Feb. 27, 1934. P. M. G. TOULON 1,948,996

MUSICAL INSTRUMENT WORKING THROUGH A KEYBOARD AND A PHOTO-ELECTRIC CELL

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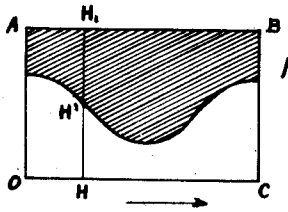


Fig. 1

Fig. 3

Fig. 2

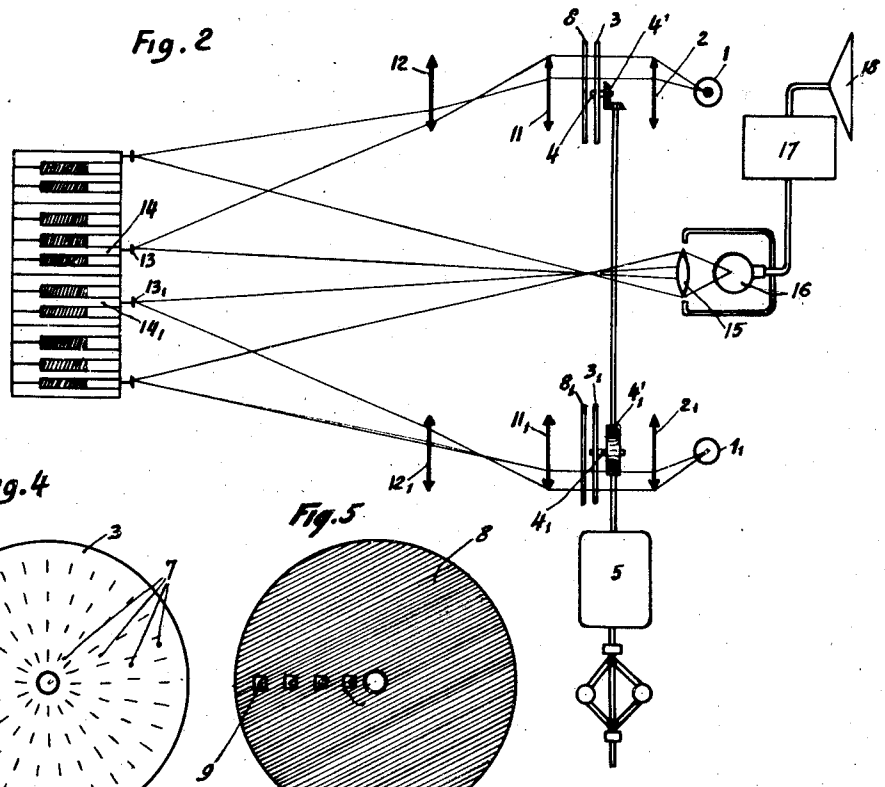


Fig. 4

Fig. 5

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Fig.8

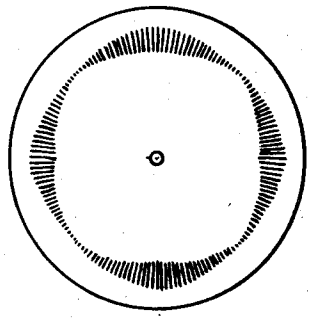


Fig.9

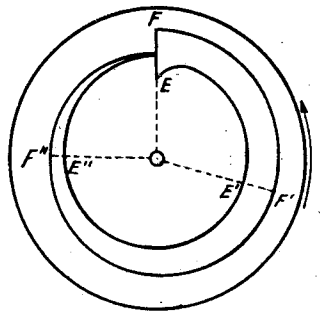


Fig.10

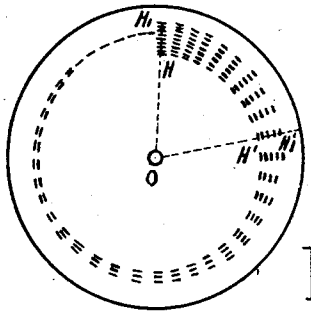


Fig.11

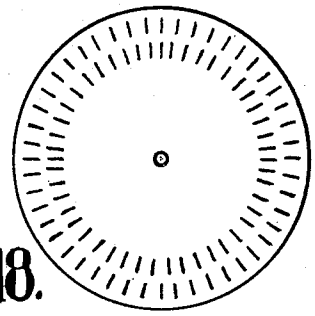


Fig18.

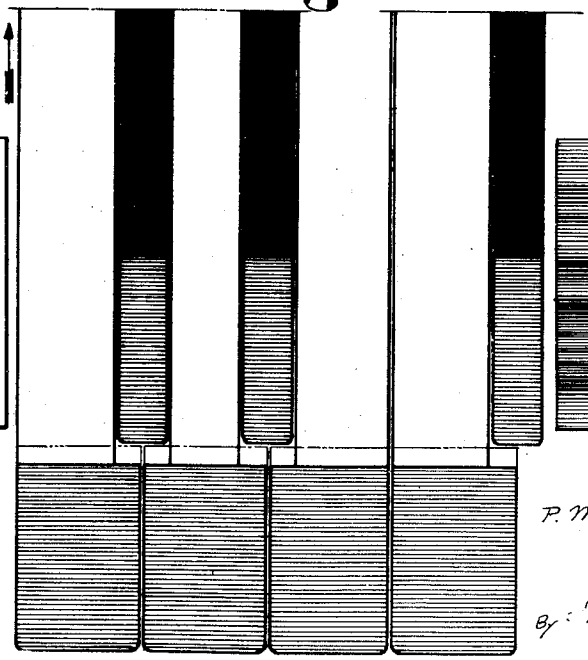


Fig.6.

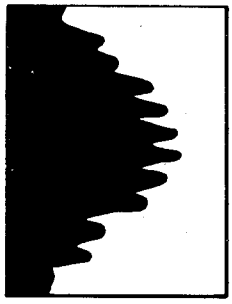
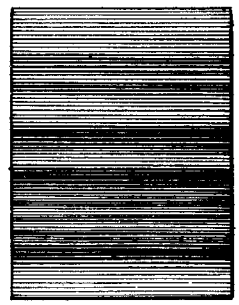


Fig.7.



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Fig.12

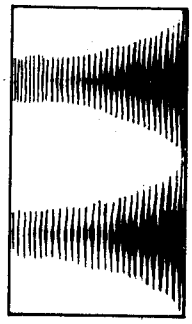


Fig.13

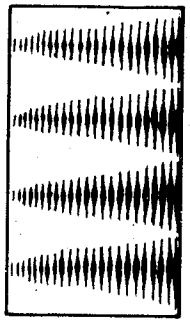


Fig.14

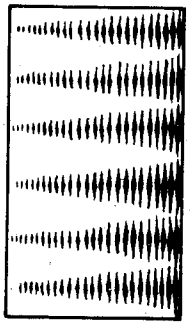


Fig.15

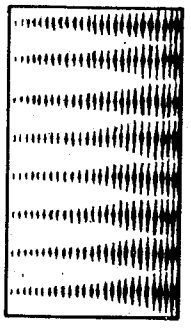


Fig.16

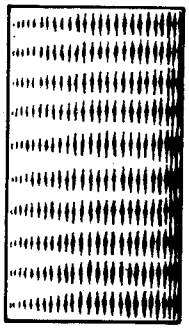
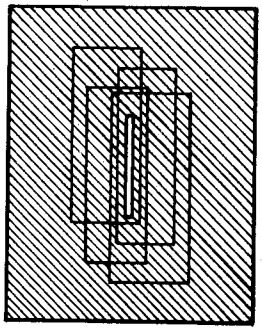


Fig.17



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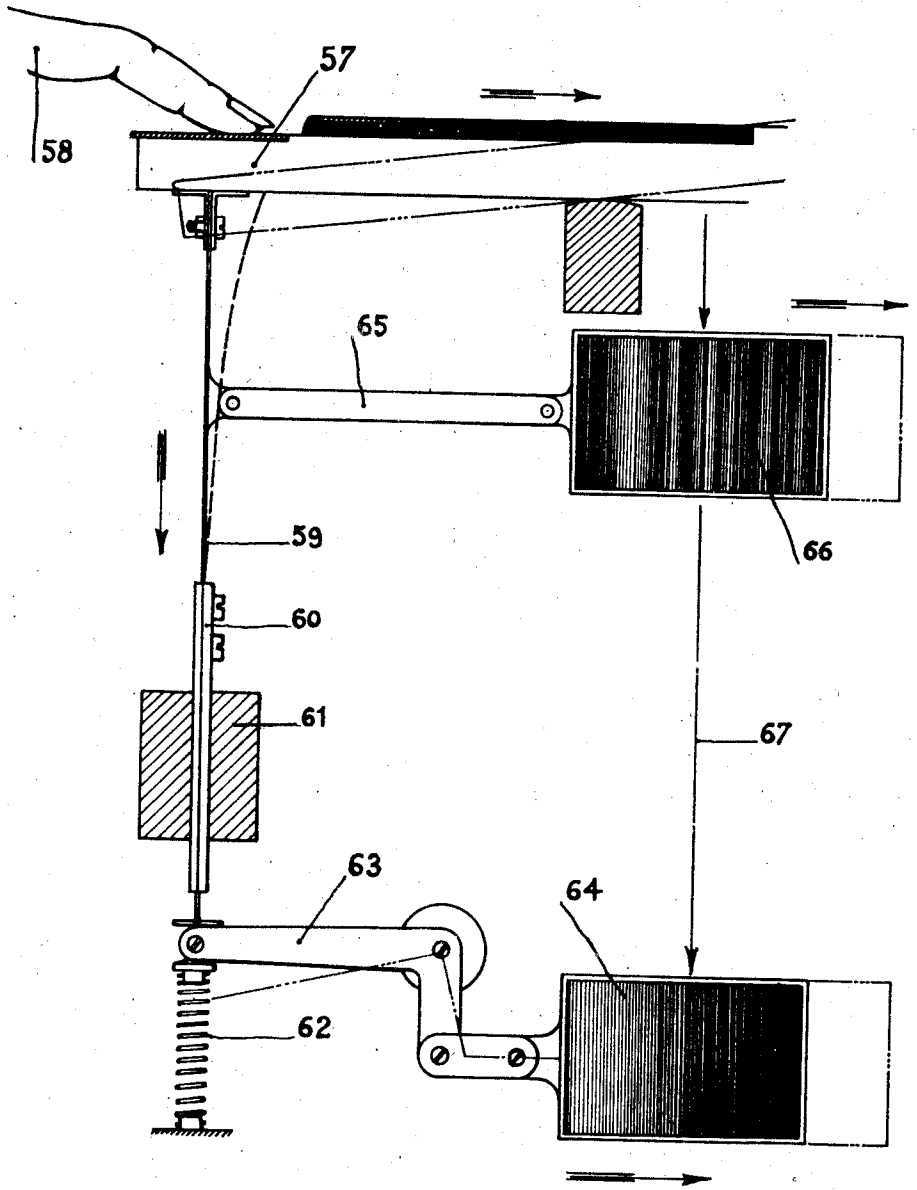
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Fig. 19.



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Patented Feb. 27, 1934

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1,948,996

MUSICAL INSTRUMENT WORKING THROUGH A KEYBOARD AND A PHOTO-ELECTRIC CELL

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Application May 14, 1928, Serial No. 277,667
In France May 19, 1927

6 Claims. (Cl. 84—1)

It has been proposed to reproduce sounds by means of devices consisting in a photoelectric cell placed in an electric circuit fed by a constant supply, a light beam of constant intensity periodically interrupted impinging on said cell. This causes variations into the intensity of the currents flowing across the cell, which, after having been conveniently amplified, are used for actuating a telephonic receiver or a loud speaker. It has been also proposed to insert between the light supply and the cell a shutter or screen cut out in convenient shape and having a relative movement in reference with the light beam impinging on the cell, so that during each luminous emission the quantity of light impinging on the cell is modulated according to the timbre of an instrument, if said tone is to be reproduced. Musical instruments have been also described wherein to each note was corresponding a special photoelectric cell which, while said note was sounding, was lighted by a steady beam of constant intensity, a periodically modulating screen cooperating with the cell; said screen being formed by a disc conveniently cut out and rotating with such a speed that the cutting out crosses the light beam with the frequency of the fundamental note, the shape of said cut out giving to this note the required timbre.

These already known proceedings and devices show several drawbacks. Proceedings wherein the light is periodically interrupted at the frequency of the required note do not allow the exact reproduction of the tone of an instrument. In none of the usual instruments occurs a sudden and absolute stop of the vibratory movement during a determined, and even very short, part of the period of said movement. On the contrary, it can always be represented by a continuous curve. This cannot be obtained by a broken illumination of the cell, and even if the quantity of light produced is modulated during the periods of illuminations, this does not amend said defect.

As for the above described proceeding using a special cell for each note, it shows also serious drawbacks; with it, it becomes necessary to have as many cells and rotating discs as notes, and nevertheless it seems impossible to superpose the effects of several discs, each corresponding to a special harmonic, in order to make a synthesis of the desired tone, it should be moreover necessary in such case to take into account the relative intensities of said harmonics and it is not seen how it could be done.

The present invention has for its object to provide a device which will avoid said drawbacks, and to allow a continuous and exact reproduction of the tone of any instrument; and even new tones; the tone being known either by the curve representing its vibratory law, or by the range and relative intensities of the compounding harmonics; in this last case a real synthesis of the sound is made. This can be accomplished by using a small number of cells, say one for each octave.

The important feature of the invention is the following: luminous beams are directed by any means, for instance, by mirrors actuated by the keys, on the photoelectric cell and impinge on it after having crossed a rotating slotted disc, the apertures of which succeed each other with the frequency of the note which must be produced, and also one or more modulating screens which give to the sounded note the desired tone.

As explained above it is necessary to avoid sudden and periodical stops in the illumination of the cell; and for that purpose, the distance between the successive apertures of the disc and the dimensions of the windows through which the beam passes before impinging on the cell are so determined that in the moment when the beam passing through one of said apertures begins to go out from the cell, the beam passing through another aperture just begins to impinge on said cell. In that way the total amount of light received by the cell remains constant. If there is no screen on the path of the beams, no variation of current occurs and consequently no sound can be perceived in the loud speaker; on the contrary if there is a screen the amount of light can be varied at will, said variation being reproduced at a frequency depending on the speed at which the apertures of the disc succeed one another in front of the cell.

The screen can be made with a part quite opaque the other having a constant translucency, the breadth of the translucent zone in a direction perpendicular to the displacement of the beam being variable and equal to the ordinate of a curve representing the vibratory law of the desired tune. Thus if the apertures in the disc are shaped in form of sufficiently narrow slots, the quantity of light impinging on the cell at any moment shall be proportional to the ordinate of said curve.

It will therefore be able to reproduce the tone of an instrument if we have plotted the corresponding curve.

Figure 1 shows by way of example such a mod-

ulating screen; a curve of sinusoidal shape representing a period of a simple sonorous vibration (OA being the axis of the ordinates and OC the axis of the time) is traced on a rectangular transparent plate OABC and the upper surface of the plate limited by the sinusoid is blackened.

If a thin rectilinear beam of light HH_1, is directed on this frame OABC perpendicularly to the axis of the time OC, the quantity of light passing through the screen will be proportional to the ordinate HH^1 of the curve. If, therefore, the screen is swept by such beams of light, for instance, from the left to the right and in such a manner that a beam of light passes out through BC at the moment when another beam of light enters through OA the curve representing, as a function of the time, the quantity of light passing through the screen, will be continued and reproduce exactly the shape or form of the curve traced on the screen. In the example of Figure 3, this curve is a sinusoid the frequency of the oscillations being equal to the number of passages per unit of time of the beams of light on the screen. If therefore the screen is swept for instance 435 times per second and if the light which has passed through the screen is sent to a cell, the cell generates a frequency current 435 which is transmitted to a loud speaker and produces the tone-value indicated by the symbol $1a_3$. This symbol designates the musical note produced at the end of the third octave of the keyboard of an ordinary piano and corresponds to a note produced at the rate of 435 vibrations per second. If instead of tracing a simple sinusoid on the screen OABC, a more complex curve containing harmonics of the fundamental frequency is traced, sounds with different timbre will be produced according to the number and amplitude of these harmonics.

The plotting of said curve is easy if we know the relative intensities of the harmonics of the tone, in another way said curve may be obtained experimentally, say by means of an oscillograph.

Instead of the black or white screen above described, a screen of variable translucency can be used, the law of variation of the translucency in the direction of the displacement of the beam being that represented by the former curve.

Of course the variation of the cell current must follow exactly and immediately those of the amount of light impinging on the cell, in consequence this latter must be of the type called devoid of inertia, such as the potassium cells and not as the selenium ones.

The screens can be operated by keys and by stops similar to those used in organs, said keys or stops being connected to the screens by intermediary of means either mechanical or electrical.

The following disclosure and the hereby annexed drawings show as example several forms of execution of the invention.

Figure 1 represents a modulating screen as described above.

Figures 2 and 3 represent diagrammatically in plan and in elevation a simple embodiment or constructional form of the apparatus constituting the subject matter of the invention wherein the sweeping of the modulating screen is obtained by means of a disk having slots and rotating in front of a luminous source.

Figure 4 is a front view of the disk with slots.

Figures 5, 6 and 7 relate to the modulating screens.

Figures 8 to 11 represent special screens allowing of varying the intensity of the tone as a function of the time.

Figures 12 to 16 show modulating screens allowing of obtaining the successive harmonics of a fundamental note.

Figure 17 shows the method of obtaining by synthesis a complex tone having numerous harmonics.

Figures 18 and 19 relate to an embodiment wherein the keys of the piano are adapted to receive two distinct displacements adapted to vary the intensity and the timbre of the tone.

An exact luminous source 1 arranged in the focus of a condenser 2 furnishes a parallel beam of light. This beam of light falls on a disk 3 which is mounted on a shaft 4 and driven at a perfectly constant speed by a motor 5 through the medium of toothed gearing 4'.

The disk 3 consists of opaque material and has a certain number of equidistant narrow slots 6 disposed according to the radii of a certain number of concentric rings 7 (Figure 4). This disk may consist, for instance, of glass covered with a photographic emulsion on which transparent lines representing the slots have been recorded on an opaque base.

The different rings 7 have numbers of different equidistant slots, the rings having the smallest number of slots are disposed in the center of the disk and the rings having the largest number of slots are on the periphery.

If, for instance, twelve dozen rings of slots are arranged on the disk 3 and if one chooses for the numbers of slots of the successive rings numbers proportional to the frequencies of the successive notes of a gamut, it will be obvious that with a suitable speed of rotation of the disk 3, it is possible that the numbers of slots of the successive rings defiling per second in front of a fixed point opposite corresponding rings will be equal to the frequencies of the successive notes of the given gamut. By doubling the speed of rotation of the disk, a higher octave is obtained while by reducing this speed one half a lower octave is obtained.

Another opaque disk 8 having the same axis as the previous one but fixed (Fig. 5) is disposed behind the disk 3 and at a small distance therefrom. The said opaque disk 8 is provided opposite each ring of slots of the disk 3 with a window 9 formed by a curvilinear rectangle limited by two radii of the disk and by two arcs of concentric circles, the height of this window 9 being equal to the height of the slots 7 and its width, that is to say the space between the two radii which limit same, being equal to the distance between two consecutive slots 7 of the corresponding ring 6 so that one of the slots appears in the window at the exact moment when the other leaves same.

The different slots of a ring of the disk 3 are presented successively on one of the edges of the window 9 of the disk 8 to disappear on the other edge after having swept continuously the surface of this window. The time which elapses between the moment when the slot appears and the moment when it disappears determines the period of the sonorous vibration which is subsequently produced: the slots of a ring being equidistant and the speed of the disk 3 being constant, the said period will be perfectly constant so that the height of the tone produced by each ring will be well determined. In order to produce a tone, one applies the method of modulating (which is indicated at the beginning of the application) the quantity of light passing through the window 9. For this purpose, there is provided in this win-

dow a modulating screen 10 according to the screen OABC of Figure 1 on which has been traced a period of a sinusoidal curve by taking as axis of the time one of the arcs of the circle limiting the window 9 and bearing the ordinates according to the radii. Since the modulating screen 10 is opaque on one side of the curve and transparent on the other side, the quantity of light transmitted through each window 9 (quantity which is constant owing to the absence of the screen 10) now varies in a periodical manner relative to the sweeping frequency.

As explained above, the harmonics are furnished by the form of the curve of the modulating screen 10 and thus determine the timbre of the tone; different timbres are obtainable by changing the form of said curve. This variety of timbre is obtained by providing according to the different radii of the disk 8 other series of windows etc. bearing modulating screens of different form or shape. A simple rotation of the disk 8 then allows of the changing of the desired timbre.

In practice, the disk 8 is made of glass covers with a photographic emulsion and is merely provided on an opaque base with transparent surfaces limited by the modulating curves.

After having cleared the disk 8, the luminous rays are immediately collected again by means of a collecting lens 11. This lens has for its object to produce a real image of the luminous source 1. As this source is very exact, the rays are collected again.

An objective 12 placed in line has for its object to produce on the mirrors 13 integral with the keys 14 real (enlarged) images of the windows 9 of the disk 8. The focal distance of the objective 12 and its location are selected in such a manner that the real images of the windows 9 are produced through the optical system (formed by the lenses 11 and 12) on the line adjoining the centers of the mirrors 13 and having a spacing equal to that of the consecutive keys 14 of the piano. Owing to this selection, each key 14 is in optical relation with the corresponding disk ring which determines the pitch of the sound, that is to say the corresponding note, (the timbre being determined by the form or shape of the modulating screen 10). A small mirror 13 is connected to each key 14 of the piano. This mirror is adjusted in such a manner that normally this mirror does not fall in the beam of light: in other words, it is outside the opening of "the real image" of the window produced by the lenses 11 and 12.

When the key 14 is depressed, the mirror 13 is tilted and brought in the beam of light at 13'. It is thus possible to return the luminous rays to an optical system 15 which has for its object to collect the rays and concentrate them on a photoelectric cell 16.

The orientation of the different mirrors 14 and the arrangement of the optical system 15 are selected in such a manner that all the luminous rays are received on the cell 16.

By depressing different keys, the performer therefore adjusts a certain number of mirrors 13 in such a manner that the corresponding luminous modulation is concentrated on the cell. Since each note receives a modulation of light, whose intensity is well determined, it is thus possible to form musical chords.

The selection of the form or shape of the curve of the modulating screen allows of modifying at will the timbre by displacing a register to suit the performer whereby a modulating screen is replaced by another, for instance, by the rotation of the disk 8 about its axis.

Since it is only possible to provide a small number of rings on each disk, it is impossible to reproduce with a single disk the whole register of a normal musical instrument. It is convenient to limit the number of rings to the twelve notes corresponding to an octave

In order to extend the apparatus to several octaves, one may either employ several photoelectric cells connected in parallel to the amplifier or concentrate on a single cell the luminous rays from several different optical systems, each corresponding to an octave. In Figures 2 and 3 there is shown on one side of the system just described a second identical system comprising a source 1_1, a disk 3_1, rotating twice as fast as the disk 3, etc., and corresponding to the octave higher than the preceding one. The luminous rays reflected by the mirrors of the keys of this second octave are returned to the same photoelectric cell 16 as before.

Fig. 6 shows a screen which may be disposed in front of the window 9 on the path of the luminous beam and by means of which one may obtain sounds having different tones. Said screen is constituted by an opaque region on a ground of uniform translucency. If, for instance, said curve is a whole period of a sinusoid, there will be obtained the fundamental note corresponding to the frequency with which the beams succeed one another upon the screen. If for instance, said separating curve has for its equation

$$y = y_0 + a \sin x + b \sin 2x$$

the former note and its octave will be obtained. Thus, generally, any tone can be reproduced at will, by choosing for separating curve one period of the curve representing the vibration law corresponding to said tone.

Fig. 7 shows another arrangement allowing to obtain the same result. This one consists in a screen whose translucency is modulated (in the direction of the movement of the beam) by scales of shades suitably determined succeeding to one another; it is obvious it can be made in such a manner, that the amount of light passing through the screen while it is swept by the beam is modulated exactly as in the former case.

It is also possible to reduce the number of the concentrical series of slots of the disc to twelve each of which corresponds to one note of the gamut; one of those series is in reality able to give not only the fundamental note but also its octaves by inserting suitable screens, corresponding to the first, second, fourth, eighth, etc., harmonics of the fundamental notes being similar to those indicated by the numeral 1, can be actuated by the keys corresponding to the different octaves. It is obvious that in such case a single disc can be sufficient.

To obtain, for instance, a sound which decreases with time, there may be interposed on the path of the light beam passing through the screen an auxiliary screen as the one represented on Fig. 9, narrowing progressively the breadth (direction perpendicular to the displacement) of the beam impinging on the modulating screen. Such screen can be also a disc entirely dark with suitable slots disposed on a circumference.

Such a screen for instance this of Fig. 9, for imitating the pianoforte tone, is caused, by lowering a key, to rotate at uniform speed, making one turn during the whole holding of the note. The light beams impinge on said screen which, when the note begins, presents the breadth EF, allowing

the passage of the whole beam, said breadth narrowing progressively while the disc is rotating in the arrow direction, presenting successively for the passage of beam breadths E'F'—E''F'' and so on.

The tone of some instruments say the hunting horn corresponds to pulsations of intensity having a very low frequency, say 8 or 10 per second. Fig. 8 represents an auxiliary screen with slots whose length varies periodically, causing thus, when rotating at uniform speed, the intensity of light impinging on the cell to vary according to the same law. Instead of these slots there may be drawn upon the screen a circular strip whose translucency should vary periodically.

It is often not enough to modify with time the intensity; the tone must also be altered; such is the case for the violin with which the tone varies according to the position of the fiddlestick. Fig. 10 shows a device allowing to obtain said result. Scales of shades

$$OH—OH_1,\ OD'—OH'_1$$

corresponding to the successive tones of the instrument are registered side by side on the successive radii of a circle; one interposes on the beam path at every moment the corresponding scale.

Some instruments, such as the pianoforte, owe their musical value to the presence of several strings having a slight difference of frequency.

This result may be imitated by disposing on a rotating screen concentric series of equal number of slots the distribution of which varies from one series to the next.

Fig. 11 shows such an arrangement with two series of unequally spaced slots.

At last the synthesis of a sound by its harmonics can be obtained by means of several screens with scales of shades correponding to the successive harmonics, and whose displacement in the convenient direction allows to modify the phase and the amplitude of each harmonic.

Fig. 12 shows a scale of shades corresponding to the fundamental note; if on said screen is drafted a straight line perpendicular to the direction of the movement of the beam (horizontal on the figure) all along this line the opacity of the screen varies according to a linear law, if a line is drawn parallel to the displacement of the beam, all along this second line the opacity varies according to a sinusoidal law whose period corresponds to this of the fundamental note.

Figures 13, 14, 15, 16 represent in the same way the scales of shades corresponding to the first, second, third and fourth harmonics, the opacity varying in the same manner according to a linear and a sinusoidal law, the period of this latter, being the half the third, the fourth and the fifth of that of the fundamental.

In order to obtain a determined tone we superpose the screens of Figs. 12, 13, 14 and so on, each having with reference to the screen 12 corresponding to the fundamental note, a peculiar shifting in the direction of the movement of the beam, which determines the phase of the corresponding harmonic, and another shifting in a perpendicular direction which determines the relative intensity of this same harmonic.

Fig. 17 shows said scales of shades shifted in both directions in front of the window through which the beam sweeps the cell with the desired frequency.

Fig. 18 is a plan view of a pianoforte keyboard allowing, by only a suitable displacement of the key, to determine the tone and the intensity of the sound.

Fig. 19 is a cross view of the same.

The keys are arranged so that they can be given a displacement from top to bottom in order to adjust the intensity and another displacement from front to rear in order to modify the tune, both movements being determined by the player's finger.

For that purpose the key 57 is for instance maintained on a vertical resilient slip 59, which is fastened to a slide 60 slidable in a block 61. A spring 62 returns the key to its first or normal position.

The movement from top to bottom actuates the bell crank 63 which moves the screen 64 whose opacity varies according to a linear law in the direction perpendicular to that of the sweeping. The displacement from front to rear by intermediary of the connecting rod 65 actuates the screen 66 upon which are drafted side by side, in the direction perpendicular to the sweeping direction, shades corresponding each to the tone of one special instrument.

Things are arranged in such a manner that the light beam 67, modulated at the desired fundamental frequency, crosses one after the other the two screens 64 and 66.

With such device, it is possible with only one instrument to reproduce the tones of many quite different musical instruments.

What is claimed is:

1. A musical instrument comprising a plurality of keys and stops, a source of light, a photoelectric cell without inertia, an acoustic receiver actuated by the variations of current in said cell, means actuated by the keys to cause beams of light coming from the source to impinge on the cell, in the path of said light beams, windows, rotating discs with concentrical series of slots, the distance from one slot to the next one and the dimensions of the windows being such that one beam begins to impinge on the cell just at the moment when the next one leaves it, means to rotate the discs at uniform speed, means for interposing in the path of the light beam, screens modulating according to any predetermined law the amount of light passing through them, while they are swept by the light beam.

2. A musical instrument comprising a large number of keys and stops, a luminous source, a photoelectric cell without inertia, an acoustic receiver actuated by the variations of current of the said cell, rotating disks having concentric series of slots and placed behind the luminous source, opaque screens placed behind the said rotating disks, windows in the said screens disposed opposite concentric series of slots of the rotating disks, the dimensions of the windows and the distance of two consecutive slots being such that a beam of light coming from the source and passing through one of these slots enters a window at the moment when the preceding beam issues therefrom, mirrors integral with the keys disposed so as to receive when actuated the beams of light passing through the windows and reflected on the photoelectric cell, means for disposing in the path of the beams of light screens of translucency periodically variable in the direction of the displacement of the beams of light so as to be able to modulate according to a predetermined law the quantity of light which is transmitted to the cell.

3. A musical instrument comprising a plurality of keys and stops, a source of light, a

photoelectric cell without inertia, an acoustic receiver actuated by the variations of current in said cell, means actuated by the keys to cause beams of light coming from the source to impinge on the cell, in the path of said light beams, rotating discs with concentrical series of slots, windows, the dimensions of the windows and the distance from one slot to the next one being such that one beam begins to impinge on the cell just at the moment where the next one leaves it, means to rotate the discs at uniform speed, means operated by the stops for interposing on the path of the light beams, screens some of which have different translucency on their points, said translucency varying according to a sinusoidal law in the direction of the displacement of the beams and according to a linear one in the direction perpendicular to said displacement, the means actuated by the stops allowing to interpose several of said screens on the path of the light beams, with shifting from one to another in the direction of the displacement of the beams and in a direction perpendicular to the same.

4. A musical instrument comprising a plurality of keys and stops, a source of light, a photoelectric cell without inertia, an acoustic receiver actuated by the variations of current in said cell, means actuated by the keys to cause beams of light coming from the source to impinge on the cell, in the path of said light beams, windows, rotating discs with concentrical series of slots, the dimensions of the windows and the distance from one slot to the next one being such that one beam begins to impinge in the cell just at the moment where the next one leaves it, means to rotate the discs at uniform speed, rotatable discs disposed on the path of the light beam and having parts to allow passage to light arranged on a circumference concentric to the shaft of the rotatable discs and having variable lengths so as to allow, by rotating the screen, to vary the amount of light impinging on the cell in order to produce damping effects, and means responsive to the operation of the stops for rotating said discs.

5. A musical instrument comprising a plurality of keys, a source of light, a photoelectric cell without inertia, an acoustic receiver actuated by its variations of current, means to cause beams of light coming from the source to impinge on the cell; in the path of said light beams, windows, rotating discs with concentrical series of slots, the dimensions of the windows and the distance from one slot to the next one being such that one beam begins to impinge on the cell just at the moment where the next one leaves it, means to rotate the discs at uniform speed, means actuated by depressing the keys to interpose in the path of the light beams, a screen with variable translucency to vary, according to the depression of the key, the amount of light falling on the cell, means actuated by giving to the key a displacement from front to rear to insert in the path of the light beams a screen modulating the amount of light passing through it while it is swept by the light beams, the modulation law varying in reference with the more or less displacement of the key.

6. In a musical instrument according to claim 5, a single rotating disc with twelve concentrical series of slots, each series corresponding to a note of the gamut, means responsive to the displacement from front to rear of a key for inserting in the path of the beam passing through the series of slots corresponding to the same note as the key, a screen, the screens being so designed that the screen actuated by a note of the second, third, and so on octave gives, by modulating the beam of light, the first, third, etc. harmonic of the corresponding note in the lowest octave.

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