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8. There is no noticeable change in pressure with time, which shows the absence of air leak into the apparatus, in spite of the presence of two stopcocks that might be expected to afford some leak. This result may be laid to a careful regrinding with fine emery and water before use.

THE STROBOSCOPIC EFFECT BY DIRECT REFLECTION OF LIGHT FROM VIBRATING MIRRORS.

L. E. DODD.

A very simple and convenient method of producing the stroboscopic effect is to reflect light directly from a vibrating mirror upon a stroboscopic screen. The mirror may be such as is afforded by a vibrating membrane which is itself reflecting or has a suitable mirror attached either directly or indirectly to it.

Any stroboscopic apparatus is divided into two principal parts, the stroboscopic screen arrangement with its similar figures in motion, and some means of obtaining periodic glimpses of the screen. The latter is commonly provided by some method of periodic illumination with suitable frequency. The manometric gas flame is the device most commonly used to produce periodic illumination, although a periodic electric spark, or a discharge tube with tuning fork interruptor of the induction coil primary, give good results. The important condition of illumination for producing the stroboscopic effect is that there shall be in any given small region of the screen the periodic change in light intensity. (It is not necessary that the light be at any time entirely reduced to zero intensity.) Given such a small region on the screen and the similar figures of suitable size, the stroboscopic effect will occur in this region if the latter undergoes a periodic change in the intensity of the light falling upon it, regardless of how this change is produced.

There are in general two possible ways in which the light intensity in the region of small area can change: (1) by a change in the intensity of the beam of light as a whole, which falls on the screen, with the beam itself possessing at any instant a uniform intensity over its cross-section, or (2) by a periodic back and forth lateral displacement of a beam whose intensity does not vary with time, but is non-uniform over the cross-section of the beam. The writer has no knowledge that this latter way has heretofore been employed to produce the stroboscopic effect.

In the case of a vibrating membrane which is itself reflecting we have of course a mirror that changes periodically from convex to plane to concave and back again, and hence a beam of light reflected from its surface to a screen will periodically change its total area of cross-section where it is intercepted at the screen. Since the total quantity of light in the beam does not change, the intensity of light in the spot on the screen varies inversely as the area included in the spot. This would give then on the screen a periodic illumination of the first general type mentioned.

Alexander Graham Bell[1] used such a reflecting membrane in his photophone, permitting the beam of light to fall upon a selenium cell. A telephone receiver in series with the cell reproduced the tone actuating the membrane. Bell explained the effect on the light sensitive cell by the changing curvature of the mirror, as described.

The explanation appears to be the obvious one, simple and final. It would appear to be justified also in the light of other experimental results obtained by Professor Bell. He constructed a hollow convex lens with walls of mica or thin glass, and filled it with a transparent liquid or gas. The walls of the lens could be made to vibrate under the action of the voice, and thus the lens curvature could be periodically changed. A beam of light passing through the lens and falling upon the selenium cell produced the same effects in the telephone receiver as the vibrating mirror.

But, taking the case of the mirror, it must be remembered that the amplitude of vibration is not large, and hence the curvature changes over only a very narrow range. One would hardly expect therefore that there could be a change in the intensity of the beam of any consequence, at least for very short distances between mirror and screen at which the stroboscopic effect can be produced. With larger distances, as in Professor Bell's work with the photophone, the effect is of course considerably greater.

[1]Bell, A. G.: "De la production et de la reproduction du son par la lumière," Annal. de Chimie et de Physique, t. XXI, 1880.

Professor Bell's explanation, in view of his results with both the vibrating mirror and the vibrating lens, of the light effect on the selenium cell may be taken as at least partial explanation of the phenomenon. However, in both cases of mirror and lens, as the cross section of the beam alternately contracts and expands, there must be a lateral displacement increasing in amount toward the margin of the beam. If the beam is not of perfectly uniform intensity over its cross section, and it is not likely to be, at any particular fixed point where the beam falls there will be changing intensity due not only to its expansion and contraction, but also to the fact that a little element of the beam incident at this fixed point is being replaced by an adjacent element of different intensity, different because of the non-uniformity of the beam. Because of the relatively small amplitude of the membrane the lateral displacement of the beam cannot be very large, especially at short distances, and yet it is sufficiently large to give the stroboscopic effect even in the case of spots of 3 or 4 mm. diameter on the stroboscopic screen, and that at relatively short distances. It cannot be supposed therefore that the lateral displacement is sufficient to cause an element of the beam to sweep clear across one of these larger spots.

It would seem that we cannot be at all certain without further investigation as to just how important a role this effect due to a non-uniform beam plays in the experimental results of Bell with a selenium cell. We may, however, be certain that it is present in both the case of the vibrating mirror and that of the vibrating lens.

One is justified in suspecting that it does play some part in Bell's results, in view of the results in stroboscopy obtained by the author. For the stroboscopic effect has been found to exist very sharply when the vibrating mirror was made by silvering one of the small circular microscope cover glasses and attaching it to a vibrating membrane by means of a bit of cork between them. Under these circumstances it is not to be expected that the mirror will change its curvature when the membrane vibrates, but will move as a whole. Moreover the stroboscopic effect was produced with a piece of ordinary mirror glass, attached to the membrane. This mirror glass was much too thick to admit the possibility of changing curvature. It appears therefore that the stroboscopic effect is to be explained, in large part at least, by the periodic lateral displacement of a beam of non-uniform intensity over its cross section. We are thus led to suspect that this same condition, present in Bell's work, played its part in the effect on the selenium cell. It is more difficult, however, to accept such a conclusion in the case of the cell's response, than in that of the production of the stroboscopic effect. In the former the total amount of light falling upon the cell must remain very nearly the same, even though at any particular point on the cell the intensity changes by the lateral displacement, while in the latter case it is a region of small area that is chiefly concerned.

In a consideration of the stroboscopic effect the fact must not be overlooked that the eye is extremely sensitive to small changes of light intensity, so that the changing area of the beam on the screen may contribute its effect, which, however, appears to be at most only a minor effect. The decisive experiment must have achieved a separation of the two mechanical conditions, that of periodic expansion and contraction of the beam with the accompanying changes in light intensity due to this expansion and contraction alone, and secondly, the periodic lateral displacement of the beam. It is easy to have the second condition alone present, as has been shown, but it is difficult to see how one could have changing curvature without lateral displacement.

While the idea of reflecting light directly from a vibrating membrane was arrived at independently by the author it was later learned that the idea was anticipated by Professor Bell about 1880, who, however, used the reflected light for a different purpose. The production of the stroboscopic effect by this method appears to be new.

In this method various kinds of diaphragms can be used. Satisfactory results have been attained with silvered mica membranes, as well as paper and rubber dam membranes (with mica mirrors attached to them either directly with paste or with bits of cork or cardboard between mirror and membrane.) Paper membranes seem to give as good results as any.

A of figure 21 shows an arrangement of a paper membrane over the end of a short glass tube, with a lever system and a small mirror (microscope cover glass) that could periodically be given an angular displacement by the vibrating membrane actuated by a sounded tone at the open end of the tube. This was one of the preliminary experiments to find a method to replace that of the manometric flame, for the purpose of stroboscopy. A reflected beam falling on a rotating mirror gave

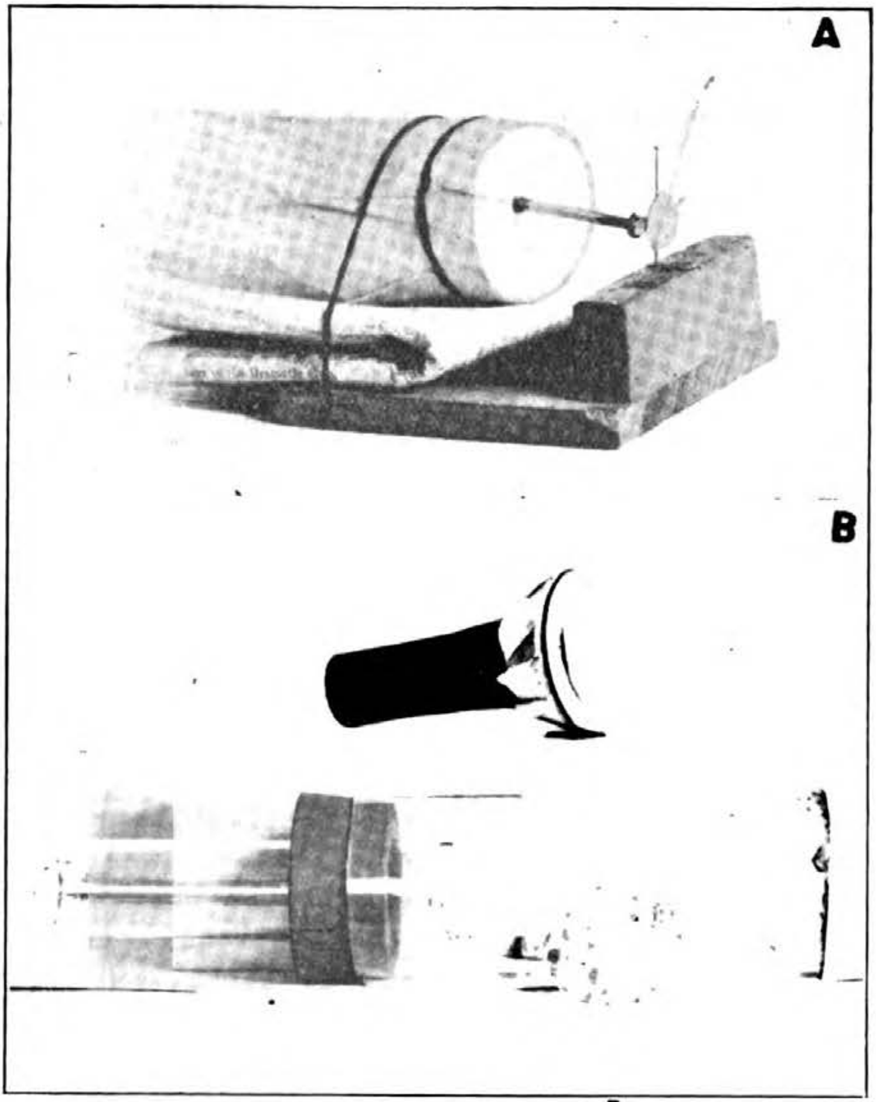

FIG. 21.

clearly defined sine waves of large amplitude. A simple step from this arrangement was to attach the small mirror directly to the membrane, and then to use a mica membrane that could be entirely silvered.

B of figure 21 shows, above, a reflecting membrane made by stretching paper over the large end of a telephone receiver shell with the cap off, and to the paper attaching as already indicated a mica mirror. Below is shown a glass tube arrangement as vibrating chamber, with the right end of the large tube covered with a silvered mica membrane. The left end of the smaller tube served for mouthpiece. Leaning against the large tube in the foreground is seen a circular piece of silvered mica such as was used for a reflecting membrane.

SUMMARY.

1. A new and simple method has been found for producing the stroboscopic effect.

2. The method appears to employ a general means of producing periodic illumination changes at a fixed point which has not been hitherto used; viz., the periodic lateral displacement of a beam of light non-uniform in intensity over its cross section.

3. A question for further investigation is: How large a contribution to the changing light intensity on the stroboscopic screen is due to changing curvature of the mirror?

4. An additional experiment suggested by the stroboscopic effect with the vibrating mirror is a similar experiment with a vibrating convex lens, similar to that used by Bell with a selenium cell.

A NEW TONOSCOPE.

L. E. DODD.

While undergoing a series of voice pitch tests some three years ago in the Psychological Laboratory of the State University of Iowa, the author learned that in his own individual case, as in some others, there existed, according to the statement of the investigator, Mr. C. J. Knock, a consistent as well as persistent tendency to miss in a definite direction certain intervals of the musical scale. The instrument used in these tests was the Seashore tonoscope,[1] an indicator of absolute pitch developed in some of its later stages at this University. In the particular results mentioned the amount of the error was not so noticeable to the ear, as the ear has its limitations, especially when it is the ear of the one who is himself forming the intervals by voice, but in an absolute instrument like the tonoscope even very small errors can be detected. The conclusion formed by the author from these results was that the musical intervals concerned had been wrongly learned in childhood.

[1] Seashore, C. E., Psych. Monographs, University of Iowa Studies in Psychology, No. VI, June 1914, p. 1.