April 28, 1931. V. K. ZWORYKIN 1,802,747

SYSTEM FOR RECORDING ELECTRICAL FLUCTUATIONS

Filed April 12, 1927

Fig. 1.

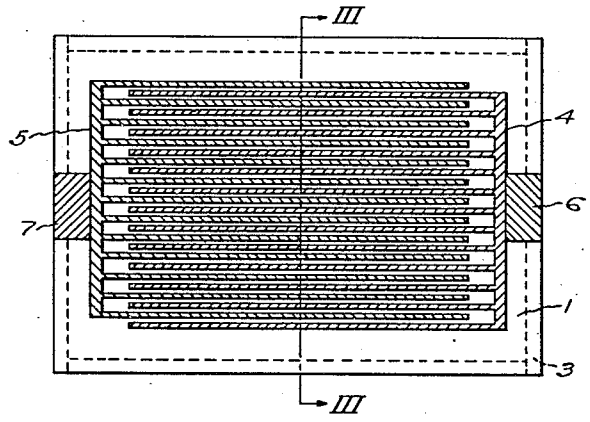


Fig. 2.

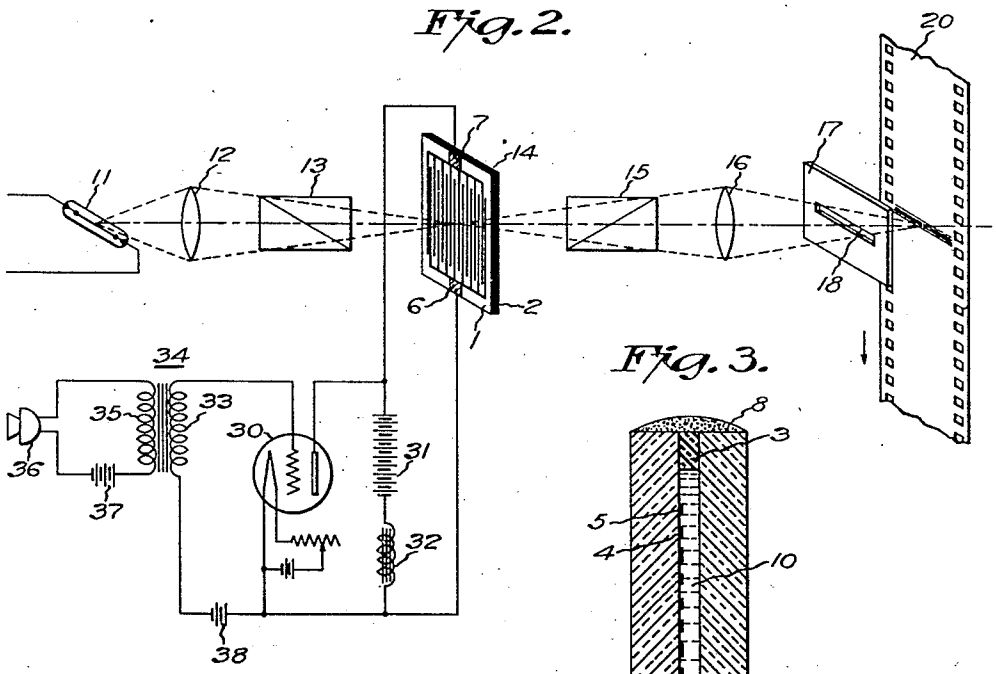


Fig. 3.

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Patented Apr. 28, 1931 1,802,747

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SYSTEM FOR RECORDING ELECTRICAL FLUCTUATIONS

Application filed April 12, 1927. Serial No. 183,226.

My invention relates to systems for recording electrical fluctuations, and in particular to systems wherein such fluctuations are photographically recorded upon a light-sensitive, moving film.

One object of my invention is to provide an improved device for translating electrical fluctuations into light-variations.

Another object of my invention is to provide a sound recording system that is substantially instantaneous in its response to electrical fluctuations representing sound frequencies.

Another object of my invention is to provide a sound recording system wherein the record is undistorted.

Another object of my invention is to provide a sound recording system wherein the intensity of the light from a constant source may be varied at frequencies corresponding to the highest harmonics accompanying vocal or instrumental music.

Still another and more specific object of my invention is to provide a Kerr cell that is much more sensitive than Kerr cells known to the prior art.

There has arisen, in connection with television systems, photo-telegraphy, talking moving pictures, and the like, a very definite need for a device for translating voltage fluctuations into light variations. Such a device should preferably have substantially no lag, should be responsive to frequencies varying from those in the lowest audible range to those lying in the so-called "radio-frequency" range, and should also be capable of effectively controlling light of a relatively high intensity.

Numerous attempts have been made to provide a suitable translating device of the character described, among which may be mentioned the use of movable mirrors, the modulation of a glow-tube, the use of the magneto-optic effect, and the use of Kerr cells.

Kerr cells of the prior art with which I am familiar, did not permit of the control of a large amount of light at high intensity, for the reason that it was necessary to very closely space the two electrodes between which the light was transmitted. The space between the electrodes varied from .3 millimeters to 1.5 millimeters, and the effect of this spacing, together with the absorption in the nitrobenzene or other dielectric in which the electrodes were immersed, acted to very seriously limit the amount of light which could be effectively controlled.

Kerr cells of the prior art were also undesirable as translating devices by reason of the extremely high potentials which had to be impressed across the electrodes. In an article by W. Schmidt in Annalen der Physik, 17, page 142, 1902, among other data relative to Kerr cells as then known, is given a formula which he states expresses the relation that exists between the rotation of a beam of polarized light in a Kerr cell and certain other factors. Where B is a constant depending upon the liquid dielectric used, P, the applied potential, A, the distance between the electrodes, L, the length of the polarized light path that is subjected to the electrostatic field, and D the rotation, the formula reads as follows:

$$D=B\frac{P^2}{A^2}L.$$

It is stated by Schmidt that when using electrodes separated a distance of 1.5 mm. he was forced to employ potentials of the order of 15,000 volts in order to obtain a satisfactory rotation of the plane of polarization of the light and it is obvious that potentials of this magnitude are not feasible for commercial use.

I have, accordingly, by the present invention, provided a Kerr cell that operates with much lower potentials than cells of the prior art, and one that permits the passage therethrough of a much larger proportion of the incident light than any of the cells heretofore known. Specifically, my invention consists in subdividing each electrode of a Kerr cell into a plurality of electrode elements, and in so intercalating these elements that the incident light is subjected to a plurality of electrostatic fields during its travel therebetween instead of being subjected to but a single field as in Kerr cells that were known to the prior art. In addition, I have pro-

vided a linear source of light and have so correlated the source and the Kerr cell that each portion of the light beam is subjected to a separate electrostatic field.

Among the features that I consider characteristic of my invention are those set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

Figure 1 is a side elevational view of my improved Kerr cell;

Fig. 2 is a view, partly diagrammatic and partly perspective, illustrating a preferred form of electrical fluctuation recording system utilizing my improved Kerr cell;

Fig. 3 is a fragmentary cross-sectional view of the cell itself, taken along a line corresponding to the line III—III of Fig. 1.

Referring to Figs. 1 and 3, my improved Kerr cell comprises a plurality of glass plates 1 and 2, the surfaces of which are preferably optically plane and perfectly parallel. These plates are separated a very slight distance by an element 3 analogous to a gasket, which is preferably made of mica, glass or quartz. One of the plates supports thereon a plurality of groups of electrode elements 4 and 5, the individual elements of the several groups being intercalated. The individual groups of electrode elements are connected in parallel and they are provided with conducting elements 6 and 7 respectively which are preferably made of tin foil or analogous material.

The plates 1 and 2 are held in assembled position, as shown in Fig. 3, by a suitable binding material 8 which is applied to the edges thereof.

The space 10 between the plates is filled with nitrobenzole or an analogous dielectric material which causes rotation of plane polarized light when such light is passed therethrough and subjected to the influence of an electrostatic field between electrodes immersed therein.

Referring to Fig. 2, a complete recording system is indicated therein. The recording system comprises a linear source 11 of light, an achromatic condensing lens 12, a polarizer 13, a Kerr cell 14, an analyzer 15, a second lens 16, a screen element 17 provided with a linear opening 18 therethrough, and a light-sensitive medium, such as a film 20.

The linear source 11 of light may be an incandescent lamp having a single straight filament, or it may be a glow tube of any well-known type. The opening 18 through the screen element 17 is at right angles to the path of travel of the light-sensitive medium and is parallel, or approximately parallel, to the long axis of the light source.

The Kerr cell 14 is so arranged that the electrodes thereof are at an angle to the long axis of the light source. These electrodes are preferably kept vertical, in order that any dust particles in the cell will settle out and will not impede the passage of the light therethrough.

The plane of polarization should be at 45° to the electrostatic field.

In order that the operation of my improved system may be clearly explained, I have shown the electrodes of the Kerr cell connected across the output circuit of a thermionic amplifier tube 30. The output circuit, in addition, comprises a potential source 31 and a resistor or reactor 32. The input circuit for the thermionic device comprises the secondary 33 of an audio frequency transformer 34, the primary 35 of which may be connected in series with a microphone 36 and a voltage source 37.

In order that the thermionic amplifying device shall operate upon the straight portion of its characteristic curve, a source 38 of biasing potential is incorporated in the grid circuit thereof. Potential changes on the grid thereof, therefore, are represented by amplified potential fluctuations across the reactor 32 in the output, or plate circuit, which amplified fluctuations are a true copy, both as to frequency and relative intensity, of the grid voltage fluctuations.

The potential changes across the reactor 32 are impressed on the electrodes of the Kerr cell 14, and cause rotation of the plane of polarization of the light passing therethrough. The rotation varies as the square of the applied potential, and the light which passes through the analyzer to affect the light-sensitive medium 20 accordingly bears a very definite relation to the excitation of the grid of the thermionic device.

It will be noted that the light from the linear source 11, after passing through the polarizer 13, falls on the electrodes of the Kerr cell in a line which is substantially at right angles to the direction in which the electrodes extend. Each individual pair of electrode-elements accordingly subjects a small portion of the light to the action of an electrostatic field, in the same manner that the two electrodes of Kerr cells of the prior art affected the entire amount of light which was caused to pass between them. The light from the source 11 is consequently subjected to a rotational force which is many times more effective than if but a single pair of electrodes is employed, and, if desirable, a beam of light having a cross section substantially equal to the width of the cell may be employed to good advantage.

When using a beam of large diameter such beam may be of relatively low intensity to

obviate heating the nitrobenzole, and it may be reduced to an appropriate size for recording by an appropriate lens system.

The microphone 36 is shown merely as indicative of a source of electrical fluctuations and it may obviously be replaced by any other equivalent device. The system may, for example, be utilized for the photographic recording of either radio or telegraphic signals, or it may be utilized in television or picture telegraphy systems.

There are two methods for preparing the thin glass plate which carries the electrode systems; one of these methods comprises plating the glass with a metal having good conductivity and then removing certain portions of the metal in order to form the two electrode systems. The other method comprises ruling the glass with two systems of parallel lines, each group being connected by a groove extending at right angles to the main grooves and then rolling a metal, such as silver or copper, into all of the grooves. The lines are ruled quite close together, the preferred spacing being one one-hundreth of a millimeter or less, and the resulting space between the metallic electrode elements is approximately one-half of this amount.

The unruled space between the electrode elements is, of course, transparent to light, and a plurality of such plates may be arranged serially in such manner that the lines and the spaces of the several plates are aligned, in order to construct a modified form of cell.

The space 10 between the two glass plates illustrated in Fig. 3 is preferably of the same order of magnitude as the space between individual electrode elements. In other words, if the electrode elements are separated by five thousandths of a millimeter, this same space is amply sufficient between the two glass plates, it only being necessary that the nitrobenzole shall be able to penetrate therebetween and cover all of the said electrode elements.

The various figures of the drawings are not drawn to scale, but the relative proportions are exaggerated in order that the details of my improved cell may be apparent. In an actual embodiment of my invention the glass plates 1 and 2 have a thickness of not more than a few millimeters, and, as before explained, they are preferably separated by a space of the order of five thousandths of a millimeter.

Each individual electrode element is made so thin that the entire assembly casts an inappreciable shadow when interposed between a source of light and a screen.

Insofar as I am aware, a Kerr cell of this type has not heretofore been made, the cells with which I am familiar comprising only two electrodes, each electrode having an appreciable thickness, between which a beam of light of high intensity was caused to pass. Such cells were unsatisfactory by reason of the fact that in order to obtain sufficient light for recording purposes it was unnecessary to use a highly concentrated beam which tended to heat the nitrobenzole and cause chemical action therein.

My improved cell is principally advantageous in that it permits of the use of voltages much lower than those heretofore employed. It is also apparent, from an inspection of the formula previously given, that inasmuch as the rotation is inversely proportional to the square of the distance between the electrodes, my improved cell will permit of much more efficient control of a light beam than cells of the prior art in which the electrodes were separated by distances of the order of three tenths to one and one-half millimeters.

My improved cell is also much more sensitive than cells with which I have previously been acquainted, the sensitivity being proportional to the square of the distance between adjacent electrode elements.

My improved system operates with substantially no lag and as a consequence the light faithfully represents the signal frequencies which are being recorded. This feature is of very considerable advantage in connection with the making of talking motion picture films.

Although I have illustrated and described only one form which my invention may take, it is obvious that many modifications thereof are possible. The invention therefore, is not to be limited except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a system for recording electrical fluctuations, a linear source of light, a light-sensitive medium, a Kerr cell comprising a plurality of linear electrodes interposed between said source and said medium, and means for impressing electric potentials across said electrodes.

2. In a system for recording electrical fluctuations, a linear source of light, a light-sensitive medium, a Kerr cell comprising a plurality of groups of linear electrodes interposed between said source and said medium, means for polarizing said light before it reaches said Kerr cell, and means for analyzing said light interposed between said Kerr cell and said light-sensitive medium.

3. In a system for recording electrical fluctuations, a linear source of light, a light-sensitive medium, a Kerr cell comprising a plurality of groups of linear electrodes interposed between said light and said medium, the electrodes of the individual groups being connected in parallel and means for impressing electrical potentials on said groups of electrodes.

4. In a system for recording electrical

fluctuations, a linear light source, a light-sensitive medium, a Kerr cell comprising a plurality of linear electrodes interposed between said source and said medium, and a screen having a linear opening interposed between said Kerr cell and said medium, the opening and the light source being approximately parallel and the said electrodes extending at an angle thereto, whereby more than two electrodes are effective in controlling the light which passes from said source to said medium.

5. In a system for recording electrical fluctuations, a linear source of light, a Kerr cell comprising a plurality of substantially parallel linear electrodes, and means whereby the light from said source falls on said electrodes in a beam transverse thereof.

In testimony whereof, I have hereunto subscribed my name this 9th day of April, 1927.

VLADIMIR K. ZWORYKIN.