application of an alternating voltage to electrodes 12, 22. Therefore, with the complete arrangement illustrated, sound signals incident on microphone 23 are amplified in amplifier 24 and applied to the electrodes 12, 22 each of which is (partially) light transparent. Light from the source 11 is collimated by the lens 14 to provide substantially parallel rays which are polarized by the polarizer 15. These rays are thereafter retarded by the plate 16 and the light emerging from plate 16 is incident upon the plate 10. The light within the plates 16 and 10 effectively has two components each of which is plane-polarized, the planes of polarization of the two components being at 90° to each other. These two components travel at different velocities through the plate 10, depending upon the potentials applied between electrodes 12 and 22. Therefore, upon emerging, these two components may have relative phase values dependent upon the potential which is applied between electrodes 12 and 22,

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and these components combine to produce a resultant elliptically polarized beam. This emerging beam is transmitted through analyzer 13 to a degree depending on the value of its component taken parallel to the vibration direction of the analyzer. The intensity passed depends on the sum of the retardations in the fixed retardation plate 16 and crystal plate 10 according to the equation $I = I_{\max} \sin^2 \delta \pi$, where δ is the total retardation expressed in fractions of a wave-length. This retardation shows that for a fixed bias retardation of $\frac{1}{4}$ wave-length, which may be supplied by retardation plate 16, the light intensity will increase with a positive retardation in crystal plate 10 and equally decrease with a negative retardation, thus providing a symmetrical modulation. Light which is transmitted through analyzer 13 is concentrated upon the film 17 by the lens 19. Accordingly, therefore, the light incident upon the film 17 varies in accordance with the sound variations which are present at microphone 23. Hence the arrangement of Fig. 1, and in like manner the other arrangements described and illustrated herein, may be termed light valves.

In place of, or in addition to, the transparent electrodes 12 and 22, a wire grid of very fine mesh may be used. Such a grid is illustrated in Fig. 2 at the reference numeral 25.

In Fig. 3 there is illustrated a color-television system utilizing an arrangement in accordance with the invention for controlling the transmission of polarized light, specifically, for controlling the color of the light which is transmitted. Referring now more particularly to Fig. 3, the system as illustrated comprises a receiver of the superheterodyne type. This receiver includes an antenna system 30, 31 connected to a radio-frequency amplifier 32 of one or more stages, to which is connected in cascade in the order named, as oscillator modulator 33, an intermediate-frequency amplifier 34 of one or more stages, a detector and A. V. C. source 35, a video-frequency amplifier 36 of one or more stages, and an image-reproducing device 37. A line-scanning circuit 38 and a field-scanning circuit 39 are coupled to an output circuit of detector 35 and have output circuits coupled, respectively, to the line-scanning plates 42, 43, and the field-scanning plates 44, 45 of signal-reproducing device 37. Image-reproducing device 37 includes a conventional electron-gun structure 46 and a fluorescent screen 47 and is provided with a suitable source of unidirectional potential 48 therefor, as illustrated. Automatic-amplification-control (A. V. C.) potentials derived from unit 35 are applied to one or more of the tubes in radio-frequency amplifier 32, oscillator-modulator 33, and intermediate-frequency amplifier 34 in a conventional manner. A sound-signal translating apparatus 40 and loud-speaker 41 of conventional design are coupled to an output circuit of intermediate-frequency amplifier 34. The stages or units 30 to 41, inclusive may all be of conventional well-known construction so that a detailed illustration and description thereof are deemed unnecessary herein.

However, referring briefly to the operation of the system described above, television signals intercepted by antenna circuit 30, 31 are selected and amplified in radio-frequency amplifier 32 and coupled to the oscillator modulator 33, wherein they are converted into intermediate-frequency signals, which, in turn, are selectively amplified in the intermediate-frequency amplifier

34 and delivered to the detector 35. Modulation components of the signal are derived by the detector 35 and are supplied to the video-frequency amplifier 36 wherein they are amplified and from which they are supplied in the usual manner to a brilliancy-control electrode of the image-reproducing device 37. The modulation components of the signal derived by the detector 35 are also applied to synchronizing-control circuits 38 and 39. The intensity of the scanning ray of device 37 is thus modulated or controlled in accordance with the video-frequency voltages impressed upon its control grid in the usual manner. Also, scanning potentials, developed in the line-scanning circuit 38 and field-scanning circuit 39, are applied to the scanning elements of the image-reproducing device 37 to produce electric scanning fields, thereby to deflect the scanning ray in two directions normal to each other so as to trace a rectilinear pattern on the screen 40 to reconstruct the transmitted image. Sound signals accompanying the received television signals are reproduced in units 40 and 41 in a conventional manner and the bias derived from unit 35 and applied to the preceding receiver stages serves to maintain the signal-input amplitude to detector 35 within a relatively narrow range for wide range of received signal intensities.

Referring now more particularly to the portion of the Fig. 3 constituting the present invention, there is provided an optical arrangement for controlling the color of light transmitted from the screen 47 of the cathode ray tube to a viewing screen 50. This optical system is generally similar to that of Fig. 1 and corresponding circuit elements have identical reference numerals while analogous circuit elements have identical reference numerals primed. Thus the optical system of Fig. 3 includes, in consecutive order in the light path, a collimating lens 14 which is focused upon screen 47, a polarizer 15, a bias plate 16', a Z-cut plate of P-type crystal material 10, an analyzer 13 and a lens 19 for focusing the image present on the screen 47 of the cathode-ray tube 37 to form an image on viewing screen 50. The cathode ray tube 37 with its actuating circuits, the lens 14, and the polarizer 15 constitute means for projecting white or polychromatic polarized light along the generally horizontal light path provided by the illustrated optical system. Electrodes 12 and 22, which are at least partially transparent to the light generated by the fluorescent screen 47 of the cathode-ray tube, are also provided. The retardation plate 16', however, has a different function than the retardation plate 16 of Fig. 1 in that it has a much higher retardation value. One preferred retardation value for the plate 16' is two wave-lengths of light at the center of the spectrum of the light output from cathode-ray tube 37. In considering the operation of the arrangement of Fig. 3, it will be seen that, if no electric signal is applied to the electrodes 12, 22 and if the system is illuminated with white light, a deep-purple color will be transmitted to the screen 50. If now a constant voltage of either positive or negative polarity is applied between the electrodes 12, 22, the retardation occurring in the crystal plate 10 will add to or subtract from the retardation obtained in the plate 16' thereby to produce a change of color of the light transmitted depending upon the polarity and amplitude values of the applied potential. By a suitable choice of the applied posi-

tive and negative potentials, therefore, it is possible to get two spectrum distributions which, together with the spectrum distribution obtained with zero potential across the plates 12, 22, can serve as three basic colors for use in a color-television system. Assuming a white light to be emitted by cathode-ray tube 17, a phase shift in the system of 1100 millimicrons for no potential applied to electrodes 12, 22, together with a phase shift of plus and minus 165 millimicrons depending upon the amplitude and polarity of the positive and negative signals applied to the electrodes 12 and 22, provides one possible set of three basic colors. This 165 millimicrons retardation variation can be obtained by applying potentials of about 5,000 volts upon a plate of primary ammonium phosphate or by applying potentials of about 3,500 volts on a plate of primary potassium phosphate. For television purposes, a substantially square-wave signal is applied to the electrodes 12, 22 from a potential generator included in detector 35. Specifically potential values consisting of one negative and one positive pulse, each lasting during a complete field period of the television signal, and a zero pulse, also lasting for a third field period of the television cycle, are used. A signal for controlling the generation of control potentials for electrodes 12, 22 is transmitted with the television signal, and is detected and separated in detector 35 and thereafter utilized to generate proper control signals. Thus, in the system described, the color of the image reproduced on screen 50 is changed in three discrete steps by the application of three discrete potential values to electrodes 12, 22, each color being incident upon the screen 50 for a complete field period.

Using the lens system 14, 19 shown in Fig. 3, the polychromatic image formed on the screen 47 of the cathode ray tube appears, in the manner just described, as a series of inverted color separation images on the viewing screen 50. Each image element on the screen 50 is reconstructed from a group of light rays which originate at the corresponding image element on the screen 47 and which are polarized by the polarizer 15. For the upper most image element on the screen 47 there are shown in Fig. 3 the uppermost and lowermost rays of the group of rays which, upon passage through the lens system, converge to form the lowermost element of the image on the screen 50. Fig. 3 shows likewise the extreme rays in the vertical plane of the group of rays passing from the lowermost element on screen 47 to the uppermost element on screen 50. It will be obvious at once that, for the formation of a useful focused image on the viewing screen 50, not only must the lenses 14 and 19 have a gross shape such as to provide the desired focusing action, but also these lenses and the other elements therebetween must have surfaces which are ground and polished or otherwise treated to avoid the scattering and defocusing action caused by minor surface irregularities and scratches. Thus the crystal plate or slice 10 has two parallel electrode faces which are substantially plane, and the bias plate 16', the electrode crystal plate 10 with associated controlling signal circuits, the analyzer 13, and the focusing lens 19 together make up an arrangement for controlling the transmission of polarized light rays constituting the image elements in a picture transmission system. When the aforementioned sequential control potentials are applied to the light valve, the analyzer 13 selects sequentially from the polychromatic light

the wave lengths of a plurality of discrete colors corresponding to the plurality of discrete steps of control potential across the plate 10. Then the focusing lens 19 and the screen 50 serve as means for utilizing the light emerging from the analyzer 13 to produce pictures, the color of which may be changed by varying the control potential steps.

In Fig. 4 there is illustrated an embodiment of the invention in which the light-controlling system is utilized to control the intensity of light transmitted in order to produce a black-and-white television picture. The system illustrated comprises a receiver of the superheterodyne type including an antenna system 49, 51 connected to a radio frequency amplifier 52. Connected in cascade to radio-frequency amplifier 52, in the order named, are an oscillator modulator 53, an intermediate-frequency amplifier 54, a detector and A. V. C. supply 55, a video-frequency amplifier 56 and an image-reproducing device 57. A line-frequency generator 58 and a field-frequency generator 59 are coupled to an output circuit of detector 55 through a synchronizing-signal separator 60, the line-scanning generator 58 and the field scanning generator 59 being coupled to line scanning windings 61, 61 and field scanning windings 62, 62, respectively, associated with the image-reproducing device 57. A sound-signal translating apparatus 64 and loud-speaker 65 are coupled to an output circuit of intermediate-frequency amplifier 54. The stages or units 49, 51 to 56, respectively, 58 to 62, respectively, and 64 and 65 are all of conventional well-known construction so that a detailed illustration and description thereof is unnecessary herein.

Referring briefly, however, to the general operation of the system described above, television signals intercepted by antenna circuit 49, 51 are selected and amplified in radio-frequency amplifier 52 and are coupled to the oscillator modulator 53, wherein they are converted into intermediate-frequency signals, which, in turn, are selectively amplified in intermediate-frequency amplifier 54 and delivered to detector 55. The modulation components of the signal are derived by the detector 55 and the video components thereof are applied to the video-frequency amplifier 56, wherein they are amplified and from which they are applied, in the usual manner, to a brilliancy-control electrode 63 of the image-reproducing device 57. The synchronizing-component output of detector 55 is applied, through the synchronizing-signal separator 60, to generators 58 and 59. The intensity of the scanning ray of device 57 is thus modulated or controlled in accordance with the video-frequency voltages impressed upon the control electrode 63 in the usual manner. Scanning waves are generated in the line-frequency and field-frequency scanning generators 58 and 59, which are controlled by the synchronizing-voltage pulses applied from the detector 55, and are applied to the scanning elements 61, 61 and 62, 62 of the image-reproducing device 57 to produce magnetic scanning fields, thereby to deflect the scanning ray in two directions normal to each other in order to trace a rectilinear scanning pattern and thereby reconstruct the transmitted image in a manner which will be explained in detail hereinafter. Sound signals, accompanying the received television signals, are translated by apparatus 64 and reproduced by loud-speaker 65 in a conventional manner. An A. V. C. potential, derived from unit 51, is applied to one or more of the stages of units 52, 53 and 54 in order to maintain the sig-

nal amplitude to detector 55 within a relatively narrow range for a wide range of received signal intensities.

Referring now more particularly to the portion of the system of Fig. 4 embodying the present invention, there is provided an optical system which is generally similar to that of Fig. 1 and similar elements have identical reference numerals. Thus the system comprises, in the following order, a light source 11, a lens 14', a polarizer 15, a Z-cut plate of P-type crystal material 16, an analyzer 13 and a lens 19' for focusing the light transmitted by the system upon a screen 67. The retardation plate 16 has been omitted for the sake of simplicity from the Fig. 4 arrangement, but it will be understood that, although it is not required, this plate can also be included. As in the other illustrated embodiments of the present invention, electrode means, disposed adjacent to at least one of the major surfaces of the plate, is provided for the application of signal potentials thereacross. Accordingly, the optical system of Fig. 4 also includes a light-transparent electrode 22, corresponding to the same element of Fig. 1, but the light transmitting electrode 12 of Fig. 1 has been modified in Fig. 4 to provide an electrode 12' which is comprised of minute individual portions of secondary-electron emitting material on the plate 10 so that an electron gun which includes the control electrode 63 can produce a charge image on the dielectric surface. This electron gun includes a cathode 68, control electrode 63, focusing and accelerating anodes 69 and 70 and a collector electrode 71. The cathode ray tube 57 includes the entire optical system mentioned above within the tube structure, the lenses 14' and 19' effectively comprising separate faces of the envelope of the tube.

A portion of the disk 10 is illustrated in Fig. 5 and in this figure there is shown in detail the plurality of transparent electrode portions of electrode 12' which are provided on the face of plate 10. These electrode portions may be provided by sputtering thin individual silver globules thereon or may be provided by first coating the surface of plate 10 with a thin coating of silver and by thereafter lining the surface in both directions with a sharp instrument to provide isolated islands of the silver coating.

For a successful reproducing unit of the type under discussion, the image charge on the image grid must be discharged during each scanning cycle. The charge image on the image grid may be discharged between scans by any one of several arrangements and an arrangement hereinafter called "a chasing-beam scanning apparatus" is illustrated in Fig. 4 for this purpose. The chasing-beam scanning apparatus includes an electron-gun, comprising a cathode 80 and focusing anodes 81 and 82 for directing a stream of relatively low-velocity biasing electrons upon electrode 12' of the image grid, and a chasing-beam scanning generator 84, having output circuits coupled to scanning windings 85 and 86, for causing the beam generated by the chasing-beam gun to scan the surface of electrode 12' in a manner to be described more fully hereinafter. Suitable operating potentials are provided for the electrodes of cathode-ray tube 57 in a manner which is well understood in the art. Scanning systems and image grids which are somewhat analogous to those utilized in the Fig. 4 embodiment of the invention are described in detail in United States Letters Patent 2,280,191 granted on April 21, 1942,

on the application of Rudolph C. Hergenrother. The secondary-emitting characteristics necessary for the image grid are specified in detail in this patent as are also the electron-gun characteristics for the gun including cathode 68 and the image-erasing gun including cathode 80. These characteristics will not be repeated here.

Considering now the operation of the tube 57 of Fig. 4 as an image-reproducing tube, it is seen that the electron gun structure comprising cathode 68 and the electrodes 63, 69, and 12' is similar to that of a conventional image-reproducing tube except that the fluorescent screen of the conventional tube is replaced by the structure of plate 10 including the electrode 12'. It is seen that the control grid 63 of this electron-gun structure is connected as a conventional image-reproducing tube to the television receiver and its operation will be considered during a scanning cycle of the television image starting with the dielectric material of plate 10 uncharged. It will be assumed that the secondary-electron emission characteristic of the structure including plate 10 and electrode 12' is suitably chosen, as taught by the above-mentioned Hergenrother patent, to provide the operation hereinafter described. Specifically, the dielectric material of the plate 10 is charged positively by the electron beam as set forth in detail in the Hergenrother patent. This results in a distribution of a positive electrical charge over the dielectric surface which includes electrode 12' that is, it results in the reproduction of a charge image which is the electrical replica of the received television image. This charge image remains on the dielectric surface of the plate 10 for an appreciable length of time.

Therefore, in the operation of the tube of Fig. 4, it is necessary to provide some biasing arrangement to bring the surface of the dielectric material, which is provided with the electrode 12', to a uniform potential between successive scan-sions. If this is not done, the charge over the entire dielectric surface approaches a constant maximum value and the image disappears. This biasing may be effected by electrical leakage of the charge through the dielectric material of plate 10 or by a bombarding of the dielectric surface which comprises electrode 12' with electrons of sufficiently low voltage that the secondary-emission ratio is less than unity, causing the charge on the dielectric to fall to the cathode potential of this bombarding beam. This cathode potential may have any convenient value. Such a discharge arrangement is provided in the Fig. 4 embodiment of the invention by the electron-gun structure which includes cathode 80. The dielectric surface, under the conditions assumed, continues to charge negatively until it reaches the cathode potential of the bias beam. This cathode potential may be made negative relative to the collector electrode 71 by a value equal to the biasing-beam voltage if the anode of the biasing-beam gun is connected to the collector electrode 71. This allows the biasing beam to enter a field-free space. The electron gun 80, 81, 82 is sharply focused to a scanning beam and is scanned over the surface of electrode 12'. This bias beam is scanned in the same manner as the signal beam from cathode 68 but the phase of the sawtooth field-scanning current is retarded by nearly a full cycle or advanced by a relatively small amount so that the bias beam follows, or chases, the signal beam by almost a full scanning period. Therefore, the charge image on electrode 12', due to the signal beam 68, is retained at full intensity for almost the entire

field-scanning period. This leads to an ideal condition giving a substantially completely flickerless image. Since it is impractical to utilize an arrangement in which the scanning beam of cathode 80 is focused as sharply as that of the image-forming beam from cathode 68, it is necessary to have a gap of appreciable width, for example 20 lines, between the image-forming beam and the bias beam. This phase relation can be obtained by advancing the phase, of the field-scanning current of the bias beam developed by the chasing-beam scanning generator 84, the equivalent of 20 lines relative to the field-scanning current developed by the generator 59. Under these conditions flicker can appear in only 20 lines so that the resultant average flicker is extremely low.

An arrangement for inserting the unidirectional component of the received television picture has not been illustrated for the sake of simplicity but this may be provided by any one of the arrangements which are well-known to those skilled in the art.

In summary, therefore, it will be understood that the video-signal output of amplifier 56 is utilized to control the grid 63 to place a charge image upon the surface of plate 10 which includes electrode 12'. The plate 10 is included at a focal point in the optical system so that an image of the light transmitted by the plate is focused on the screen 67. This image, of course, depends upon the charge image which is present at the surface including electrode 12'. This charge image is erased by the beam from cathode 80 just before it is to be scanned again by the beam from cathode 68 in order to place a new charge image upon the surface which includes electrode 12'. It will thus be seen that the embodiment of Fig. 4 is an arrangement for controlling the transmission of polarized light, specifically light which has been polarized due to its passage through element 15. The system also comprises a Z-cut plate of P-type crystal material 10 in the path of the light, together with means for applying variable video potentials across minute individual portions of the plate 10 in the direction of light travel. As illustrated in Figs. 4 and 5, this last-named means not only includes the grounded, transparent electrode 22 adjacent to the right hand or exit surface of plate 10 and the electrode 12' adjacent to the left hand surface made up of conducting islands as described above, but also includes means for scanning the left hand major surface of the plate 10 with a modulated electron beam, the latter means being constituted by the electron gun 68—71, its scanning and brilliancy-control elements 61—63, and the associated sweep, synchronizing, and video amplifier circuits. The conducting islands of the electrode 12' form minute individual electrode portions in the light path, corresponding to the aforementioned minute individual portions of the plate 10 itself, and these portions are at least partially transparent to the light to permit light to enter the plate 10. The analyzer 13 is provided for light emerging from the plate 10. The viewing screen 67 then serves as an image-forming surface for receiving and displaying the modulated light projected through the individual portions of the plate 10.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed in

the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An arrangement for controlling the transmission of polarized light comprising; a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying variable potentials across said plate in the direction of light travel; and an analyzer for light emerging from said plate.

2. An arrangement for controlling the transmission of polarized light comprising; a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially transparent to said light; means for applying variable potentials across said plate in the direction of light travel and including an electrode portion, disposed adjacent to one of the major surfaces of said plate, which is at least partially transparent to said light to permit said light to enter said plate and an electrode portion disposed adjacent to the other major surface of said plate; and an analyzer for light emerging from said plate.

3. An arrangement for controlling the transmission of light comprising: a polarizer in the path of said light; a Z-cut plate of P-type crystal material, disposed in said path following said polarizer with the thickness direction of said plate approximately coincident with said light path, and which is at least partially transparent to said light; an analyzer in said path following said plate; and means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying variable potentials across said plate in the direction of light travel.

4. An arrangement for controlling the transmission of light comprising: a polarizer in the path of said light; a Z-cut plate of P-type crystal material, disposed in said path following said polarizer with the thickness direction of said plate approximately coincident with said light path, and which is at least partially transparent to said light; an analyzer in said path following said plate; and means for applying variable potentials across said plate in the direction of light travel and including electrode portions in said path disposed adjacent to both sides of said plate and which are at least partially transparent to said light.

5. An arrangement for controlling the transmission of polarized light comprising; a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying variable potentials in the audio frequency range across said plate in the direction of light travel; and an analyzer for light emerging from said plate.

6. An arrangement for controlling the transmission of polarized light of a relatively wide range of wave-lengths comprising: a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially

transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying potentials, variable in a plurality of discrete steps, across said plate in the direction of light travel; and an analyzer for light emerging from said plate to provide light in a plurality of discrete colors corresponding to said above-mentioned plurality of discrete potential steps.

7. An arrangement for controlling the transmission of polarized light of a relatively wide range of wave-lengths comprising: a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying potentials, variable in a plurality of discrete steps, across said plate in the direction of light travel; an optical-bias plate included in the path of said light; and an analyzer for light which has been transmitted through said Z-cut plate and through said bias plate to provide light in a plurality of discrete colors corresponding to the above-mentioned plurality of discrete potential steps.

8. An arrangement for controlling the transmission of polarized light comprising; a Z-cut plate of P-type crystal material having its thickness direction approximately coincident with the path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying variable potentials across minute individual portions of said plate in the direction of light travel; and an analyzer for light emerging from said plate.

9. In a color-picture reproducing system, an arrangement for controlling the transmission of polarized light of a relatively wide range of wave lengths comprising: means for projecting polarized polychromatic light along a light path; a Z-cut plate of P-type crystal material which has its thickness direction approximately coincident with said path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate, for applying potentials, variable in a plurality of discrete steps, across said plate in the direction of light travel; an analyzer for light emerging from said plate to select from said polychromatic light wave lengths of a plurality of discrete colors corresponding to said above-mentioned plurality of discrete potential steps; and means for utilizing the light emerging from said analyzer to produce pictures, the color of which may be changed by varying said potential steps.

10. In a television system, an arrangement for controlling the transmission of polarized light comprising: means for projecting polarized light along a light path; a Z-cut plate of P-type crystal material which has its thickness direction approximately coincident with said path of said light and which is at least partially transparent to said light; means, including electrode means disposed adjacent to at least one of the major surfaces of said plate and including means for scanning one of said major surfaces with a modulated electron beam, for providing video potentials across minute individual portions of said plate in the direction of light travel; an analyzer

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for light emerging from said plate; and an image-forming surface for receiving the modulated light projected through said individual portions of said plate.

11. In a television system, an arrangement for controlling the transmission of light comprising: means for projecting light along a light path; a polarizer in said light path; a Z-cut plate of P-type crystal material, disposed in said path following said polarizer with the thickness direction of said plate approximately coincident with said path of said light and which is at least partially transparent to said light; an analyzer in said path following said plate; means, including an electrode disposed adjacent to each of the major surfaces of said plate, for applying variable video potentials across minute individual portions of said plate, said electrodes including corresponding minute individual electrode portions in said path which are at least partially transparent to said light to permit light to enter said plate and a conductive electrode in the path of said light which is at least partially transparent to said light to permit light to emerge from said plate; and an image-forming surface for receiving the light projected through said individual portions of said plate.

12. A light valve for controlling the transmis-

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sion of polarized light rays constituting the image elements in a picture transmission system comprising a slice cut from a single crystal of a P-type crystal material and having two substantially plane faces oriented substantially perpendicular to the optic axis of said crystal, light-transmitting electrodes adjacent said faces respectively, and an analyzer for light emerging from said crystal slice.

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