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Sept. 20, 1932. J. ROBINSON 1,878,891

ELECTROOPTICAL APPARATUS

Filed Nov. 18, 1929

Modulated Light

Amplifier resonant to modulation freq.

May use series of P.C.'s

Fig. 1.

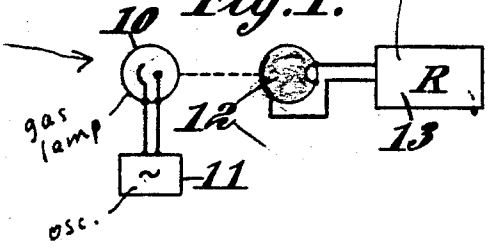


Fig. 2.

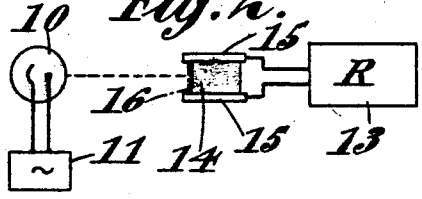


Fig. 3.

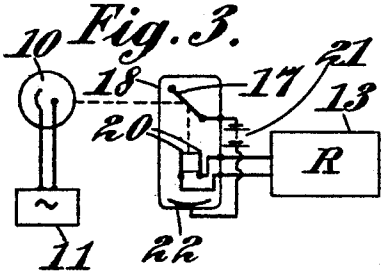
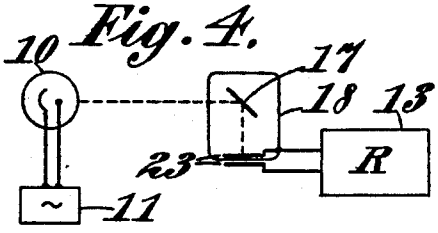


Fig. 4.



Regenerative (Optical)

amplifier

Fig. 5.

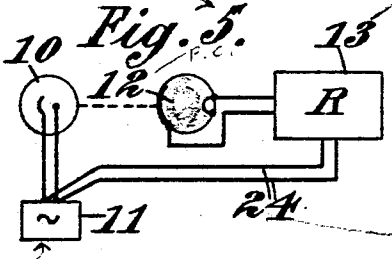
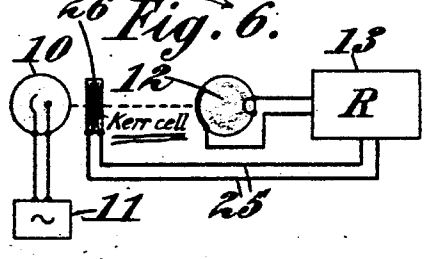
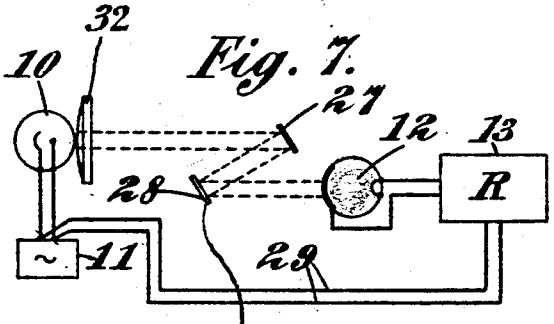


Fig. 6.



neon lamp for regeneration

Fig. 7.



reflectors to adjust ϕ between light pulses and P.C. output

INVENTOR

James Robinson

By Watson, Cole, Grosvenor & Plumb

Attys

[redacted]

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1,878,891

UNITED STATES PATENT OFFICE

JAMES ROBINSON, OF MILL HILL, LONDON, ENGLAND, ASSIGNOR, BY MESNE ASSIGNMENTS, TO BRITISH RADIOSTAT CORPORATION, LIMITED, A CORPORATION OF CANADA

ELECTROOPTICAL APPARATUS

Application filed November 18, 1929, Serial No. 408,129, and in Great Britain December 1, 1928.

This invention relates to the conversion of light and similar radiant energy into electrical and other forms of energy which may be utilized in various ways such for example as in signalling and other communication systems, and the apparatus for such use.

This invention comprises a method of utilizing light energy to control, or to convert it into, other forms of energy consisting in modulating or interrupting the light energy to produce light pulses and causing said light pulses to impinge on a responsive device coupled to a resonant system tuned with respect to the modulating frequency to control or produce energy in said system.

The term "light energy" is employed herein broadly to include wave energy of any frequency between wireless waves of the highest known frequency and X-rays of the highest frequency and this term thus includes visible and invisible light and X-rays. The modulation or interruption may be at frequencies from below that of an audible note up to values approaching the frequency of light waves, or in figures say from 10 to 10^8 cycles per second.

In one manner of carrying out the method of this invention, the light pulses are caused to impinge upon a piezo-electric crystal to produce corresponding electrical oscillations which are passed on to the tuned system. The crystal constitutes a mechanical resonator and is in tune with the frequency of the modulation.

According to the invention the control of the responsive device by the light pulses may be effected or assisted by a photoelectric effect (for example, by producing, by electronic action, stress in or on a quartz resonator).

In another manner of carrying out the method according to the invention the light impulses are caused to impinge upon a light sensitive device such as a selenium cell coupled to the resonant system in such a manner as to produce oscillations therein.

The invention comprises the method of utilizing light-energy wherein the electrical oscillations produced or controlled in the resonant system are led back to react upon the light pulses in order to produce a regenerative effect.

In the accompanying drawing there are illustrated by way of example and in a purely diagrammatic manner, in Figures 1 to 7, several arrangements for carrying out the method according to the invention in various ways.

Like reference numbers indicate like parts in the several figures of the drawing.

In carrying this invention into effect any suitable source of light is modulated at a selected modulating frequency (or at more than one of such frequencies); the Poulsen arc is one type of source which can be made to oscillate efficiently at frequencies of a quarter of a million or over, and a neon lamp can be made to oscillate at still higher frequencies. For modulating frequencies of the order of one million or more, highly rarefied tubes may be used, employing the well-known electrodeless discharge, or a Kerr cell may be used.

In Figure 1 a neon lamp 10 is shown, energized by a source 11 of modulating frequency energy to produce modulated light rays from the neon lamp. These modulated light rays or light pulses impinge upon a light-sensitive device 12. The light sensitive device 12 is coupled to a resonant system 13 which is tuned to the frequency of the modulating frequency source 11.

The resonant system indicated at 13 comprises a tuned circuit to which varying electric effects produced or controlled at the light sensitive cell are applied. In the case of a photoelectric cell the potentials produced therein are fed to the tuned current and when a selenium cell is employed a source of electric energy is used in conjunction therewith so that the selenium cell controls the effect of this source upon the tuned circuit. This arrangement using a selenium cell is a useful one for the reproduction of sound from sound record films.

A mechanically resonant responsive device such as a quartz crystal tuned to the modulating frequency, may be used, taking advantage of the piezo-electrical effect as shown in Figure 2, the light pulses from the neon

lamp 10 are caused to impinge upon a facet of the crystal 14. The mechanical pressure of the light is rendered operative by making the surface of the crystal either highly reflecting or black. As such a crystal has very small damping, the pulses of light will make the device oscillate at the modulating frequency, building up to a considerable amplitude. By employing the piezo-electrical properties of the crystal, the electrical charges produced on the surface of the crystal are collected by plates 15 of a condenser between which the crystal is supported. The plates 15 are connected to the resonant system 13 comprising a tuned circuit as aforesaid for the resulting electrical oscillations.

Instead of using the mechanical pressure of the light or in addition thereto, a photoelectric effect may be obtained by coating the facet of the quartz crystal upon which the light pulses fall (as indicated at 16) with potassium, zinc or some other material which emits electrons when light falls on it. The quartz crystal is preferably enclosed in an evacuated vessel in this case. When the electrons are emitted there will be the equivalent of a force acting on the surface of the crystal, so that in this manner also it may be caused to oscillate by illuminating it by the pulses of light.

In a modified arrangement, instead of using a photoelectric material on the face of the crystal, there may be provided a metallic surface for collecting the electrons. Thus, as shown in Figure 3, the light pulses from the neon lamp 10 are caused to impinge upon a photoelectric surface 17 in a vacuum tube 18. The quartz crystal 19 is also located in the tube and is mounted between plates 20 which are connected to the resonant system 13. The resonant system may be a simple tuned circuit or a plurality of such circuits coupled in cascade with or without the use of valves, or alternatively it may be a valve oscillator. When light falls on the surface 17 and causes the emission of electrons, these electrons will impinge on the surface of the crystal and produce by resonance considerable oscillation thereof. The electrons are preferably given a high velocity by applying a suitable potential, e. g. by means of a battery indicated at 21 connected to an electrode 22 in the tube 18 and to the electron emissive surface 17 so as to enhance the effect on the crystal. The resulting electrical oscillations are applied to the resonant system 13 as before.

In the arrangement shown in Figure 4, the light pulses from the neon lamp 10 are caused to impinge upon a photoelectric surface 17 in the vacuum tube 18 and the resulting electronic emission charges up a condenser 23 at the frequency of the pulses of light. The condenser is coupled to the resonant system 13 and may form part of the tuned circuit as aforesaid in which electric oscillations are thus built up.

In carrying out this invention the electrical output of the resonant system may be used to control the intensity of the light which energizes the light-responsive device, thus providing what might be called an optical regenerative effect. As shown in Figure 5, the light pulses from the neon lamp 10 impinge upon the light-sensitive device 12 which is coupled to the resonant system 13 as described with reference to Figure 1. A portion of the electrical output from the system 13 is fed back by the conductors 24 to the neon lamp to control the intensity of the light. If, for example, a thermionic valve amplifier is employed in the resonant system 13, the anode voltage of one of the valves may be associated (e. g. by the conductors 24) with the supply 11 for the neon lamp, so that the voltage available for the lamp then depends upon the anode current of the valve which in its turn depends on the amount of light falling on the light-sensitive cell. By suitable adjustment, the light from the lamp may be made to increase or to decrease as the photoelectric current increases. Amplification is obtained by arranging that the light of the lamp increases as the photoelectric current increases.

Another manner of obtaining the regenerative effect is shown in Figure 6 which is similar to that shown in Figure 5 with this exception that, instead of feeding back electrical energy to the neon lamp, the electric output of the system 13 (or the output of a valve employed therein) is taken by conductors 25 to a Kerr cell 26 arranged in the path of the light pulses from the neon lamp 10 to the light-sensitive device 12. The Kerr cell energized in this way is arranged to control the amount of light falling upon the light-sensitive device 12.

This optional regenerative effect is particularly convenient for application when the high frequencies are employed; thus, for example, if the lamp is modulated at a frequency of, say, one-hundred millions and the wave-length of the light pulses is about three metres, then, by adjusting the distance between the lamp and the photoelectric cell, the phase relationship between light pulses and phototelectric current is under control. As shown in Figure 7, the light pulses emitted by the neon lamp 10 are projected in the form of a beam by means of a lens 32 and this beam is directed by reflectors 27, 28, on to the light-sensitive device 12 coupled to the resonant system 13 and from which latter a feed back of electrical energy is made by conductors 29 to the neon lamp. The reflectors are adjustable and in this manner the path of the light pulses may conveniently be adjusted in order to provide the desired phase relation between the light pulses and the electrical output.

It will be understood that any object may be placed between the light source and the light-responsive device so as to produce an analogous effect upon the electrical output, or light may be reflected or diffused from the object on to the responsive device for this purpose.

The resonant system hereinbefore described may include a thermionic valve arrangement of any desired form for detecting and/or amplifying the electrical oscillations.

It also lies within the scope of this invention to employ the pulsating illumination aforesaid with a series of light-sensitive devices and lamps controlled thereby, the lamp controlled by one light-sensitive device shining from another light-sensitive device so as to control the lamp associated with the second device. By using a series of such parts any desired degree of amplification may be obtained.

It will further be understood that the invention is not restricted to the several specific examples given of carrying the invention into effect.

I claim:—

1. Apparatus for utilizing light energy to control or to convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a light-responsive device on which the light pulses impinge and produce corresponding electrical pulses, and an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the light-responsive device are applied.

2. Apparatus for utilizing light energy to control or to convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a photo-electric surface upon which the light pulses impinge, a piezo-electric device energized by the photo-electric effect according to the light pulses and producing corresponding electrical pulses, and an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the piezo-electric device are applied.

3. Apparatus for utilizing light energy to control or to convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a photo-electric surface upon which the light impulses impinge and arranged to emit electrons according to the light pulses, a piezo-electric device energized by the said electrons and producing corresponding electrical pulses, and an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the piezo-electric device are applied.

4. Apparatus for utilizing light energy to control or to convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a light-responsive device on which the light pulses impinge and produce corresponding electrical pulses, an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the light-responsive device are applied, and means for feeding back energy from the said electrical system to re-act upon the light whereby a regenerative effect is obtained.

5. Apparatus for utilizing light energy to control or convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a light-responsive device on which the light pulses impinge and produce corresponding electrical pulses, an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the light-responsive device are applied, a Kerr cell interposed between the source of light and the light-responsive device, which Kerr cell is electrically connected with the said electrical system whereby a regenerative effect is obtained.

6. Apparatus for utilizing light energy to control or to convert it into other forms of energy, comprising a source of light, means for modulating the light to produce light pulses, a light-responsive device on which the light pulses impinge and produce corresponding electrical pulses, an electrical system tuned to the modulation frequency of the light pulses, to which electrical system the corresponding electric pulses from the light-responsive device are applied, means for feeding back energy from the said electrical system to re-act upon the light whereby a regenerative effect is obtained, and means in the path of the light energy emanating from the source for controlling the length of the path of the light whereby an adjustment of the phase of the energy fed back in relation to the phase of the light energy at the source is obtained.

7. The method of utilizing light energy to control or to convert it into other forms of energy consisting in modulating the light energy to produce light pulses, converting said light pulses into corresponding electric pulses, and selectively receiving said electric pulses according to the frequency of the modulation.

In testimony whereof I affix my signature.

JAMES ROBINSON.