ART. XLII.—*An Instrument designed to illustrate certain resultant vibrations in Polarized Light*; by Prof. E. S. SNELL, Amherst College.

I HAVE lately designed and constructed an instrument for exhibiting the combinations of two rays of light, polarized in planes at right angles to each other, when they coincide in direction, but one is in advance of the other by any fraction whatever of the wave-length.

I am aware that an instrument for presenting these resultant forms and motions has been invented by Plucker, a German physicist. But it appears to me that its mechanical difficulties must be so serious, as to render it practically useless. There is also much inconvenience in attempting to show by it one polarization by itself, then the other, and finally some resultant of both combined. Besides, after sending forward two or three waves at most, the process comes to an end, and there must be a backward movement, before another progression of waves can be shown. I have never seen one of Plucker's instruments in operation, but the description and engravings satisfy me, that unless the parts are almost absolutely free from friction, the rods will bind on the surfaces and in the grooves, and stop all progress, or become bent in the attempt to continue the motion.*

The apparatus here described is free from these several objections. The friction of the parts has no tendency to make them bind against each other, and thus check the motion of the waves; the change can be made in a moment from each single polarized system to the other, and to any desired combination of the two systems; and finally, the series of waves, of whatever kind, passes along uninterruptedly, so long as the experimenter chooses.

The general plan of giving motion to the rods which carry the balls is the same as that employed in the instrument for showing the molecular motion in water-waves, an account of which was published in this Journal, October, 1845, and which has recently been figured and described in Mr. Ritchie's catalogue of philosophical apparatus. Fig. 1 is a perspective view of the instrument, when opened so as to show the mechanism. The balls at the top represent so many particles of the luminiferous ether. They receive their vertical motions from the cams on the lower axis, which is turned by the crank (*a*); and their horizontal motions from a similar system of cams on the upper axis, which is made to revolve by a band from the lower. Fig. 2 presents a view of one of these systems of cams, twenty-four in

* For a description and representations of Plucker's instrument, see "Introduction à la Haute Optique, par A. Beer, traduit par M. C. Forthomme," pp. 148-153.

number, of circular section, and arranged in a regular helix, making two revolutions from end to end. The upper and lower axes, so far as the cams are concerned, are precisely alike, and parallel; and by means of a metallic band and pins, they have the same velocity of revolution, whenever the lower one is turned. The lower axis is placed near the front of the box, and on each cam rests a horizontal rod or bar of wood, eighteen inches long, free to revolve in a vertical plane on a pivot at the back side of the box. The rods lie between guides, which prevent lateral motion. On the front extremity of each bar there stands another bar, upright, fifteen inches long, the two being pivoted together by a joint which allows free motion. These vertical rods also play between guides, (c), which permit motion in vertical planes coincident with those in which the horizontal bars respectively move. An elastic cord, about three inches long, is fastened to each pair of rods near their angle of meeting, and tends by its contraction to hold back the vertical rod against its cam on the upper axis. Inserted in the extremity of each vertical rod is a black iron wire, reaching through a slit in the top of the box, having a white ball upon it, which thus appears in sight, when all the mechanism is concealed from view.* The whole vertical rod, from the hinge to the ball, is eighteen inches long, the same as the horizontal bar. Fig. 1 presents one of the resultant forms of wave, when the rods are in contact with their respective cams on both axes.

1.

Back of the lower axis, and below the horizontal bars, lies a strip of board, which can be turned up on hinges, so as to lift all the bars off from the cams; a similar piece is hinged below the upper axis, and behind the vertical rods, which, being turned

2.

* The top piece containing the slits is not represented in the figure.

into a horizontal position, presses the rods forward, and releases them from the upper cams. While they are placed thus, all the lower bars lie in a horizontal plane, and the upright ones in a vertical plane, so that the balls are in a straight line, representing the particles of ether at rest. If the crank is turned, both systems of cams revolve, but produce no motion of the balls. If the lower support is turned down, the horizontal bars fall upon their respective cams, the balls assume the arrangement of vertical waves, and on turning the crank, the wave-motion is seen in a *vertical plane* alone, representing a *plane-polarized pencil of light*. Now let the lower support be raised again, and the upper one be turned down; then the vertical rods are held back by the elastic cords against the upper system of cams, while the pivots at the bottom are in a horizontal line. If the crank is now turned, the lower cams produce no effect, but the upper system, revolving by the band, gives the balls a wave-motion in a *horizontal plane*, thus representing a pencil of light *polarized in a plane at right angles to the former*. Finally, if the lower support is once more let down, and the crank turned, the vertical waves coexist with the horizontal ones, and *some resultant mode of polarization is represented*, the precise character of which depends on the relation of phases in the two systems. The contrivance for varying the species of polarization, by bringing together any phases we please, is very simple. On the lower axis, the cams are all firmly attached to the short cylinder about which the band passes; but on the upper axis, the cylinder is divided, and the band passes over the detached portion or wheel, which is free to revolve on the central axis, but which can be held in any given position upon it, by a tooth on the main cylinder, which tooth is forced by a spring into a notch on the edge of the wheel. The wheel and spring are seen in fig. 2. Hence, by raising the tooth and turning the crank, the lower axis revolves, giving rotation also to the wheel, but not to the upper axis, until the balls assume the required relation to each other, when the tooth is dropped into the corresponding notch, and the desired polarization is produced, and can be continued at pleasure.

The resultant modes of polarization, as theory shows, are the following:

- (1.) *Plane polarization*, the vibrations being in a plane inclined 45° to the right.
- (2.) *The same*, the plane inclined 45° to the left.
- (3.) *Circular polarization*, the atoms revolving from the right over to the left.
- (4.) *The same*, the revolution being from left over to right.
- (5.) *Elliptical polarization*, the transverse axis inclined 45° to the right, and the atoms revolving from right over to the left.
- (6.) *The same*, and the axis the same, but the atoms revolving from left to right.

(7.) *The same*, the axis inclined 45° to the left, and the atoms revolving from right to left.

(8.) *The same*, and the axis the same, but the atoms revolving from left to right.

Moreover, in all the cases of elliptical polarization, the eccentricity may vary to any degree, from the straight line on the one hand, to the circumference of a circle on the other.

It is unnecessary to state what is the relation of the cams of the two axes, for presenting all these varieties of polarization; to describe one or two is sufficient.

Let a cam of the lower axis, Fig. 3, be at its highest position, and about to descend to the right, while the corresponding cam of the upper axis is farthest to the right, about to commence its motion to the left, as it descends; then the ball both *descends* by the first cam, and *moves to the left* by second, at equal rates; and therefore oscillates in a plane, which inclines upward 45° to the right.

All the balls in regular succession do the same, so that the polarization is that of (1.) Again, change the relation of the axes, so that when one of the lower cams is at the highest point, the corresponding upper one shall be also at the highest point; then, when the ball *descends* by the first motion, it *moves to the right* by the second, till a quadrantal arc is described; then, continuing to descend, it moves to the left, till a semi-circumference is completed, and so on. This is *right-hand circular polarization* (4), provided the vibrations are propagated from particle to particle *toward the observer*. These and the other cases can be exhibited by the instrument in less time than is required to describe them.

In one particular this instrument is inferior to Plucker's. In his, the balls in their component motions, strictly describe straight lines, in a vertical or a horizontal plane. But in this, these molecular motions, as exhibited by the balls, are obviously arcs of circles; consequently, all the compound motions deviate from the lines which have been mentioned. As the radius, however, is 18 inches, and the arc only about two inches, the curvature is not easily noticed. Since the whole purpose of the instrument is to produce motions which visibly agree with those determined by theory, in order to illustrate the subject to the mind of the pupil, the failure to fulfil the exact theoretical conditions is unimportant, while the mechanical advantages of this mode of producing the vibrations are obvious.

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