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51 E. M. JONES 2
SYSTEM FOR PREVENTING TRANSIENTS IN PHOTOELECTRIC
MUSICAL INSTRUMENTS

2,576,758

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2 SHEETS--SHEET 1

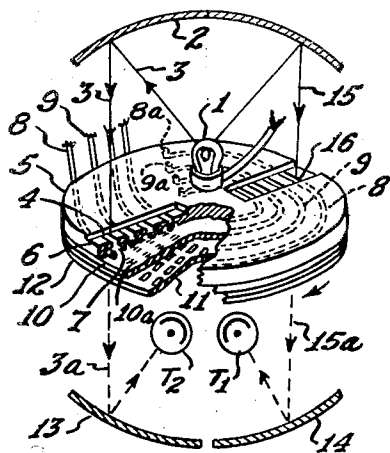


Fig.1.

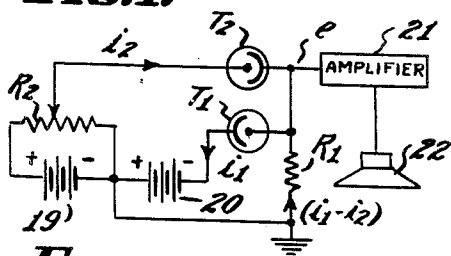


FIG. 2

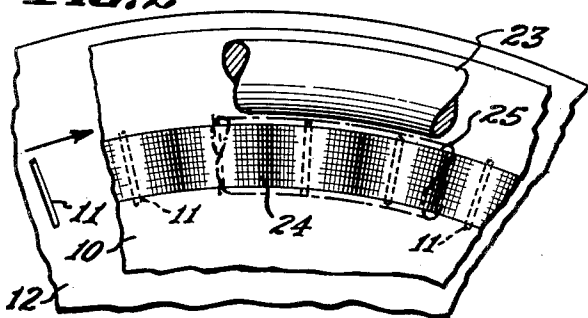


FIG. 3.

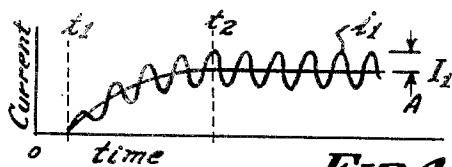


FIG. 4.

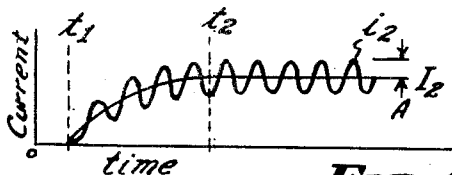


FIG. 5.

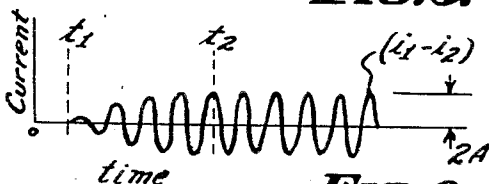


FIG. 6.

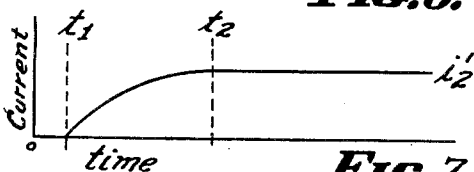


Fig. 7.

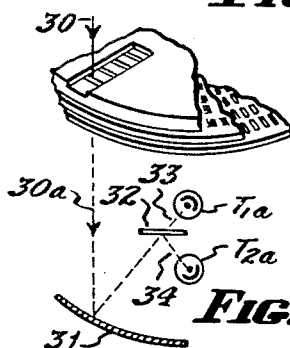


FIG. 11.

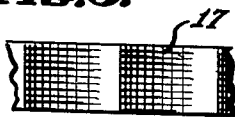


FIG. 8

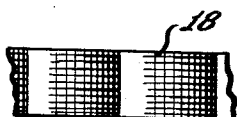


Fig. 9.



FIG. 10.



FIG. 12.



FIG. 13.

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2 SHEETS—SHEET 2

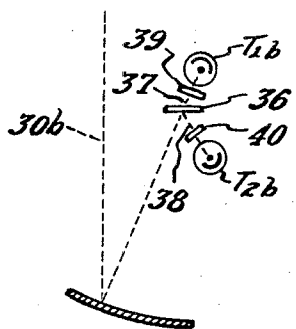


FIG. 14.

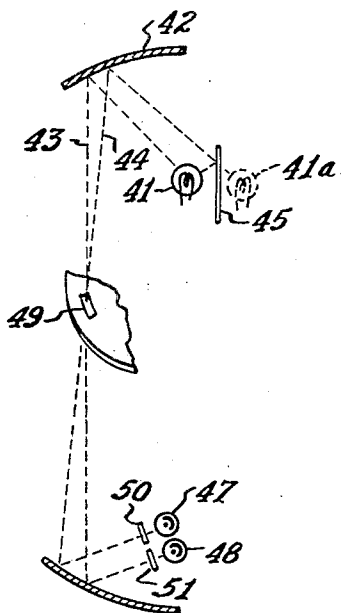


FIG. 15.

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UNITED STATES PATENT OFFICE

2,576,758

SYSTEM FOR PREVENTING TRANSIENTS IN PHOTOELECTRIC MUSICAL INSTRUMENTS

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Application January 4, 1949, Serial No. 69,081

21 Claims. (Cl. 84—1.18)

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My invention relates generally to photoelectric musical instruments of the type wherein a beam of light is modified or interrupted to produce in a photocell circuit electric pulsations which may be amplified and converted into musical tones by an electro-acoustic system. In particular, my invention relates to the problems arising from transients in such instruments at the beginning and ending of respective trains of pulsations, which result in objectionable "thumps" in the corresponding musical tones.

Therefore, it is a general object of my invention to provide methods and means for preventing undesirable transients from occurring in the tones produced by photoelectric musical instruments.

Photoelectric instruments present an exaggerated problem in this connection in that the impingement of beams of light upon a photocell produces pulsating currents having large direct current components, and the sudden onset or cessation of these components, or in the case of a plurality of notes being played in overlapping relationship, the sudden occurrence of substantial variations in the magnitude of these components, causes transients giving rise to audible thumps in the acoustic system quite distinct from and much more objectionable than the so-called key-clicks which result from the sudden onset of a train of alternating current oscillations as such. The shutters of photoelectric instruments ordinarily open gradually rather than instantaneously and while this may sufficiently reduce key-click, as defined above, the speed of shutter operation necessitated by the requirements of musical compositions is so great that the thumps caused by direct current components or variations cannot be effectively eliminated in this way.

A specific object of my invention is to provide methods and means for producing photoelectrically pulsations having alternating components corresponding to desired musical tones but having substantially zero direct components.

Another object is to provide means whereby individual rays of light can be so modified that, although these beams of light are caused to act on photocells, electric pulsations devoid of direct current components may be produced therefrom.

A further object having to do with one aspect of my invention is to provide a system wherein the desired compensation or elimination of direct current components can be accomplished by means of a single beam of light modified as hereinafter described.

These and other objects which will be set

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forth hereinafter or will be apparent to those skilled in the art upon reading these specifications, I accomplish by the circuits, constructions and arrangements of parts of which I shall now set forth exemplary embodiments. Reference is made to the appended drawings wherein:

Figure 1 is a diagrammatic representation, partially in perspective and partially in section, of certain elements of a photoelectric musical instrument employing my invention;

Figure 2 is a schematic diagram of an electric circuit such as may be employed with the photocells of Figure 1;

Figure 3 is an enlarged broken view of certain elements of Figure 1;

Figures 4-7 are graphical representations of electric currents present in various branches of the circuit of Figure 2 under different conditions;

Figures 8-10 illustrate certain wave form patterns such as may be employed in the structure of Figure 1;

Figure 11 illustrates the essential elements of a preferred embodiment of my invention;

Figures 12 and 13 show wave form patterns which may be employed with the structure of Figure 11; and

Figures 14 and 15 illustrate other embodiments of my invention.

It is well known in the photoelectric art that when either a steady or pulsating light, directed upon the photosensitive surface of a photocell, increases in intensity from zero to some average value, the electric current in the usual circuit employed with such a cell rises from zero to some average value. The faster the light builds up from zero to such an average value, the steeper will be the front of the current vs. time characteristic. Such transients in the direct current components of pulsating currents, when amplified and passed through an electroacoustic system, cause objectionable sounds, commonly known as "thumps," to be transmitted therefrom. In a photoelectric musical instrument wherein the onset rate of tones is directly proportional to the velocity of depression of respective keys in a keyboard, the faster the key stroke, the more objectionable the thump becomes.

According to my invention I connect two photocells in a circuit such that their respective currents are subtractive in an associated circuit. If, then, I direct upon one photocell pulsating light which is substantially opposite in phase to the light directed upon the other photocell,

and if the average D. C. components of the respective pulsating currents are adjusted so as to be approximately equal, the subtracting of the currents will result in a pulsating current which is substantially devoid of a direct component. If the alternating components of the respective pulsating currents are approximately equal before the subtraction is effected, the resultant oscillation will have an amplitude of twice that of the individual pulsations. It is not necessary, however, that the A. C. components be equal. For example, if one A. C. component is zero, the D. C. components will still cancel (if adjusted so as to be equal), resulting in an oscillation of the same amplitude as the one containing an A. C. component, but devoid of a D. C. component. Hence, as a variant of the above procedure I may direct upon one of the photocells pulsating light, and upon the other a steady light controlled as to average intensity and specific variation of average intensity in accordance with the first light. I shall now describe my invention with reference to the accompanying drawings.

In the practice of my invention I prefer to employ an instrument similar to that described by John F. Jordan in his co-pending application entitled *Shutter Mechanism*, Serial No. 45,897, filed August 24, 1948, now Patent No. 2,506,599, dated May 9, 1950. Certain elements of such an instrument are shown in Figure 1. Light from a source 1 is converted to parallelism by a concave parabolic reflector 2, individual rays such as 3 being directed downward through an aperture 4 in a shutter plate 5. As described in the above mentioned application, apertures such as 4 are produced by the intersection of radial recesses 6 on one side with annular concentric grooves 7 on the under side of the shutter plate 5. The grooves 7 are in two sections, one being wider than the other radially, so that playing key-operated shutter wires 8 may assume either a closed position as illustrated for the shutter wire 9, in which position the wire obstructs the passage of light through a radially narrower section of an annular groove 7, or may assume an open position, such as that illustrated for the shutter wire 8, wherein a ray of light such as 3 is permitted to pass through the aperture 4. Jordan selects different notes by depressing playing keys (not shown) which exert longitudinal forces upon shutter wires such as 8 and 9, anchored to the plate 5 at 8a and 9a, respectively. A compressive force, for example, acting upon the free end of a wire such as 8 causes the wire to move radially outward in its annular groove. Jordan selects different tone colors by exposing recesses such as 6, normally covered by doors or plates (not shown), under each of which is a different series of tone color or wave form patterns, as next described.

Upon a fixed disc 10 and aligned with respective apertures are wave form patterns, indicated generally at 10a, which may be of the type illustrated in detail in Figures 3, 8 and 9. The wave form patterns convert uniform rays of light such as 3 to rays of non-uniform intensity circumferentially so that when each patterns is scanned by transparent slots 11 in an opaque rotating pitch disc 12, a ray 3a pulsating in accordance with a desired wave form is produced. More than one cycle of a particular wave form pattern may be scanned simultaneously by an equal number of slots, so long as the aperture is of such length that each succeeding slots starts scanning a cycle at the point in that cycle corresponding to the point in another cycle where a preceding slot

stops scanning. The apparatus thus far described is typical merely of a photoelectric instrument to which my invention may be applied, and is not limiting.

In the Jordan instrument a single photocell, located at the focus point of a lower parabolic reflector, collects the rays 3a. Resultant oscillations in a photocell circuit are then amplified and reproduced by a loud speaker. The problem of eliminating undesirable transients from the tones produced by this and similar photoelectric instruments, has not hitherto been solved. I introduce certain modifications in such structures as hereinafter described, to accomplish the objects of my invention.

According to one modification of my invention I may employ two concave reflectors 13 and 14 (Figure 1) for directing separate rays of light 3a and 15a respectively upon separate photocells T₂ and T₁. These rays are separately modified. The ray 15a pulsates in accordance with a wave form pattern located under an aperture 16 which is illuminated by a uniform ray 15. Also, the wave form pattern modifying the ray 15 may be such that it will produce a pulsating ray 15a in which the tone producing pulsations are opposite in phase to those produced in the ray 3a. For example, a wave form pattern such as 17 in Figure 8 may be employed to modify the ray 3 while a wave form pattern such as 18 in Figure 9 may be used to modify ray 15. It will be noted that wave form patterns 17 and 18 are opposite in phase, that is, from left to right the wave form pattern 17 becomes lighter, or more transparent, during a cycle, while the wave form pattern 18 becomes darker, or less transparent. It will be understood that the showing in Figures 8 and 9 is largely diagrammatic. The wave form representations 17 and 18 may be highly complex and contain a plurality of variations or transverse bands for the purpose of combining specific harmonics with the fundamental pulsations. The wave-form representations or images, however, will be so arranged that in scanning the images, the variations or pulsations produced in ray 3a will be substantially equal and opposite to those in ray 15a, while the general or average light intensity (including its increase from zero to a maximum, and its cessation) is preferably substantially the same for both rays.

By connecting the photocells T₁ and T₂ as shown in Figure 2, their respective currents i_1 and i_2 are caused to flow through an output impedance R₁ in opposition. A potentiometer R₂ provides means for adjusting the current i_2 so that its D. C. component may be made to equal that of i_1 . Suitable sources 19 and 20 of direct current may be connected as shown in the photocell circuits of T₂ and T₁ respectively. An electric potential to ground $e = (i_1 - i_2) R_1$ is thus applied to an amplifier 21 the output of which may be connected to a loud speaker 22. This is typical of circuits in which the outputs of photocells T₁ and T₂ may be caused to act in opposition, and other circuits may be employed.

I shall now explain in detail how the D. C. components of the tube currents i_1 and i_2 cancel each other. Assuming for simplicity a condition wherein the currents i_1 and i_2 are sinusoidal and opposite in phase, their characteristics as a function of time may be represented by the curves i_1 and i_2 of Figures 4 and 5 respectively. After the instant t_1 when a shutter wire such as 23 in Figure 3 begins to expose a wave form pattern such as 24 from a closed position (indicated by

the dot-dash outline 25), the curve i_1 of Figure 4 builds up from zero toward an average value I_1 which is reached at a time t_2 when the shutter wire 23 has assumed an open position entirely exposing the wave form pattern. Between substantially the same instants t_1 and t_2 , the current i_2 (represented in Figure 5) builds up from zero to an average value I_2 . The current $(i_1 - i_2)$ flowing through the resistor R_1 of Figure 2 will have a wave form indicated by the curve $(i_1 - i_2)$ of Figure 6, the amplitude being 2A or twice the amplitude A of the individual currents i_1 and i_2 . Thus I produce oscillations which are devoid of direct current components, and hence of the objectionable thump arising therefrom.

The direct current component I_1 of a pulsating current (as diagrammatically illustrated in Figure 4) may be canceled by applying against it a current of the same average intensity but devoid of the audio-frequency pulsations. In this event, the amplitude of the oscillations will be that of the pulsations in the first mentioned current, and will not be doubled as in the last described example. One way of accomplishing this is to substitute a uniform density pattern such as 25 in Figure 10 for a non-uniform wave form pattern under the aperture 4. The current i_2 flowing through the cell T_2 may thus be made to vary as indicated by the curve i'_2 in Figure 7. If the pattern 26 does not have an average intensity equal to the average intensity of the wave form pattern under aperture 16, the potentiometer R_2 may be adjusted until i'_2 (steady state) is equal to the average current I_1 .

Although the operating principles of my invention are more easily described in connection with the above embodiments, I prefer to employ the embodiment illustrated in Figure 11, which is simpler mechanically. In this system I need employ only one beam of light for each note to obtain electric pulsations devoid of D. C. components. Here I employ wave form patterns whose transmission characteristics for one color, or wave length range, differ from those of another color, or wave length range. For example, by the use of wave form pattern 27 of Figure 12, comprising a red filter section 28 of decreasing intensity from left to right and a green filter section 29 of increasing intensity from left to right, it will be obvious that an opposite phase relationship is present between the red and green components of a ray of light which scans such a wave form pattern. If, then, a ray 30 (Figure 11) is caused to pass through a wave form pattern such as 27, the modified ray 30a, having red and green components in opposite phase relationship, may be directed by a concave reflector 31 toward a photocell T_{1a} . If, also, I place a dichroic mirror 32 of the proper type in the path of the reflected beam, the green component 33 of the beam 30a will be permitted to impinge photocell T_{1a} , while the red component 34 of the beam 30a will be reflected toward the photocell T_{2a} . It will be obvious that the current passing through the cells T_{1a} and T_{2a} will be opposite in phase. Therefore, in a circuit such as that illustrated in Figure 2 oscillations devoid of D. C. components may be produced in an output system.

Red and green are mentioned as exemplary colors or wave-length bands, and are not limiting. Where wave-form representations or images are formed in colors, these colors are used as filters to pass certain wave-lengths. The action of such colors in separating the incident light

into the desired components is not always perfect. To avoid the production of extraneous modifications of the rays as to their content of other wave-lengths or bands which might affect the photocells, it is within the scope of my invention to employ additional filtering either of the incident light, or of the modified rays prior to their impingement upon the photocells.

As an example of a dichroic mirror which I may use, I mention one in which a very thin layer of gold leaf is sandwiched between layers of glass. Other forms of dichroic mirrors may be employed.

I may also employ wave form patterns such as 35 in Figure 13 wherein a single color filter (such as red) of varying intensity constitutes the wave-form image. In this case, a red component of light in the beam 30 passes through the wave form pattern without modifications thereby, while other portions of the ray, such as the green component of the beam 30 are subjected to variation in intensity in accordance with the wave form pattern 35. The modified ray 30a may be divided by the system of Figure 11 into components such as 33 and 34 respectively; but the red component 34 will be a uniform ray having no pulsating component. By electrical subtraction in a circuit such as that shown in Figure 2) oscillations devoid of D. C. components may be produced. The amplitude of such oscillations, as in the above case employing the wave form pattern 26, will be equal to that of the amplitude of the A. C. component of the current flowing through the cell T_{1a} .

It is also within the scope of my invention to employ the structure illustrated in Figure 14. A mirror 35 may be partially coated with a totally reflecting surface or fully coated with a partially reflecting surface, such as a thin layer of silver, so that a portion of the light is allowed to pass through while the remainder is reflected. A ray 30b, similar to 30a of Figure 11 is thereby divided into two constituents 37 and 38 which may be directed upon photocells T_{1b} and T_{2b} (Figure 14) which are responsive to two different wave length ranges respectively by virtue either of the inherent characteristics of the cells or the use of light filters 39 and 40, which may be green and red respectively, placed in the path of the rays 37 and 38 to produce in the circuits of cells T_{1b} and T_{2b} currents varying in accordance with constituents determined by the pattern 35.

Yet again, it is within the scope of my invention to employ a system such as that embodied in the structure of Figure 15 wherein light from a polychromatic source 41, located at the focal point of a parabolic reflector 42 is converted into two beams of which the rays 43 and 44 respectively are a part. The ray 43, as in the case of the ray 30 of Figure 11, may be perpendicular to the plane of a shutter plate, such as 5, indicated generally at 49. The ray 44, however, reflected by a mirror 45 producing an image 41a of the source 41, intersects this plane at an angle slightly different from 90° and is directed by the reflector 46 through an appropriate filter 59 toward a cell 47, the ray 43, as modified by a filter 51, being caused by the same reflector to impinge upon a cell 48 located at the focal point of the reflector 46. The filters 50 and 51 may be red and green respectively. Or I may, as in the case of Figure 14, omit the filters and employ photocells whose inherent characteristics render them responsive to desired wave lengths of light. If the respective rays are modified at 49 by a wave form, such

as 35 (Figure 13), the desired effect may be attained. This last system is a simplification of a similar one wherein 41a is a separate source of light. In either event separate rays are formed initially, which are then brought directly to different photocells. In this last system and its modifications, if a wave form such as 35 in Figure 13 were employed, the tube 41 should preferably be the source to whose rays are imparted a variation in intensity by the pattern 49. If this is the case, errors in modification of the ray 44 due to lack of perpendicularity are of no consequence, because the average intensity of the ray 44 rather than its instantaneous intensity, is the characteristic which determines the average current (in a circuit such as is shown in Figure 2), which is subtracted from a pulsating current such as $\frac{1}{2}$ in Figure 5.

Other modifications may be made in my invention without departing from the spirit of it. Having thus described my invention in certain exemplary embodiments, what I claim as new and desire to secure by Letters Patent is:

1. The method of producing electric pulsations devoid of transient and steady state direct components, comprising photoelectrically generating a first current having alternating and direct components, simultaneously photoelectrically generating a second current having an alternating component differing from said alternating component in said first current and a direct component of a magnitude substantially equal to that of said direct component in said first current, and electrically subtracting said currents one from the other to cancel said direct components.

2. The method claimed in claim 1, wherein the alternating component of said second current is substantially zero.

3. The method claimed in claim 1, wherein the alternating component of said second current is substantially opposite in phase to the alternating component of said first current.

4. In a photoelectric musical instrument, a light source, means including wave form patterns for imparting to one constituent of a beam of light from said source intensity variations differing from the variations imparted thereby to another constituent of said beam, two photocells adapted to receive respectively said constituents, and a circuit in connection with said cells subtractively combining their outputs, whereby the direct components of said pulsations are made to cancel.

5. The combination set forth in claim 4, wherein said wave form patterns comprise light filters providing uniform transmissibility to one constituent and non-uniform transmissibility to another constituent of said beam.

6. The combination set forth in claim 5, including dichroic means adapted to direct one constituent upon one photocell and another constituent upon the other photocell.

7. The combination set forth in claim 5, wherein said constituents comprise respectively one group of rays originating directly from said source and other group of rays reflected from said source by a mirror.

8. In a keyboard photoelectric musical instrument, a source of light having constituents of at least two different wave lengths, stationary means having thereon a wave form pattern corresponding to a musical tone quality, moving pitch means operative to cause said wave form pattern to be secured by respective rays of light from said source, said pattern being capable of

imparting to respective constituents characteristics differing one from the other, at least two photosensitive cells, focussing means for directing said rays toward one of said cells, a dichroic mirror interposed between said focussing means and said last-mentioned cell, said mirror allowing one constituent of each ray to fall upon said last-mentioned cell but causing the other constituent to be reflected therefrom, the other of said cells being located at the focal point of the reflected constituent of said rays, and circuit means in connection with said cells for obtaining an electric potential proportional to the difference between the currents flowing through the respective cells.

9. In a photoelectric device a source of light, a pair of photocells, the light from said source impinging on said photocells in separate rays having different intensity variations, shutter means for simultaneously and substantially equally controlling the average intensity of said rays, light modifying means for imparting to at least one of said rays pulsations responding to the note of a musical scale, and a circuit for combining the outputs of said photocells subtractively whereby to derive said pulsations free from direct current components.

10. The structure claimed in claim 9 wherein the light modifying means act upon both rays to produce substantially out-of-phase pulsations therein.

11. The structure claimed in claim 10 wherein said light modifying means include a filter image effective in producing pulsations in less than the full spectrum of the light from said source.

12. The structure claimed in claim 11, wherein said means produce pulsations in both of said rays, but in different wave lengths therein, and including separation means acting on said rays to confine differently pulsating light to the separate photocells.

13. In a photoelectric instrument a source of light, light modifying means including a color filter for imparting pulsations to certain wave lengths of light from said source, a pair of photocells, a dichroic mirror in the path of said light, said photocells being arranged to receive from said dichroic mirror components of said light of different effective wave lengths, and a circuit in which the outputs of said cells are combined subtractively.

14. The structure claimed in claim 13 wherein the wave form modifying means contains separate color filter images in out-of-phase relationship.

15. A method of producing electrical pulsations devoid of transient and steady state direct current components, which comprises causing beams of light to impinge separately upon separate photocells, controlling said beams of light concurrently and substantially equally as to average intensity, and producing in at least one of said beams of light pulsations responding to a note of a musical scale, and subtractively combining the outputs of said photocells simultaneously.

16. The method of claim 15 wherein both beams are modified to produce pulsations therein, the pulsations in one beam being substantially out-of-phase with the pulsations in the other.

17. The method claimed in claim 15 wherein said pulsations are produced in less than the full spectrum of said beam, wherein the beams impinging on said photocells follow in part the same

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path, and wherein the two beams are filtered to produce a difference in the pulsations therein.

18. The method claimed in claim 17 wherein pulsations are produced in both beams but in different portions of the spectrums thereof.

19. The method of producing electric oscillations devoid of direct current components, comprising the steps of modifying a beam of light so as to provide two rays having different intensity variations, photoelectrically generating a first electric current having alternating and direct current components responding to the intensity variations of one of said rays, simultaneously photoelectrically generating a second electric current having alternating and direct current components responding to the intensity variations of the other of said rays, the direct current component of said second current being substantially equal to the direct current component of said first current, and electrically subtracting one of said currents from the other of said currents.

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20. The method claimed in claim 19, wherein the alternating component of one of said currents is substantially zero.

21. The method claimed in claim 19, wherein the alternating component of one of said currents is substantially opposite in phase to the alternating component of the other of said currents.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,986,547	Winch	Jan. 1, 1935
2,294,377	Bierwirth	Sept. 1, 1942
2,459,293	Shonnard	Jan. 18, 1949