
(Communicated at the meeting of November 30, 1929).

Doppler has shown in 1842 that there is a change of pitch of a sound, when source and observer are in relative motion in the connecting line and that an action of the same kind is to be expected for the luminous phenomena 1).

Fizeau appears to have been the first to show (in 1848) that a shift in the position of the lines in the spectrum was to be observed by the motion of the earth towards or away from a star.

The principle of Doppler-Fizeau has been verified by astronomical observations on the most extensive scale ever since Huggins succeeded in 1868 in measuring the relative motion of some stars and the earth in the line of sight.

The effect was observed rather late in the laboratory, for the velocities there available are small in comparison with those at the disposition of astronomers.

The experiments of Bielopolski 2), Galitzine and Wilip 3), Majorana 4), Pérot 5) introduced the phenomenon into the laboratory. These physicists succeeded in showing that the extremely small displacement of the spectrum lines was of the calculated order of magnitude, the deviation from the theoretical value being in some cases only 4 or 5 percent 6).

In these observations use was made of revolving mirrors and multiple reflections. For the analysis of the light the interferometer, the echelon spectroscope and the étalon were employed.

1) The papers of Chr. Doppler have been edited in 1907 in Ostwald's Klassiker No. 161, with critical remarks and commentary by H. A. Lorentz.


4) Majorana, Phil. Mag. 35, 163, 1918.

5) Pérot, Comptes rendus 178, 380, 1924.


A more simple way for observing the change of frequency was given by Buisson and Fabry 1).

They employed a horizontal disc of paper of 16 cm diameter, which could be put into rapid rotation, so that the points of the edge obtained a velocity of 100 m per second. The disc was observed illuminated by means of a Hewitt lamp, placed along a diameter. The disc was observed in a very oblique direction, so that it appeared as an elongated ellipse, one end of the major axis moving towards, the other end away from the observer.

By means of an étalon of Fabry and Perot with a distance of 6.5 cm between the plates the ring systems corresponding to the light from both ends could be observed consecutively.

"On n'a pas cherché à apporter le maximum de précision dans la vérification numérique; une seule expérience de mesure a été faite, sans prendre beaucoup de précautions".

From the data relating to this single experiment:

"On déduit que la variation de l'ordre d'interférence au centre des anneaux doit être de 0.200. La mesure directe a donné 0.206, ce qui constitue une concordance meilleure qu'on ne pouvait l'espérer étant donné les conditions dans lesquelles la mesure était faite".

We have made an experiment closely akin to that of Fabry and Buisson, but with some variations, which are we think improvements.

Our attention was drawn to the subject, which otherwise perhaps would not have been followed up, by a bequest made to one of us (P.Z.) by an amateur physicist consisting in a motor of the S.K.A. type (firm Heemaf, Hengelo) of 30 H.P. and a disc of nickel steel of 130 cms diameter. This disc is carried by the horizontal shaft of the motor.

The question what shall we do with this legacy made us realize that these apparatus were very suitable for a verification of Doppler's principle 2).

The motor, with its shaft in horizontal position, is mounted on a block of concrete, the height being chosen in such a manner that the disc is quite free from the laboratory floor.

The position of the block could be controlled by screws so that the plane of the disc could be made accurately vertical. The disc was most accurately balanced out. Near the edge of the disc a matt white circle is painted with slaked lime 3).

The velocity of the edge is 175 metres per second when the motor is running at full speed. The light of a mercury lamp is concentrated

1) Buisson et Fabry, Journal de Physique, Tome 9, 234. 1919.
2) Stark's experiments on the light emitted by the canal rays in vacuum tubes are not intended primarily for the verification of Doppler's principle.
3) The circle is made of 12 strips of aluminium, width 30 mm, thickness 5 mm all of the right curvature. The strips are screwed to the disc by means of 1/4 inch screws in 36 holes. The inlaid aluminium circle has its outer circumference at 5 mm from the edge.
on the edge, the incidence being in a direction normal to the velocity of the edge. The particles of the white circle act as independent luminous sources; emitting light of the same wavelength as that of the incident light. If the disc is in motion an observer looking in the direction of a horizontal tangent line to the circle, will see a change of wavelength, due to the Doppler effect.

The effect can be doubled, so that we observe a Doppler effect corresponding to a speed of 350 metres per second by using a simple artifice. This consists in the use of a small silvered mirror with its plane normal to the edge and mounted on a separate stand so that it leaves a free space of 1 mm width between the disc and the mirror (see Fig. 1). In this mirror one sees the edge of the disc moving in a direction opposite to that of the front part of the disc.

The change of wavelength was measured by a Fabry and Pérot étalon with 10 mm distance piece of fused silica. As is well known the influence of a change of temperature is largely eliminated by this means. In order to eliminate still further temperature effects and effects of changes of the barometer photographs were taken alternately.

In the schematic drawing Fig. 2 (not quite to scale), \( M \) is the small mirror, \( C \) a condensor, \( I \) represents the étalon. There is always some danger in experiments with a high speed disc (weight 158 KG.), the more so in the present case as near the edge the disc has been perforated at a number of places for the aluminium circle \(^1\).

A slight lateral displacement of the lens \( L \) makes it possible to focus the pencil circle or its image on the etalon.

For the protection of the observer (and the optical instruments) motor and rotating disc were placed in a separate room.

A glass window in the heavy separation wall shut off from the étalon the intense air currents originating in the neighbourhood of the disc. Generally the arrangement was somewhat less simple than in the drawing, a constant deviation spectroscope being used so that the observer could not see the rotating disc.

The angle between the disc and the line of sight amounted to \( 4^\circ 30' \).

The theory of the comparison of wavelengths by means of the étalon

As the diameter of the disc is 130 cms, the center line of the strip is a circle of 126 cms diameter. This center line was marked by a fine pencil. By means of this central pencil circle all optical adjustments could be very precisely carried out. The constituents of the circle are scarcely visible in Fig. 1.

\(^1\) See note pag. 1142.
is very simple and in this application, as in the similar one of the magnetic resolution of spectral lines \(^1\)), leads to,

\[
\frac{\Delta \lambda}{\lambda} = \frac{\Delta \nu}{\nu} = \frac{1}{8 f^2} (x_1^2 - x_2^2)
\]

\(x_1\) and \(x_2\) being the linear diameters of the rings of the compared wavelengths, \(f\) the focal length.

The experiments were made with the mercury violet and green lines. The results are recorded in the following tables:

<table>
<thead>
<tr>
<th>Number of Plate</th>
<th>Combination of photograms</th>
<th>Difference of squares (\times 10^5)</th>
<th>(\frac{\Delta \lambda}{\lambda} \times 10^9)</th>
<th>(\frac{\Delta \lambda}{\lambda} \times 10^9) for (v = 350) M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>{ 4(\rightarrow)5(\rightarrow)6 } 796</td>
<td>1183</td>
<td>1186</td>
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</table>

For this series \(f = 29.00 \pm 0.06\) cm.

Mean of fifth column after correction\(^2\) 1191. Mean error 33.

Hence for 4358 \(\frac{\Delta \lambda}{\lambda} = 1191 \pm 33 \times 10^{-9}\) for \(v = 350\) M/sec.

Theoretical value \(= 1167 \times 10^{-9}\).

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\(^1\) P. ZEEMAN, Researches in Magneto-optics. Mac Millan. 1913, p. 111.

\(^2\) For small tachometer fault and angle between disc and line of sight.
P. ZEEMAN AND M. RISCO: EXPERIMENTAL VERIFICATION OF THE PRINCIPLE OF DOPPLER-FIZEAU FOR LIGHT.

A reproduction of microphotometer curves of the violet line, exhibiting the effect of change of direction of the speed is given in Fig. 3.

Mercury green 5461.

<table>
<thead>
<tr>
<th>Number of Plate</th>
<th>Combination of Photograms</th>
<th>Difference of squares $\times 10^5$</th>
<th>$\frac{A\lambda}{\lambda} \times 10^9$</th>
<th>$\frac{A\lambda}{\lambda} \times 10^9$ for $v = 350$ M.</th>
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<td></td>
<td>2-3-4</td>
<td>743</td>
<td>1146</td>
<td>1158</td>
</tr>
</tbody>
</table>

For this series $f = 28.47 \pm 0.01$ cm. Mean of fifth column 1196. After correction 1194. Mean error 9. Hence for $v = 350$ metres/sec.

$$\lambda = 4358 \quad \Delta \lambda = 1191 \pm 33 \times 10^{-9}$$

$$\lambda = 5461 \quad \Delta \lambda = 1194 \pm 9 \times 10^{-9}$$

Theoretical value $\frac{\Delta \lambda}{\lambda} = 1167 \times 10^{-9}$

In Angström units we get:

$$\lambda = 4358 \quad \Delta \lambda = 0.00519 \pm 0.00014 \ \text{Å} \ . \text{U.} \quad \Delta \lambda_{th} = 0.00508$$

$$\lambda = 5461 \quad \Delta \lambda = 0.00652 \pm 0.00005 \ \text{Å} \ . \text{U.} \quad \Delta \lambda_{th} = 0.00637$$

For the mercury green line the deviation between the theoretical value and the observed one is perhaps somewhat in excess in what might have been expected from the mean error.

The authors are much indebted to Mr J. VAN DER ZWAAL for help in the experiments and the mounting of the apparatus and to Mr. GISOLF for repeating some series of measurements and calculating and checking the results.