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Lord Rayleigh F.R.S.

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XXII. *Is Rotatory Polarization influenced by the Earth's Motion?* By LORD RAYLEIGH, F.R.S.*

THE question whether the rotation of the plane of polarization of light propagated along the axis of a quartz crystal is affected by the direction of this axis relatively to that of the earth's orbital motion, is of considerable theoretical importance. According to an investigation of Lorentz, an effect of the first order might be looked for. Such an effect would be rendered apparent by comparing the rotations when the direction of propagation of the light is parallel to that of the earth's motion and in the reverse direction, and it might amount to $\frac{1}{10,000}$ of the whole rotation †. According to Larmor's theory ‡ there should be no effect of the first order.

The question was examined experimentally many years ago by Mascart §, who came to the conclusion that the reversal of the ray left the rotation unchanged to $\frac{1}{20,000}$ part. In most of the experiments, however, the accuracy was insufficient to lend support to the above conclusion.

Dr. Larmor (*l. c.* p. 220) having expressed the opinion that it might be desirable to re-examine the question, I have made some observations which carry the test as far as can readily be done. It appears that the rotation is certainly not altered by $\frac{1}{100,000}$ part, and probably not by the half of this, when the direction of propagation of the light is altered from that of the earth's motion to the opposite direction.

I should scarcely have been able to carry the test to so satisfactory a point, had it not been for the kindness of Prof. MacGregor, who allowed me the use of certain valuable quartz crystals belonging to the Edinburgh collection of apparatus. These crystals, five in number, are all right-handed, and measure about 50 mm. each in the direction of the optical axis, to which the polished faces are approximately perpendicular. They were prepared for Prof. Tait, and were employed by him for his "rotatory polarization spectroscopy of great dispersion" ||. For the most part they are nearly free from blemish, and well adapted to the purpose in view.

In principle the experiment is very simple, scarcely differing

* Communicated by the Author.

† This fraction representing approximately the ratio of the velocity of the earth in its orbit to the velocity of light.

‡ 'Æther and Matter,' Cambridge, 1900.

§ *Annales de l'École Normale*, vol. i. p. 157 (1872).

|| *Nature*, vol. xxii. 1880; Tait's 'Scientific Papers,' vol. i. p. 423.

from ordinary polarimetry, as, for example, in determining the rotation due to sugar and other active bodies. But the apparatus needs to be specially mounted upon a long stiff board, itself supported upon a point, so that the absolute direction of the light may be reversed without danger of even the slightest relative displacement of the parts. The board swings round in the horizontal plane; and if its length is directed from east to west, or from west to east, observations taken at noon (in June) correspond pretty accurately to propagation of the light with or against the earth's motion in its orbit. Similar comparisons at 6 o'clock are nearly independent of the earth's motion.

In another respect the experiment is peculiar on account of the enormous amount of the rotation to be dealt with. For sodium light the rotation is 22° per millimetre of quartz, so that the whole rotation is 5500° , or more than 15 complete revolutions. In the preliminary experiments, with one of the crystals only, sodium light was employed; but the observations were unsatisfactory, even although the light was resolved into a spectrum. If the flame was well supplied with salt, the extinction of the D-line by suitable adjustment of the nicol still left the *neighbouring* region of the spectrum so bright as to prejudice the observation by lessening the sensitiveness of the eye. This effect, which is quite distinct from what is ordinarily called the broadening of the D-lines and can be made still more pronounced by stimulating the flame with oxygen, does not appear to present itself in any other method of observation, and is of interest in connexion with the theory of luminous emission. A very moderate rotation of the nicol revives the D-lines sufficiently to extinguish the neighbouring spectrum, just as the first glimpse of the limb of the sun after a total eclipse extinguishes the corona*.

When all five quartzes were brought into use it was hopeless to expect good results from a soda-flame. From the fact that the rotation is as λ^{-2} we see that there must be 11° difference of rotation for the two D-lines, so that a satisfactory extinction is out of the question. For the observations about to be recorded a so-called vacuum-tube, charged with *helium*, was employed, the yellow line (situated close to the D-lines)

* July 6.—A doubt having suggested itself as to whether this effect might not be due to an actual whitening of the Bunsen flame, such as sometimes occurs rather unexpectedly, the experiment was repeated with a flame of pure *hydrogen*. The region of the spectrum in the neighbourhood of D was even brighter than before. An attempt to produce an analogous effect with *lithium* was a failure, apparently in consequence of insufficient brightness of the flame.

being chosen. It was actuated by a Ruhmkorff coil and four Grove cells, situated at some distance away.

The various parts, all mounted upon the pivoted board, will now be specified in order. First came the helium tube with capillary vertical, then at a distance of 25 cm. a collimating spectacle-lens, followed by the polarizing nicol. The field of view presented by this nicol was contracted to a circular aperture 7 mm. in diameter, and was further divided into two parts by a "sugar-cell." This cell was the same as that formerly used in a cognate research on the rotation of the plane of polarization in bisulphide of carbon under magnetic force*. "The polarimeter employed is on the principle of Laurent, but according to a suggestion of Poynting (Phil. Mag. July 1880) the half-wave plate of quartz is replaced by a cell containing syrup, so arranged that the two halves of the field of view are subjected to small rotations differing by about 2° . The difference of thickness necessary is best obtained by introducing into the cell a piece of thick glass, the upper edge of which divides the field into two parts. The upper half of the field is then rotated by a thickness of syrup equal to the entire width of the cell (say $\frac{1}{2}$ inch), but in the lower half of the field part of the thickness of syrup is replaced by glass, and the rotation is correspondingly less. With a pretty strong syrup a difference of 2° may be obtained with a glass $\frac{3}{16}$ inch [inch = 2.54 cm.] thick. For the best results the operating boundary should be a true plane perpendicular to the face. The pieces used by me, however, were not worked, being simply cut with a diamond from thick plate glass; and there was usually no difficulty in finding a part of the edge sufficiently flat for the purpose, *i. e.* capable of exhibiting a field of view sharply divided into two parts By this use of sugar, half-shade polarimeters may be made of large dimensions at short notice and at very little cost. The syrup should be filtered (hot) through paper, and the cell must be closed to prevent evaporation."

The light next traversed the quartz crystals, each mounted upon a small stand admitting of adjustment in azimuth and level so as to bring the optical axis into parallelism with the line of vision. The analysing nicol, mounted near the end of the board, was distant 102 cm. from the polarizer. After passing the nicol the light traversed in succession a direct-*prism* prism of sufficient aperture and a small opera-glass focussed upon the sugar-cell. The aperture limiting the field had been so chosen that, as seen through the spectroscope, the

* Phil. Trans. clxxvi. p. 343 (1885); 'Scientific Papers,' vol. ii. p. 363.

yellow image under observation was sufficiently separated from the neighbouring red and green images corresponding to other spectral lines of helium. The position of the analysing nicol was read with a vernier to tenths of a degree—an accuracy which just sufficed, and the setting could be made by causing the two halves of the field of view afforded by the sugar-cell to appear *equally* dark.

A good deal of time was spent in preliminary experiment before the best procedure was hit upon. It is necessary that the optic axes of the crystals be adjusted pretty accurately to the line of vision, and this in several cases involved considerable obliquity of the terminal faces. In these adjustments the sugar-cell and its diaphragm are best dispensed with, the crystals being turned until the rotation required to darken the field is a minimum and the darkness itself satisfactory. When the first crystal has been adjusted, a second is introduced and adjusted in its turn, and so on. In some cases a further shift of the crystal parallel to itself was required in order to remove an imperfection from the part of the field to be utilized. In the end a fairly satisfactory darkness was attained, but decidedly inferior to that obtainable when the quartzes were removed. Part of the residual light may have been due to want of adjustment; but more seemed to originate in imperfections in the quartzes themselves.

In my former experiments upon bisulphide of carbon advantage was found from a device for rocking the plane of polarization through a small constant angle*. During the observations now under discussion this effect was obtained by the introduction of a second sugar-cell, not divided into two parts or seen in focus, just in front of the analysing nicol. The cell was mounted so that it could slide horizontally in and out up to fixed stops. The thickness of the cell being sufficient, the strength of the syrup was adjusted to the desired point. Thus when the nicol was correctly set, the upper half of the field was *just distinctly* the brighter when the cell was *in*, and the lower half with *equal distinctness* the brighter when the cell was *out*, the object to be aimed at in the setting of the nicol being the *equality* of these small *differences*. For the results now to be given the setting of the nicol was by myself and the reading of the vernier was by Mr. Gordon. A second observer is a distinct advantage.

As a specimen, chosen at random, I will give in full all the

* *Loc. cit.* ; 'Scientific Papers,' vol. ii. p. 366.

readings made in the neighbourhood of noon on June 19. Five readings were taken in each position and then the board was reversed. The headings "East" and "West" indicate the end at which the observer was sitting; "East" therefore meaning that the course of the light was from West to East.

TABLE I.

Time 11 ^h 30 ^m . Temp. 17°·4. East.	Time 11 ^h 50 ^m . Temp. 17°·7. West.	Time 12 ^h 5 ^m . Temp. 17°·9. East.	Time 12 ^h 15 ^m . Temp. 17°·9. West.	Time 12 ^h 25 ^m . Temp. 17°·9. East.
45·7	45·4	45·6	45·9	46·0
45·5	45·9	45·8	45·7	46·1
45·5	45·4	45·5	45·9	46·1
45·6	45·7	45·6	45·7	46·0
45·6	45·7	45·7	45·8	46·0
45·58	45·62	45·64	45·80	46·04

The mean of the three "East" is 45·75, and of the two "West" is 45·71; so that

$$E - W = +·04°.$$

All these numbers are in decimals of a degree. The progressive alteration in the readings corresponds to the rise of temperature. It would appear that, as was natural, the quartzes lagged somewhat behind the thermometer.

TABLE II.—Noon.

Date.	E - W.
June 17.....	+·03
„ 18.....	-·05
„ 19.....	+·04
Mean	+·007

Three sets of observations were taken at noon, and the results are recorded in Table II. In two other sets taken

about 6^h the differences $E - W$ were even less. The comparison of the two hours serves to check possible errors, *e. g.* of a magnetic character, such as might be caused by the magnetism of the Ruhmkorff coil, if insufficiently distant.

It seems certain that at neither hour does the difference $E - W$ actually amount to $\frac{1}{2^0}$ of a degree, *i. e.* to $\frac{1}{100,000}$ of the whole rotation. In all probability the influence of the reversal is much less, if indeed it exists at all.

P.S.—Since the above observations were made, I see from the Amsterdam Proceedings (May 28, 1902) that Lorentz maintains his opinion against the criticism of Larmor. Lorentz's theoretical result contains an unknown quantity which might be adjusted so as to make the influence of the earth's motion evanescent; but for this special adjustment there appears to be no theoretical reason. I hope that the above experimental demonstration of the absence of effect, to a high order of accuracy, will be found all the more interesting.

XXIII. *Experiments on the Electro-thermal Effect in Tourmaline.* By R. STRAUBEL*.

AS was first shown by W. Thomson in 1877, from thermodynamical considerations, there corresponds to the pyro-electric phenomenon—*i. e.* the electrification produced by a uniform rise of temperature—a reverse effect, namely, a temperature change due to a variation of the electric state. If a pyro-electric crystal be brought into an electric field so that the lines of force run from the analogous to the antilogous pole, it will be heated; if the orientation of the crystal in the field is reversed, a cooling will take place.

On the effect so predicted by theory I carried out some experiments about two years ago, using a Brazilian tourmaline. These experiments, though only qualitative, will be briefly described in what follows.

Four plates, each 0.2 cm. thick, were cut from the tourmaline crystal in a direction normal to its axis. The plates were then arranged in two pairs, in one of which the analogous poles, and in the other the antilogous poles, were uppermost. Between the plates of each pair was introduced one set of junctions of a home-made thermopile of ten elements, made of fine wires of constantan and iron. The

* Translated from the *Nachrichten der K. Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse.* 1902. Heft 2.