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April 8, 1952 H. JAFFE 2,591,701

ELECTRICAL LIGHT-TRANSMISSION CONTROLLING ARRANGEMENT

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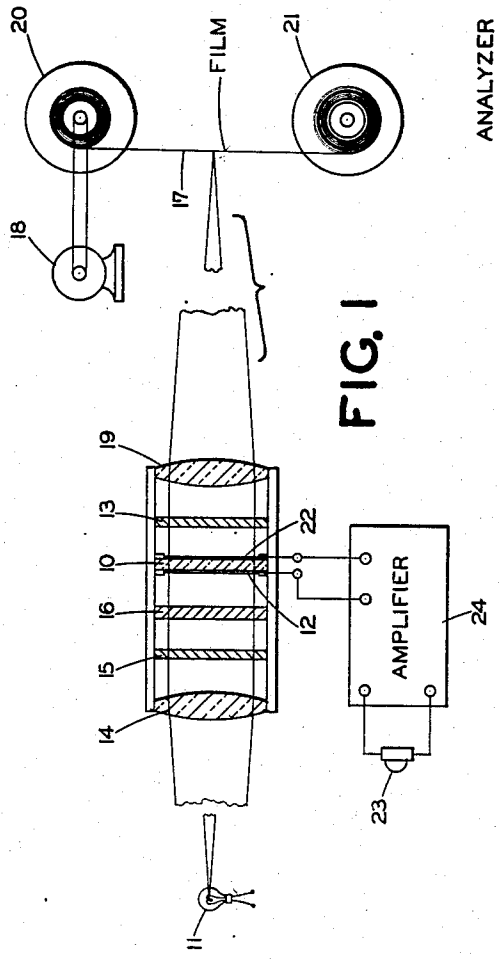


FIG. 1

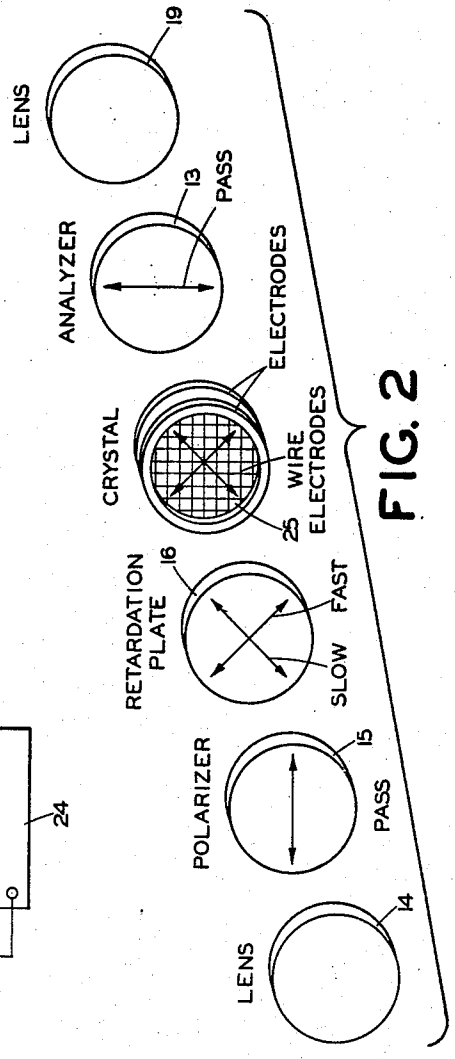


FIG. 2

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ELECTRICAL LIGHT-TRANSMISSION CONTROLLING ARRANGEMENT

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Application October 15, 1947, Serial No. 780,021

8 Claims. (Cl. 88—61)

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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 controlling the intensity of light transmitted or for 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 invention.

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 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 most commercial applications. Such prior devices have been characterized by one or more of the following deficiences.

(*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, and;
(*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 also been proposed to provide a light valve using a crystal substance which is piezo-electric and in which the controlling potentials thereto are applied to provide an electric field parallel to the optic axis of the system.

In general, such arrangements are not subject to the defect mentioned above of a small cross-section in the light path at the point of light control. However, there are several other disadvantages which are present in all such arrangements which have heretofore been available. Specifically, the crystal, namely, Zinc Blende, which was proposed for use in such prior devices has not been available commercially. Also, the transparency of this crystal is quite

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defective. However, all of the above deficiencies are eliminated by a light valve constructed in accordance with the teaching of my copending application for United States Letters Patent Serial No. 780,022, filed concurrently with the instant application and assigned to the same assignee as the instant application. In this copending application it is proposed to use a crystal control element, in a light valve of the general type under consideration, which is selected from the class of materials defined as "P-type crystal materials." As here used, the expression "P-type crystal material" is intended to mean primary ammonium phosphate; 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.

It has been found, however, that there are particular advantages associated with the use of the primary-phosphate crystal materials in the above-defined class of materials when used as the light-controlling element in a light valve. Primary ammonium phosphate has its melting point near 200° 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 effect. 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 ¼ wave-length at 4500 volts for green mercury light and have determined that the high value of about ⅔ of this effect is a direct-electro-optic effect. Also, I have found the electro-optic effect of a field parallel to the optic axis of a primary potassium phosphate crystal to be even higher. Specifically, the direct electro-optic effect in primary potassium phosphate is approximately 50% higher than for primary ammonium phosphate, and amounts to the amazingly high fraction of nine-tenths of the total effect. This characteristic of a high direct-electro-optic effect is of particular utility in a light valve if the intensity of the light passed by the system is to be controlled or changed very suddenly. The reason for this is that it is impossible for a crystal to respond mechanically to very sudden changes in an electrical control signal applied thereto in order that the light transmitted by the system may be varied by the indirect-electro-optical effect of the crystal which, in turn, depends upon a mechanical deformation. On the other hand, there are no such

limiting mechanical time constants associated with the use of the direct-electro-optic effect and thus it is possible to use such an arrangement for controlling at much higher frequencies the light passed by the system.

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

It is still another object of the invention to provide an arrangement for controlling the transmission of light which does not have a high mechanical time constant which limits the speed with which the light passed by the system may be controlled.

It is specifically an object of the invention to provide an arrangement for controlling the transmission of light in which the control action is dependent primarily upon a direct electro-optic effect as distinguished from a light control which is in turn dependent upon an electro-mechanical effect.

In accordance with the invention, an arrangement for controlling the transmission of polarized light comprises: a Z-cut plate of P-type primary-phosphate crystal material in the path of the light and which is at least partially transparent to the light; means for applying variable potentials across this plate in the direction of light travel; and an analyzer for light emerging from the crystal plate.

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 drawing and its scope will be pointed out in the appended claims.

In the single sheet of the drawing, Fig. 1 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 on a film and Fig. 2 is an exploded view of the crystal element and lens assembly of Fig. 1.

The present invention is of particular utility in any of the arrangements described in my above-mentioned copending application, filed concurrently with the present application. A preferred embodiment of the invention is illustrated in Fig. 1. Fig. 1 of this application is identical with Fig. 1 of the concurrently filed copending application. All embodiments of the present invention depend upon a relative phase shift between two polarized components of light transmitted through a crystal, this phase shift being produced by electrical signals applied to the crystal. Various paths through the crystal may be utilized to effect this controlling action and these paths may include one or more internal reflecting surfaces in the crystal material. An arrangement utilizing such internal reflecting surfaces may be such as to cause the light to travel parallel to the electric field utilized as a control effect in more than one direction in the crystal, thus effectively increasing the effect of the electric field in producing a phase shift between the two components mentioned. Specifically, an arrangement having an optical system generally in accordance with that disclosed in Figure 10 or Figure 12 of United States Letters Patent No. 2,276,359, granted on March 17, 1942 to M. Von Ardenne can be utilized. However, a preferred embodiment of the invention is one in which the light enters one face of the crystal plate and leaves the opposite face of the plate. Such an arrangement is illustrated in Fig. 1.

In Fig. 1 of the drawing, there is illustrated an arrangement for controlling the transmission of light which includes a Z-cut plate 10 of P-type primary phosphate crystal material in the path of the light and which is at least partially transparent to the light of a source 11. This plate may be either primary ammonium phosphate or primary potassium phosphate. The system 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. The analyzer 13 is on the opposite side of plate 10 from the source 11. 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 on a film 17 which is driven past the focal point by means of a motor 18 which drives 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 the analyzer 13 in crossed position with the $\hat{X}$-axis of the crystal plate 10 at 45° to the analyzer position. In terms of the $\hat{X}$, Y, Z coordinate system, a field parallel to the Z-axis will produce an expansion or contraction, as the case may be, along the X-axis in the plate 10 and a contraction or expansion along the $\hat{Y}$-axis in a primary phosphate crystal material as explained in more detail in the above-mentioned parent application. Fig. 2 also illustrates the retardation plate 16 with the orientation of the slow ray parallel to the $\hat{X}$-direction of the crystal 10.

In considering the operation of the arrangement of Fig. 1, it will be understood that, in the absence of an applied voltage between electrodes 12 and 22 and in the absence of retardation plate 16, the system does not transmit any light. On the other hand if a potential is applied to electrodes 12, 22 sufficient to produce ½ wave phase difference in the two optical components of polarized light transmitted by the plate 10, light 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 A. C. signal applied to the system will 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 ¼ wave-length is used as it provides a symmetrical increase and decrease of transmitted light intensity upon the application of an alternating voltage to the crystal electrodes 12, 22.

Therefore, with the complete arrangement il-

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lustrated, 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 plate **10** effectively has two components each of which is linearly polarized. These two components travel at different velocities through the plate **10** depending upon the potential applied between electrodes **12** and **22**. Therefore, upon emerging, these two components may have relative phase values depending upon the potential which is applied between electrodes **12** and **22** and these components combine to produce a resultant ray, which in general is elliptically polarized. The shape of the ellipse describing the shape of polarization depends upon the relative retardation of the two components. This emerging light is, therefore, transmitted through analyzer **13** to a degree depending upon the retardation of the light so that variations in the potential applied to electrodes **12** and **22** cause variation in the intensity of the light transmitted through analyzer **13**. Light which is transmitted through analyzer **13** is concentrated upon the film **17** by the lens **19**. Accordingly, therefore, the light incident on the film **17** varies in accordance with the sound variations which are present at microphone **23**.

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

While there has been described what is at present considered to be the preferred embodiment 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 primary-phosphate crystal material in 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 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 primary-phosphate crystal material in 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 in said light path which is at least partially transparent to said light to permit said light to enter said plate; and an analyzer for light emerging from said plate.

3. An arrangement for controlling the transmission of polarized light comprising: a Z-cut plate of P-type primary potassium phosphate

crystal material in 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 in said light path which is at least partially transparent to said light to permit said light to enter said plate; and an analyzer for light emerging from said plate.

4. An arrangement for controlling the transmission of polarized light comprising: a Z-cut plate of P-type primary ammonium phosphate crystal material in 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 in said light path which is at least partially transparent to said light to permit said light to enter said plate; and an analyzer for light emerging from said plate.

5. An arrangement for controlling the transmission of light comprising: a polarizer in the path of said light; a Z-cut plate of P-type primary-phosphate crystal material in said path following said polarizer 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.

6. An arrangement for controlling the transmission of light comprising: a polarizer in the path of said light; a Z-cut plate of P-type primary-phosphate crystal material in said path following said polarizer 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 and including electrode portions in said path which are at least partially transparent to said light.

7. A light valve comprising a slice of ammonium dihydrogen phosphate crystal having two substantially plane faces substantially perpendicular to the optic axis, and electrodes adjacent said faces respectively having light-transmitting apertures aligned in the direction of the optic axes.

8. A device for delaying the travel of light waves comprising a Z-cut crystal plate of ammonium dihydrogen phosphate, and light-transmitting electrodes adjacent to the major faces respectively of said crystal plate.

HANS JAFFE.

REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
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2,493,200	Land	Jan. 3, 1950

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342,219	Great Britain	Jan. 29, 1931