THE MAGIC LANTERN AS A MEANS OF DEMONSTRATION.

BY HENRY MORTON, PH D.

PART 2.

We have thus far considered the condensers chiefly in reference to the first portion of their office, namely, that of collectors of light from the radiating source. We will now, however, pass to some of those general considerations which may claim our attention when we look at the condensers in their relation to the objects and object glasses or objectives.

RELATIONS OF CONDENSERS AND OBJECTIVES.

To make the subject entirely clear, we should revert for a moment to the general properties of lenses as producers of images from luminous objects. Let C D (Fig. 6) be such an object, as a candle flame, placed a little beyond the principal focus of the lens, A B. Then all rays emanating from any point (as, for example, C) will be collected at a corresponding point, E, and will there form a point of the image, E F. This will be true for each point of the flame, C D, and consequently a perfect image of this flame will be formed at E F. The perfection of this image would evidently be unaffected by any possible irregularity in the rays from C D. Thus, if very few rays went in the direction, C A, and nearly all followed the line, C B, the point of the image, at E, would be the same as if all the rays reaching it came through C A*.

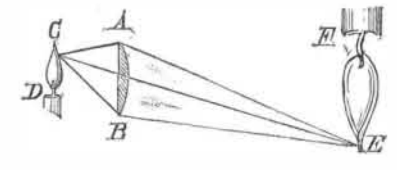

FIG. 6.

If, now, in place of the candle flame, we suppose a luminous surface to exist, at C D, an image of this surface will be produced at E F, and will be clear and uniform, provided only that the surface, C D, is uniform in emitting equal amounts of light from its different points, no matter how irregular may be the directions of the rays leaving these points, always providing that they enter the lens, A B.

Thus, suppose that, in the luminous surface, A C B (Fig. 7), rays from A were so emitted that above they were closely packed, while below they were thinly scattered; rays from B were emitted in an opposite order, and from C were close packed in the center and scattered on the outside; yet, if an equal number of rays or quantity of light came from each element, the image of each would be equally bright: and if this were true of each point or element of the surface, the image would show an uniform field of light, no matter how irregular the emission of the various points might be as regards the direction of the rays. If, however, one point emitted or furnished more rays than another, or gave light of a different color, any such irregularity or difference would be represented faithfully in the image.

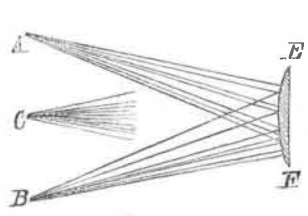

FIG. 7.

We will now apply these general principles to the case of the magic lantern. Let A B (Fig. 8) be the front element of the condenser, through which rays are passing into the object glass, C D, which is at such a distance that it makes on the screen, E F, an image of any point in A B. Then, if an equal amount of light is coming through each point of A B, an uniform white disk will appear on the screen, E F, no matter how irregular (in the sense above described) are the directions of the rays. The irregularities will, in fact, be very great, for besides such as are due to the aberrations of the condensers, these lenses will themselves be tending to form somewhere an image of the source of light. In fact, such an image would be formed, at O, about the principal focus of the lens, A B, if the objective, C D, were removed. This formation of an image at O involves a great irregularity of the distribution of light between O and A B, indeed, the existences of imperfect images of the source of light. But of all this, the objective, C D, takes no account, and simply forms, at E F, an image of the distribution of light which actually exists at A B. Suppose now, however, that C D were removed to C' D'. Its focus remaining as before, it would clearly form an image, not of the surface, A B, which is now beyond its reach, but of a surface, A' B', at its proper distance. But it evidently would by no means follow that, because the light was evenly distributed at A B, it must also be so at A' B'. On the contrary we have already seen that, as we advance from A B, the distribution of the light will become more and more irregular; and it will be an image of this irregularly luminous surface which will be thrown on the screen at E F.

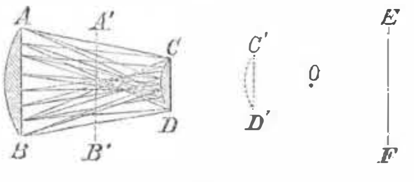

FIG. 8.

This shows us that, to secure a clear and even field of light on the screen, we must, in the first place, have such a combination of lenses in the condenser as will secure an even distribution of light at the outer surface of the last lens; and, secondly, that the objective must be so placed that it will, as we say, "focus" on this surface, that is, have this outer surface of the condenser and the screen as conjugate foci. To fulfil this last conclusion it is evidently necessary that the object (such as the picture to be shown, or the like) should be placed close to the front of the condenser, since it, as well as this surface, must be in the focus of the lens, that is, the conjugate focus with the screen. It is for this reason that the plan, sometimes proposed, of using a small picture with large condensers, by bringing the picture forward on the cone of rays to some point where they will just embrace it, fails of a satisfactory effect. The field of light is more or less discolored and unequal; and though, by cutting off its margin, we can improve this, it is at best but unsatisfactory as compared with the effect obtained with the same light and smaller condensers. The same explanation also shows us the advantage of that divisibility of the condenser, which we have before mentioned, into the collecting lens or lenses, by which diverging rays are brought into a parallel bundle, and of the condenser proper by which they are concentrated into the objective. Thus, for example, suppose that we desire to polarize the light, by reflection, from a bundle of glass plates. If the condensers are inseparable, the object must be placed beyond the reflecting surface, and therefore very far from the surface of the condenser, and thus involve an uneven field of light, not to mention imperfect polarization, in consequence of the difference in angle of various parts of the cone of light.

If, however, we can separate the condensers from the collectors, and introduce the reflecting surface between, we then have the rays all parallel, when reflected hence at the same angle and equally polarized, and the object in contact with the front surface of the condenser (see Fig. 9). Again, if we desire to exhibit objects that must be kept in a horizontal position, such as waves in a tank of water and the like, this separation of the condensers affords a ready means of accomplishing it in a most satisfactory manner. This modification of the instrument is, however, so important an appliance to the magic lantern, when used as a means of demonstration, that it deserves some more extended notice.

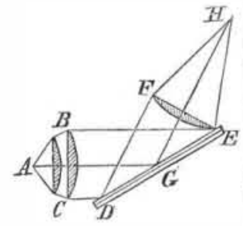

FIG. 9.

THE VERTICAL LANTERN.

This instrument involves such natural and simple applications of appliances, familiar to every one using such apparatus, that, as we might naturally expect, in some form or other it has been independently devised by several persons. Thus such an attachment to his ordinary lantern was made by Duboscq, at least as early as 1868, as the present writer is informed by Dr. H. Schellen, the renowned author of "Spectrum Analysis," though this manufacturer does not seem to have thought it worth while to describe it until very recently. From the imperfect arrangement of the condensers, it also does not yield very satisfactory results.

Professor J. P. Cooke, of Cambridge, Mass., used a vertical lantern at a very early date, of which he published a description in the *Journal of the Franklin Institute* for December, 1871, Vol. LXII. page 411. In the *Chemical News* for July 8, 1869, is described a very imperfect arrangement in which the lantern is turned over on its back, and a square prism is used to throw the rays upon the screen. Beside the inconvenience and danger to the lenses, of having them thus directly over the light, the square prism fails to reflect a large part of the rays unless the screen is very much above the level of the lantern.

In the *Chemical News* for February 25, 1870, there is described, by Edwin Smith, M. A., an arrangement for showing the motions of a galvanometer on a screen, identical in all respects with that of Duboscq and Professor Cooke. In none of these were the conditions required by theory, as above explained, fully provided for, and the action was consequently so far unsatisfactory that the instrument was never brought into any general use.

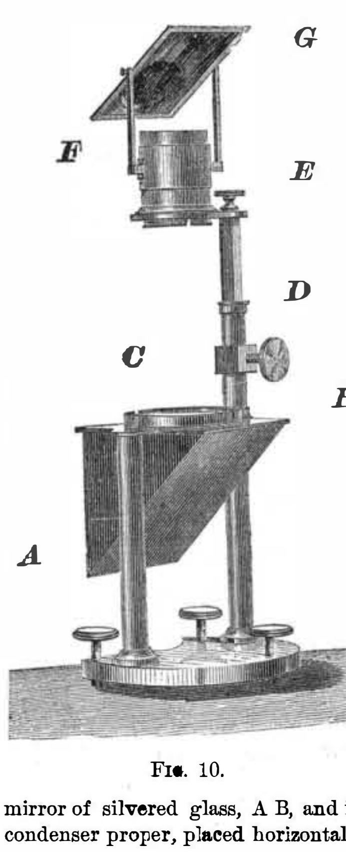

FIG. 10.

The form devised by the present writer, in 1871, which seems first to have made its way into general use and to have conferred the name "vertical lantern" on the instrument, is shown in the accompanying engraving, Fig. 10. The collecting lenses of the condensers are attached to the ordinary lantern box, and are omitted in the figure; and from them a bundle of parallel rays falls on the mirror of silvered glass, A B, and is reflected upward to the condenser proper, placed horizontally at C. Passing through this it meets the object, a tank of water or the like, resting or supported immediately above, and then traversing the objective, E F, is, by the mirror of silvered glass, F G, thrown upon the screen.

Mr. George Wale, of Hoboken, N. J., by whom this instrument was first made for the present writer, has devised a very pretty arrangement by which all the advantages of the vertical lantern can be combined with those of the ordinary instrument, and has manufactured a large number of such instruments, which are now in use in the principal colleges of the country.

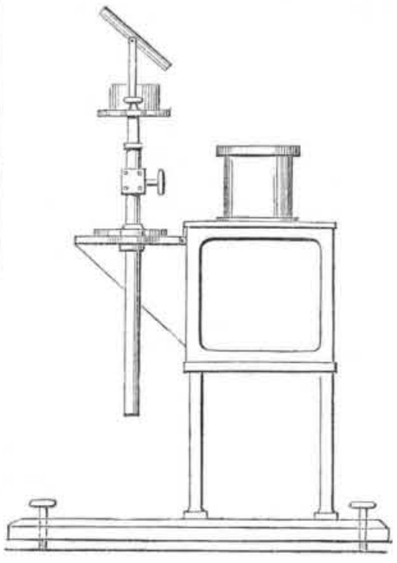

FIG. 11.

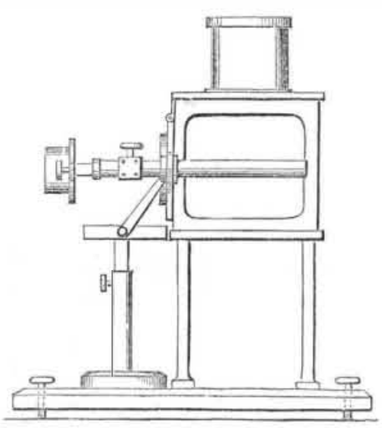

FIG. 12.

Its arrangement is as follows: A metal box, mounted on pillars, contains the source of light; to its front, inside, are attached the collecting elements of the condenser. The condensing element is supported in a hinged plate, to the side of which is also secured a stout rod with rack work, etc., carrying the object glass and upper mirror. When the instrument is to be used as a vertical lantern (see Fig. 11) this hinged piece is raised into a horizontal position, and supported by a triangular case holding the first mirror; and when employed as an ordinary lantern (Fig. 12) this case is removed; the condenser, and with it the rackwork and objective, is lowered and the upper mirror is slipped off. This instrument is probably the most complete, for purposes of demonstration, which has been heretofore constructed. But while it is desirable to have the most perfect appliances where we can, yet much may be accomplished with very simple means. Thus Dr. R. M. Ferguson, in the *Quarterly Journal of Science*, 1872, No. XXXIV., page 267, suggests the following arrangement, in which only such apparatus as is found in any laboratory is needed, in addition to an ordinary magic lantern. The condensers of ordinary lanterns are generally of rather long focus, so that if the light is brought to within about three inches, a bundle of approximately parallel rays will be obtained. An ordinary retort stand is then so arranged in front of the lantern that its lowest ring shall carry a mirror, and the next one a large watch glass filled with water. This makes the condenser; and, if we want to show the motions of waves or cohesion figures, this water-lens itself furnishes the necessary tank. The object glass and second mirror are carried by another ring of the same retort stand. The present writer has further simplified this construction by using a small watch glass, also filled with water, for the objective. This last, indeed, gives us a curious means of illustrating certain relations of lenses. Thus, with the ordinary vertical lantern, we remove the objective and substitute a watch glass. Then, placing a conspicuous picture as an object upon the condenser, we see only a blur of light on the screen; but as soon as a little water is poured into the watch glass, the image starts out with perfect distinctness. If, now, the size of the image on the screen is noted, and alcohol, bichloride of tin, or other highly refracting liquid, is substituted for the water in the watch-glass-objective, we shall find it necessary to bring the lens nearer to the object to secure a good definition; while, at the same time, the image on the screen will be proportionately enlarged. Watch glasses of various curvature may be likewise employed to illustrate the effect of this condition. The only serious objection to the use of water lenses, as above described, both for condenser and objective, is their liability to disturbance by motion, which obliges us to avoid the least jar to the apparatus, since this entirely confuses the image on the screen.

*NOTE.—We are here, of course, neglecting all effects of aberration, or, in other words, are assuming an ideally perfect lens, as the point in question does not depend upon any of the conditions so excluded.

Loose Pulleys.

G. P. says: "I have had great trouble in procuring a small loose pulley that would stand running at a high rate of speed with a very tight belt. After trying a large number of different kinds, of wood and iron, with long and short bearings, bushings of Babbitt, copper, etc., none of which would stand more than two months, I at last procured some sole leather; I put the flat surfaces together and bolted through with four bolts; after boring and turning, I soaked it well in oil and put in place. It has now been running about one year and is, apparently, as good as new. It requires very little oil."

REMARKS BY THE EDITOR.—If a loose pulley is properly arranged, it will run as well as a shaft bearing. It must be long enough, and have efficient provisions for lubrication.