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Rotating Disk Experiments

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We consider the historic Harress–Sagnac experiment in the light of our absolute space–time theory, proposing two modifications, and we give an account of its recent practical performance. We show that the effect of the rotating disk experiment is a direct result of the light velocity's direction dependence and we point out that our recently performed coupled-mirrors experiment, with whose help for the first time we have measured the Earth's absolute velocity, can be considered as a logical result of the rotating disk experiment.

1. INTRODUCTION

A good formula is like a flour bag: however much you shake off, something always remains. The same can be said about a good experiment.

The rotating disk experiment of Harress[1,2] and Sagnac[3] was performed more than sixty years ago and repeated by Pogany[4] and Dufour and Prunier.[5] After the invention of the ring laser, Rosenthal[6] proposed to use the "Sagnac effect" for the measurement of very slow rotational velocities; later the so-called laser gyroscope was constructed, which has many different practical applications.[7]

Certain physicists (including Sagnac) have considered the rotating disk experiment as a confirmation of the light velocity's direction dependence and the existence of absolute space (see on this topic the note by Telegdi.[8]) Nevertheless, when today ballistic rockets can fly with the help of laser gyroscopes working on the Sagnac effect from the Soviet Union to the shores of America (and vice versa) and find their target to within 1km, physicists overwhelmingly assert that this effect is not due to an "aether wind." Thus, in order to explain the Sagnac effect without appeal to the aether wind assumption, thousands of pages have been written.

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We have established in practice by the help of the disrupted rotating disk experiment[9,10] that the velocity of light is direction dependent not only along a closed path over the Harress–Sagnac disk, but also along a straight line on this disk; and with the help of the coupled-mirrors experiment[11,12] we have measured the absolute veclocity of the Earth in our laboratory.

In this paper we give a report on the performance of two important modifications of the rotating disk experiment which support our absolute space–time conceptions; and then we show that the coupled-mirrors experiment can be considered as a logical modification of this fateful experiment.

Our absolute space–time theory proceeds from the aether model for light propagation and, within effects of first order in v/c, is identical with the traditional Newtonian theory. Since in this paper we shall consider only such effects, the whole analysis can be based on common Newtonian conceptions.

2. THEORY OF THE ROTATING DISK EXPERIMENT

Figure 1 presents our setup for the performance of the rotating disk experiment. A medium with refractive index n can rotate (in a clockwise

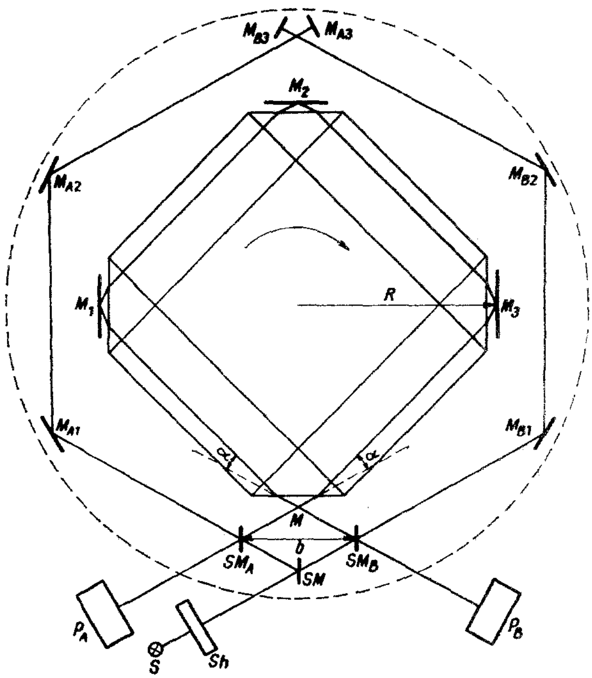

Fig. 1. Scheme of the rotating disk experiment in our version.

direction) with the semitransparent mirrors SM, SM_A, and SM_B and the mirrors M_1, M_2, M_3, M_{A1}, M_{A2}, M_{A3}, M_{B1}, M_{B2}, and M_{B3}, or without them; or only the mirrors can rotate and the medium can remain at rest. In the last case, a medium with refractive index $n = 1$, i.e., vacuum (air) also can be taken. So, four different combinations are possible, which we name as follows:

1. The *Harress–Sagnac experiment*, performed first by Sagnac,[3] in which the mirrors rotate and the medium is vacuum.

2. The *Harress–Pogany experiment*, performed first by Harress[1,2] and repeated very carefully by Pogany[4] in a slightly different arrangement, in which the mirrors rotate together with the medium.

3. The *Harress–Marinov experiment*, performed recently by us and reported further in this paper, in which the mirrors rotate and the medium is at rest. This experiment in a somewhat different arrangement was performed first by Dufour and Prunier,[13] and in their arrangement we call it the Harress–Dufour experiment.

4. The *Harress–Fizeau experiment*, performed first by Fizeau[14] in a substantially different arrangement (called the "water tube" experiment and repeated by Zeeman[15] with solid media), in which the medium rotates and the mirrors are at rest. Our performance of the Harress–Fizeau experiment, which is reported further in this paper, can be considered as original. Indeed, Post[16] writes (p. 484), "A rotational version of this (Fizeau's "water tube") experiment has apparently not yet been made. Such an experiment would not be altogether trivial because it could inform us about the extent to which the translational coefficient of drag can be extrapolated to cases of nonuniform motion."

In Fig. 1, S is a light source emitting coherent light; Sh is a shutter, which is governed by the rotating disk (the turnabout) and allows short light pulses (10^{-6} sec) to pass only at a strictly defined position of the disk when the diametrically opposite facets of the transparent medium are exactly parallel to the mirrors M_1, M_2, M_3. The area of the facets are small and the mirrors M_1, M_2, M_3 are placed near the medium. Thus we can assume that the photons travel between the single mirrors along the corresponding chords of a circle with radius R. P_A and P_B are two photoresistors put in both arms of a Wheatstone bridge. Always when the shutter Sh allows light to pass, the photoresistors are illuminated *uniformly* by interfered light. To explain the character of the interference, let us consider four photons that are emitted by S at the same moment and let us suppose that they cover the following paths:

First photon: SM-SM_A-M_{A1}-M_{A2}-M_{A3}-M_{A2}-M_{A1}-SM_A-P_A.

Second photon: SM-SM_B-M_1-M_2-M_3-SM_A-P_A.

Third photon: $SM\text{-}SM_B\text{-}M_{B1}\text{-}M_{B2}\text{-}M_{B3}\text{-}M_{B2}\text{-}M_{B1}\text{-}SM_B\text{-}P_B$

Fourth photon: $SM\text{-}SM_A\text{-}M_3\text{-}M_2\text{-}M_1\text{-}SM_B\text{-}P_B$.

The first and the third photons cover the same paths for rest and motion of the mirrors. As a matter of fact, there are differences which are of second order in v/c, and we consider them in Ref. 17; however, as already said, in this paper we consider only effects of first order in v/c.

The second photon (which we shall call "direct") travels along the direction of rotation, and the fourth photon (which we shall call "opposite") travels against the direction of rotation. The differences in the optical paths of the first and second photons, on the one hand, and of the third and fourth photons, on the other hand, will change oppositely when chanigng the rotational velocity. Hence if, at certain angular velocity Ω_1 , the Wheatstone bridge is in equilibrium (this signifies that the difference of the differences in the optical paths of the first and second photons, on the one hand, and of the third and fourth photons, on the other hand, is equal to an integer number of wavelengths) and we change the rotational velocity, the bridge comes into greater and greater disequilibrium, passes through a state of maximum disequilibrium, and at certain angular velocity Ω_2 comes again into equilibrium. If the time spent by the second (or fourth) photon to cover its path at the angular velocity Ω_2 differs by Δt_A (or Δt_B) from the time spent at the angular velocity Ω_1 , and we introduce the notation $\Delta t = \Delta t_A + \Delta t_B$, then $\Delta = c\,\Delta t$ will be equal to the wavelength λ of the light.

Let us now find the expressions for Δt through the parameters of the device for the different types of rotating disk experiment, taking into account also the dispersion of the medium. We shall make the calculations, proceeding from the simple scheme of the rotating disk experiment given in Fig. 2. Here S is a light source, Sh a shutter governed by the turnabout, M is a semitransparent mirror where the light pulses separate into "direct" and "opposite," M_1 , M_2 , and M_3 are mirrors and O is an observer who registers the different interference pictures. In Fig. 1, to the semitransparent mirror M there corresponds a *point* M which can be considered as an effective point of separation.

First we shall consider the Harress–Marinov and Harress–Dufour experiments, whose schemes are given, respectively, in Figs. 2a and 2b. The deduction of the relevant formulas is given in Refs. 18 and 19; however, the calculations there are too cumbersome. We shall give simple deductions based on Newtonian conceptions, taking into account the dispersion of the medium.

We suppose that the mirrors in Fig. 2 rotate in a direct (clockwise) direction with angular velocity Ω relative to the medium, which is at rest with respect to absolute space. According to Fig. 3 (see also Figs. 2 and 1),

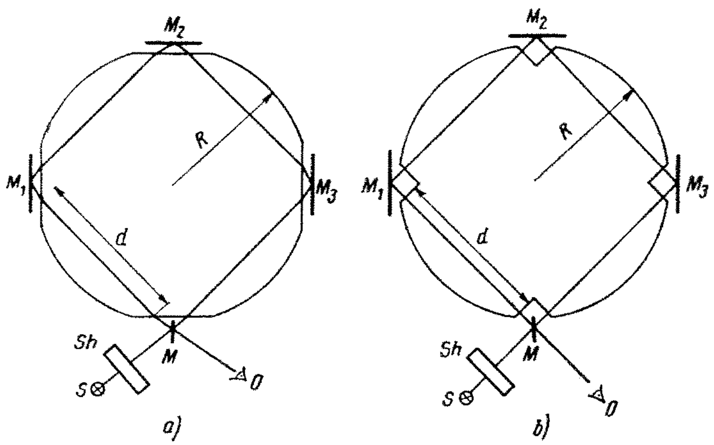

Fig. 2. The rotating disk experiment: (a) The Harress–Marinov variant, (b) the Harress–Dufour variant.

a "direct" photon (traveling along the direction of rotation), which separates from an "opposite" photon (traveling against the direction of rotation) on the semitransparent mirror M will reflect not at point M_1 (where it has to reflect when the mirrors are at rest), but at a point M_1', and thus in the case of rotation its path will be longer by

$$\Delta d = (\Omega R^2/c)\, n \tag{1}$$

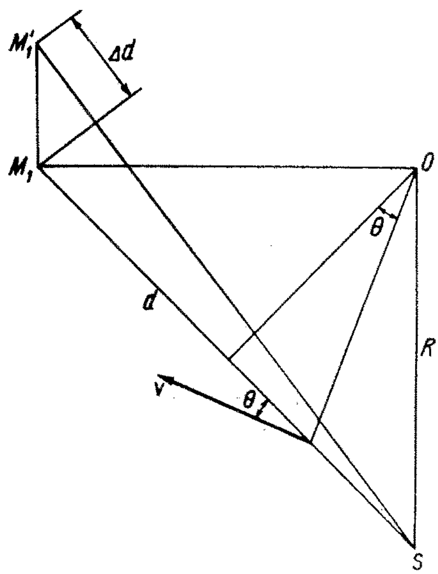

Fig. 3. Detail of the rotating disk experiment.

where $d = R\sqrt{2}$ is its path when the mirrors are at rest and R is the distance of the mirrors from the center of rotation. The relation between d and R given here is to be considered as approximate, since the mirrors M_1, M_2, and M_3 and the point of separation M are not exactly tangent to the circumference of the medium's disk and certain parts of the disk are "cut away." Here we shall consider an idealized case where this relation is exact (see Section 4, where the practical realization of this experiment is described).

When the mirrors rotate, an "opposite" photon has to cover between mirrors M and M_3 a distance which is Δd less than in the case where the mirrors are at rest.

Since mirror M (or mirrors SM_A and SM_B in Fig. 1) moves, then, because of the Doppler effect, the frequencies of the "direct" photons received by the molecules of the medium will be

$$\nu_0 = \nu\left(1 + 2\frac{v}{c}\cos\frac{\pi}{4}\right) = \nu\left(1 + \sqrt{2}\frac{\Omega R}{c}\right) \tag{2}$$

while the frequencies received by the "opposite" photons will remain the same.

Hence, if we take into account dispersion, the refractive index of the medium for the "direct" photons becomes

$$n^+ = n(\nu_0) = n + \sqrt{2}\frac{\Omega R}{c}\nu\frac{dn}{d\nu} \tag{3}$$

Obviously, if the mirrors rotate, a "direct" photon will return to mirror M after an "opposite" photon with the following time delay:

(a) For the Harress–Marinov experiment,

$$\Delta t_{\mathrm{HM}} = 4\frac{d + \Delta d}{c/n^+} - 4\frac{d - \Delta d}{c/n} = 8\frac{\Omega R^2}{c^2}\left(n^2 + \nu\frac{dn}{d\nu}\right) \tag{4}$$

(b) For the Harress–Dufour experiment,

$$\Delta t_{\mathrm{HD}} = 4\left(\frac{d}{c/n^+} + \frac{\Delta d}{c}\right) - 4\left(\frac{d}{c/n} - \frac{\Delta d}{c}\right) = 8\frac{\Omega R^2}{c^2}\left(n + \nu\frac{dn}{d\nu}\right) \tag{5}$$

Thus if we rotate the disk with the mirrors attached to it first at angular velocity Ω_1 and then at angular velocity Ω_2, and if we denote $\Omega = \Omega_2 - \Omega_1$, we shall obtain for the difference in the light paths the following results:

(a) For the Harress–Marinov experiment,

$$\Delta_{\mathrm{HM}} = 8\frac{\Omega R^2}{c}\left(n^2 - \lambda\frac{dn}{d\lambda}\right) \tag{6}$$

(b) For the Harress–Dufour experiment,

$$\Delta_{\mathrm{HD}} = 8\,\frac{\Omega R^2}{c}\left(n - \lambda\,\frac{dn}{d\lambda}\right) \tag{7}$$

For the sake of simplicity we shall call the *common type* of rotating disk experiment, where the medium is at rest and the mirrors rotate, the Harress–Marinov experiment.

Let us now analyse the Harress–Fizeau experiment. It can be performed also in two somewhat different arrangements shown in Figs. 2a and 2b, which we shall call, respectively, the Harress–Fizeau–Marinov and Harress–Fizeau–Dufour experiments. To save time, we shall consider only the first one, which was practically realized by us, calling it the Harress–Fizeau experiment.

We suppose that the medium rotates in a direct (clockwise) direction with angular velocity Ω relative to the mirrors, which are at rest with respect to absolute space. Now, as can be seen from Fig. 3, the molecular velocity that makes an angle θ with the direction of propagation of the "direct" photons will have the magnitude

$$v = \frac{\sqrt{2}}{2}\,\frac{\Omega R}{\cos\theta} \tag{8}$$

Since the medium moves with respect to the mirrors, then, because of the Doppler effect, the frequencies of the "direct" and "opposite" photons received by the molecules will be, respectively,

$$\nu_0 = \nu\left(1 \mp \frac{v}{c}\cos\theta\right) = \nu\left(1 \mp \frac{\sqrt{2}}{2}\,\frac{\Omega R}{c}\right) \tag{9}$$

The molecules along the light path have different velocities; however, it is clear that the projections in the direction of light propagation, which are responsible for the Doppler effect, are equal. For this reason, all molecules of the medium will receive the frequencies (9).

Hence, if we take into account dispersion, the refractive indices for the "direct" and "opposite" photons become, respectively,

$$n^{\pm} = n(\nu_0) = n \mp \frac{\sqrt{2}}{2}\,\frac{\Omega R}{c}\,\nu\,\frac{dn}{d\nu} \tag{10}$$

Obviously, if the medium rotates, according to the well-known formula for the velocity of light in a moving medium (see, for example, Ref. 20), a "direct" photon will return to mirror M before an "opposite" photon with the time anticipation

$$\Delta t_{\mathrm{HF}} = \frac{4d}{c_m^-} - \frac{4d}{c_m^+} = 8\,\frac{\Omega R^2}{c^2}\left(n^2 + \nu\,\frac{dn}{d\nu} - 1\right) \tag{11}$$

Thus, if we rotate the disk with the medium attached to it first at angular velocity Ω_1 and then at angular velocity Ω_2, and if we denote $\Omega = \Omega_2 - \Omega_1$, we obtain for the difference in the light paths the value

$$\Delta_{\mathrm{HF}} = 8\,\frac{\Omega R^2}{c}\left(n^2 - \lambda\frac{dn}{d\lambda} - 1\right) \tag{12}$$

The formula for the Harress–Sagnac experiment is to be obtained from (4) or (5), putting $n = 1$:

$$\Delta t_{\mathrm{HS}} = 8\Omega R^2/c^2 \tag{13}$$

In the Harress–Pogany experiment the time delay with which a "direct" photon returns to mirror M after an "opposite" photon is equal to the difference in the time delays in the Harress–Marinov and Harress–Fizeau experiments. Thus, from formulas (4) and (11), we obtain

$$\Delta t_{\mathrm{HP}} = \Delta t_{\mathrm{HM}} - \Delta t_{\mathrm{HF}} = 8\Omega R^2/c^2 \tag{14}$$

The Harress–Pogany experiment can be immediately explained with the help of our "hitch-hiker" model for light propagation in a medium.[20] Indeed, its effect must be the same as the effect in the Harress–Sagnac experiment because in both of them the "direct" and "opposite" photons cover the same distances in absolute space as "free" photons. Obviously, the time in which both photons are "hitched" on the molecules of the medium are the same, so that in the Harress–Pogany experiment both photons return to mirror M a little bit later (than in the Harress–Sagnac experiment) but with the *same* time delay after each other.

Here we have to emphasize that, when calculating the effects in the Dufour variants of the Harress–Marinov and Harress–Fizeau experiments, one has, even in the limiting case, to take into account that parts of the medium's disk are "cut away." In the Harress–Dufour experiment these parts also produce some effect (there is a Harress–Sagnac effect), while in the Harress–Fizeau–Dufour experiment these parts do not produce any effect. Only after performing the suitable exact calculations can one find the effect in the Harress–Pogany experiment (performed with a medium in the Dufour form) according to formula (14).

We must turn the reader's attention to the fact that in the Harress–Marinov and Harress–Fizeau experiments there is the *same relative motion* between mirrors and medium. However, the results of these two experiments are substantially different because in the Harress–Marinov experiment the medium rests with respect to absolute space, while in the Harress–Fizeau experiment the mirrors rest with respect to absolute space.

For an illustration we note that if the Harress–Marinov experiment is performed at a pole with Ω equal and oppositely directed to the angular diurnal rotational velocity of the Earth, then the Harress–Fizeau experiment would be realized.

3. THE INERTIAL ROTATING DISK EXPERIMENT

The explanation of the rotating disk experiment given by the theory of relativity is full of contradictions. Certain relativists assert that this experiment can be explained only by the apparatus of general relativity because the motion there is not inertial (see, for example, Ref. 21). However, other relativists assert that this can be done also in the frame of special relativity and if one performs suitable calculations, making use of the Lorentz transformation.[22,23]

The mirrors M, M_1, M_2, and M_3 in Fig. 2 move with a normal acceleration when rotating. However, this normal acceleration is *not* decisive for the result of the experiment. Indeed, we propose the following modification of the Harress–Sagnac experiment (called by us the *inertial rotating disk experiment*), which will give the same result and where any noninertial motion is excluded.

Let (Fig. 4) mirrors M_1, M_2, and M_3 be at rest and let the semitransparent mirror S rotate with angular velocity Ω about some center C. We assume that when the semitransparent mirror S is vertical, then, over some small angle α, a "finger" reduces the rotational motion to a translational one with velocity $v = \Omega R$, where R is the radius of the rotational motion of S.

Let a light pulse fall over S and split into "direct" and "opposite" portions. If the semitransparent mirror S is at rest, then a certain interference picture will be observed produced by the "direct" and "opposite" photons after their unification. If now S is put in motion, then the interference picture will change because of the time delay with which the "direct" photons will return to S after the "opposite" photons, and this time delay will be given by formula (13).

Indeed, the time t in which the "direct" and "opposite" photons cover path $4d$ is equal to

$$t = \frac{4d}{c} = 4\sqrt{2}\,\frac{R}{c} \tag{15}$$

In this time the semitransparent mirror S will cover a distance

$$\Delta s = vt = 4\sqrt{2}\,\frac{\Omega R^2}{c} \tag{16}$$

between the positions S′ and S″.

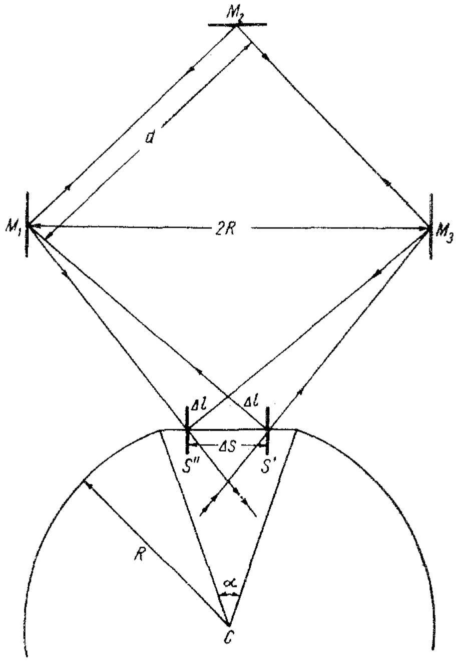

Fig. 4. The inertial rotating disk experiment.

If Δl is the difference between the paths of the "direct" and "opposite" photons when S is in motion and at rest, then the time with which the "direct" photons will come to the semitransparent mirror S after the "opposite" photons will be

$$\Delta t = 2\frac{\Delta l}{c} = \sqrt{2}\,\frac{\Delta s}{c} = 8\,\frac{\Omega R^2}{c^2} \tag{17}$$

4. PRACTICAL PERFORMANCE OF THE HARRESS–MARINOV AND HARRESS–FIZEAU EXPERIMENTS

We have carried out the Harress–Marinov and Harress–Fizeau experiments. Our scheme (Fig. 1) differs somewhat from the traditional scheme (Fig. 2) for the performance of the rotating disk experiment. The first difference consists in the following: In our realization the "direct" and "opposite" light pulses interfere with light pulses that always cover the same path. Thus the illuminations over the photoresistors P_A and P_B change oppositely, and we can use our convenient bridge method described in detail in Ref. 24. The second difference consists in the following: In Fig. 2, mirrors

M_1, M_2, and M_3 are tangent to the circumference of the medium; however, semitransparent mirror M is not tangent and cannot be placed close enough to the medium. In our realization the separation of the photons that will later interfere proceeds first at semitransparent mirror SM and then at semitransparent mirrors SM_A and SM_B, so that instead of mirror M, we have an *effective point of separation M* which can lie close enough to the circumference of the medium. Now, however, we have to take into consideration the difference in the light paths that appears along the contour $SM\text{-}SM_A\text{-}M\text{-}SM_B\text{-}SM$ when the mirrors rotate. Let us calculate the corresponding correction.

Denoting the distance between SM_A and SM_B by b, we obtain for the surface enclosed by this contour

$$S = \frac{b^2}{2}\cot\left(\frac{\pi}{4} + \alpha\right) = b^2\,\frac{(2 - n^2)^{1/2}}{2n} \tag{18}$$

When the mirrors rotate with angular velocity Ω the second photon will rendezvous with the first photon on mirror SM_A with the following additional time anticipation:

$$\Delta t_{\text{add}} = \frac{S\Omega}{c^2} = \frac{\Omega b^2}{c^2}\,\frac{(2 - n^2)^{1/2}}{2n} \tag{19}$$

while the fourth photon will rendezvous with the third photon on mirror SM_B with the same time delay.

Hence in our realization we obtain the following difference in the light paths for the Harress–Marinov experiment:

$$\Delta_{\text{HM}} = 8\,\frac{\Omega R^2}{c}\left(n^2 - \lambda\frac{dn}{d\lambda}\right) - \frac{\Omega b^2}{c}\,\frac{(2 - n^2)^{1/2}}{n} \tag{20}$$

As a medium we have taken distilled water in a metal vessel of the form shown in Fig. 1. Glass windows are put at the points where the light beams must cross the walls of the vessel. Glass windows also are put on the metallic interfaces that divide the square ring into compartments. Taking into account the thickness of the glass plates and their refractive index, we have put the mirrors M_1, M_2, and M_3 at such positions that the real light path (distance multiplied by refractive index) along the contour $M\text{-}M_1\text{-}M_2\text{-}M_3\text{-}M$ is exactly equal to the light path that would be covered if mirrors M_1, M_2, and M_3 had been *immersed* in water.

We have $n = 1.3317$ and $dn/d\lambda = -2.7 \times 10^{-5}\text{nm}^{-1}$, assuming $\delta n = 0$ and $\delta(dn/d\lambda) = 0$, for light of wavelength $\lambda = 632.8\text{nm}$ of the He–He laser used. Also, $R = 30.6 \pm 0.2$ cm and $b = 10.0$ cm, assuming $\delta b = 0$ and taking a large enough error $\delta R = \pm 0.2$ cm, which has to compensate also possible errors introduced in the measurement of the thickness of the glass plates and errors that could appear from the replacement of the real light path by an idealized light path only in water.

We have made the light paths of the first and second photons (as well as of the third and fourth photons) equal. However, since laser light with good coherence is used, this is by no means necessary and the light paths of the first and third photons can be substantially reduced.

The sensitivity of our bridge method is analyzed in more detail in Ref. 24. The maximum sensitivity occurs when the sum at rest of the differences in the light paths of the first and second photons and in the light paths of the third and fourth photons is $(2n + 1)\,\lambda/2$, and is[24] $\delta\Delta = \pm 2.5 \times 10^{-4}\lambda$. When this difference is $n\lambda$, the sensitivity falls to zero. We have not searched for a highest sensitivity by the help of a "tuner," as described in Ref. 24, and we have taken an average sensitivity $\delta\Delta = \pm 10^{-2}\lambda$. The tuner described in Ref. 24 can be used also for calibration during the run. However, in our method, where we change the rotational velocity until $\Delta = c\,\Delta t$ becomes equal to λ, *no* calibration need be made.

The number of revolutions per second of the disk $N = \Omega/2\pi$ is measured by a light stroboscopic cyclometer maintained automatically with precision $\delta N = \pm 0.02$ rev/sec. We rotated the disk first counterclockwise with angular velocity Ω_1 and then clockwise with angular velocity Ω_2, taking $\Omega = \frac{1}{2}(\Omega_1 + \Omega_2)$. We obtained $N = 22.68 \pm 0.04$ rev/sec for the Harress–Marinov experiment and $N = 50.60 \pm 0.04$ rev/sec for the Harress–Fizeau experiment. Putting the numerical values into formulas (20) and (12), we obtain

$$c_{\mathrm{HM}} = (3.01 \pm 0.07) \times 10^8\ \mathrm{m/sec}$$
$$c_{\mathrm{HF}} = (2.97 \pm 0.07) \times 10^8\ \mathrm{m/sec} \qquad (21)$$

where for δc we have taken the maximum measuring error.

The inertial rotating disk experiment can be carried out with our setup shown in Fig. 1 if one attaches only the semitransparent mirrors SM_A and SM_B to the rotating turnabout and leaves all other elements at rest.

5. THE COUPLED-MIRRORS EXPERIMENT

With the help of our deviative[11] and interferometric[12] coupled-mirrors experiments, for the first time in history, we have established the Earth's absolute motion by performing measurements in a laboratory. The Earth's absolute velocity on 12 July is $v = 279 \pm 20$ km/sec and its apex has equatorial coordinates $\alpha = 14^h 24^m \pm 20^m$, $\delta = -26° \pm 4°$. After the performance of this experiment physics has to return to Newtonian conceptions about absolute space–time and to the aether model of light propagation, which have been abondoned in the last 70 years as not corresponding to reality. According to our absolute space–time theory,[25] the unique new element that is to be introduced into the old Newtonian theory is only the *absolute* time dilation (including the axiomatic assumption that the rate of any light clock does not depend on the orientation of its "arm"). Thus the correction that 20th century high-velocity physics makes to classical (Newtonian) physical conceptions is very limited and, in our opinion, is no occasion at all to speak about some radical revolution.

It is interesting to note that the coupled-mirrors experiment is not a result of technological progress in experimental physics, nor of conceptual progress in theoretical physics. We are convinced that the coupled-mirrors experiment could have been performed by Foucault in the middle of the last century, since it represents only a modification of his method for the measurement of light velocity with the help of a rotating mirror.

Thus we are surprised, indeed, that Michelson did not perform the coupled-mirrors experiment and overlooked its magnificent first-order in v/c possibilities. And what should one say about the other generations of physicists coming after him?

Now we shall show that the coupled-mirrors experiment can be considered as a logical result of the rotating disk experiment. However, we shall not speak further about the coupled-mirrors (quasi-Foucault) experiment, but about the "coupled-shutters" (quasi-Fizeau) experiment, because methodologically the latter is simpler.

6. THE COUPLED-SHUTTERS EXPERIMENT

The coupled-shutters experiment represents only a modification of the historic Fizeau experiment for the measurement of the light velocity with the help of a rotating cog-wheel.

The principal scheme of the coupled-shutters experiment (proposed in a different arrangement by Dart[26]) can be seen in Fig. 5: We have two cog-wheels C_1 and C_2 fixed on a common shaft with length d, which is set in rotation by the electromotor EM. Intense light is emitted by the sources S_1 and S_2. After passing through the notches of the cog-wheels C_1 and C_2 (respectively, C_2 and C_1) this light is observed by the observers O_1 and O_2. We shall call the direction from S_1 to O_1 "direct" and that from S_2 to O_2 "opposite."

Suppose that the velocity of light in the direct and opposite directions has the same value, c. If both wheels have the same number of cogs placed respectively against each other (i.e., "cogs against cogs") and they are set in

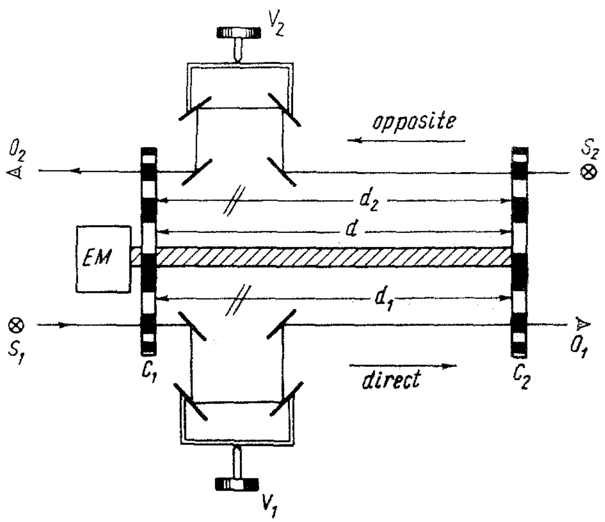

Fig. 5. Rigidly connected coupled shutters.

rotation, then the observers will establish maximum photon fluxes in the case where the distance d between the wheels is covered by light in the same time that the wheels are rotated an integer number of notches. If any of the wheels has p notches and makes N revolutions per second, the wheels will rotate $f = pN$ notches in a second. We call this number f the "frequency of chopping." Obviously the condition for observation of a maximum photon flux can be written $n = (d/c)f$, where n must be an integer.

With the help of the verniers V_1 and V_2 we can change the paths d_1 and d_2 of the light beams between both wheels. If the velocity of light in the direct and opposite directions is the same, then, obviously, O_1 and O_2 will observe maximum (or minimum) photon fluxes when $d_1 = d_2$.

Let us now suppose that the velocity of light is $c - v$ in the direct and $c + v$ in the opposite direction. The conditions for passing of the chopped direct and opposite beams will be

$$n_1 = \frac{d_1}{c - v} f, \qquad n_2 = \frac{d_2}{c + v} f \tag{22}$$

Since maximum photon fluxes can be observed by both observers when $n_1 = n_2$, this can be realized if

$$d_1 = d\left(1 - \frac{v}{c}\right), \qquad d_2 = d\left(1 + \frac{v}{c}\right) \tag{23}$$

or if

$$\Delta d = d_2 - d_1 = 2(d/c)\, v \tag{24}$$

Obviously, if we choose a lower chopping frequency, a longer shaft must be used. It is easy to see that the chopping frequency that can be achieved by a rotating cog-wheel requires a steel shaft so long that practically it cannot be constructed. Indeed, if we want to measure the absolute velocity v within an accuracy δv and we assume that the observers register the presence of light when $(1/n)$th part of the chopped light pulses passes through the "receiving" shutter, then the uncertainty in Δd will be

$$\delta(\Delta d) = 2\frac{1}{n}\frac{c}{2f} = \frac{c}{nf} \tag{25}$$

if both observers should place the verniers V_1 and V_2 in such positions that no light is to be registered by both of them. The factor 2 is taken in the nominator because there are two observers and the duration of the light pulse is one-half the duration of the chopping period. From formulas (24) and (25) we obtain $d = c^2/nf\,\delta v$. Putting $\delta v = 10$ km/sec, $n = 100$, $f = 5 \times 10^5$ Hz (this was the order of the chopping frequency that Fizeau used in the mid-19th century when measuring c), we get $d = 90$ km.

Since such a long steel shaft can not be made, the idea arises of using two independent cog-wheels not fixed on a common shaft but rotating with the same angular velocity.

For the sake of generality, we shall further speak not of two independently rotating cog-wheels but of two independently operating pairs of shutters (say, Kerr cells). Any pair of these shutters (Fig. 6) is driven by a common chopping mechanism, say, two resonators R_A and R_B.

Now the following two problems arise:

(a) How to maintain *equal* chopping frequencies of both pairs of shutters.

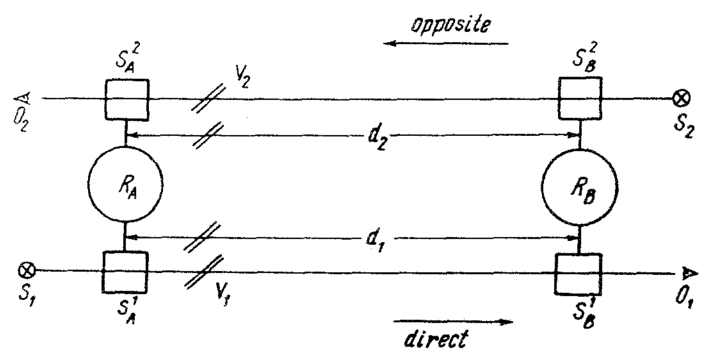

Fig. 6. Independent coupled shutters.

(b) How to maintain a phase difference between them equal to zero, i.e., how to ensure that both pairs of shutters will close and open *together*.

The first difficulty can be overcome if we use the same resonator for both pairs of shutters, which can be put near the shutters S_A, near the shutters S_B, or in the middle. However, if we transmit the signals for opening and closing of the shutters by an electric line, then a phase difference would appear between the pairs. It can be easily shown that the phase difference appearing at the motion of our apparatus in absolute space will exactly cancel the effect that we intend to observe.

Hence the resonators producing the chopping frequency must be independent. We have to take two good atomic clocks that produce the same chopping frequency or whose chopping frequencies are maintained equal, comparing them every now and then. The chopping frequency f_B of the resonator R_B can be maintained equal to the chopping frequency f_A of the resonator R_A if we tune f_B in such a manner that the "beating" of the light spot observed by O_2 will be reduced to zero.

When we use independent shutters, we cannot know the phase difference between them (i.e., we would have to know, when the first pair of shutters is opened, how far from opening is the second pair of shutters). Hence again we cannot measure the absolute velocity v.

However, as Dart has proposed,[26] we can rotate our apparatus with respect to absolute space. When the axis of the apparatus is perpendicular to v, we shall arrange the phase difference between both shutters such that both observers O_1 and O_2 would not see any light. If now the apparatus is put parallel to v, so that the direct direction will coincide with the direction of v, then some light will be seen by the observers; and only if we change the distances d_1 and d_2, with the help of the verniers V_1 and V_2 to give a difference Δd according to formula (24), will no light be left to pass through both pairs of the coupled shutters.

However, taking into account the absolute time dilation defended by our theory,[25] we can easily see that this prediction of Dart will not correspond to reality.[2] Indeed, during the rotation both resonators will move at different velocities with respect to absolute space. Thus their time rates will be different and just such that the new phase difference that will appear after the rotation will *exactly* cancel the effect to be observed if the phase difference after the rotation had remained the same as before the rotation.

To prove this, let us suppose that the axis of the apparatus is first perpendicular to its absolute velocity. Let us then rotate the apparatus with angular velocity ω, say, about the middle point, until the direct direction of

[2] In a letter to the author, dated 5 February 1975, Dart agreed that there are errors in his proposal.

the axis becomes parallel to v. Let the readings of two clocks (suppose, for simplicity, light clocks) attached to R_A and R_B be t_A', t_B' before the rotation and t_A'', t_B'' after the rotation. Let the proper times $t_A = t_A'' - t_A'$, $t_B = t_B'' - t_B'$ correspond to the same absolute time interval t. Because of the absolute time dilation, we have

$$t_A = \int_0^t (1 - v_A^2/c^2)^{1/2}\, dt, \qquad t_B = \int_0^t (1 - v_B^2/c^2)^{1/2}\, dt \tag{26}$$

where

$$\begin{aligned} v_A^2 &= v^2 + (\tfrac{1}{2}d\omega)^2 - vd\omega \cos \omega t \\ v_B^2 &= v^2 + (\tfrac{1}{2}d\omega)^2 + vd\omega \cos \omega t \end{aligned} \tag{27}$$

are the velocities of the resonators during the rotation of the apparatus.

If we work within an accuracy of second order in v/c, we obtain, after performing the integration, putting $\omega t = \pi/2$, and subtracting the second of formulas (26) from the first,

$$\Delta t = t_A - t_B = dv/c^2 \tag{28}$$

This formula shows that if before the rotation the phase difference between both pairs of shutters is equal to zero, then after the rotation the shutter $S_B{}^1$ will open with a delay Δt relative to the shutter $S_A{}^1$, while the shutter $S_A{}^2$ will open with the same anticipation relative to the shutter $S_B{}^2$. Thus for the same light paths, $d_1 = d_2$, minimum photon fluxes will pass through both coupled shutters.

Let us explain more clearly the difference between the independent shutters and the cog-wheels connected by a common rigid shaft. The relation between the absolute time and the proper times elapsed on two clocks moving with velocities v_A and v_B are given by formulas (26) only if these clocks are independent. If we consider both rotating cog-wheels as clocks, we do not have the right to use formulas (26) because the wheels are *rigidly* connected by a common shaft and there is a *unique* clock—the motor driving the shaft, which, if placed at the middle, does not change its velocity during the rotation. Thus, after the rotation, a change in the phase difference between both cog-wheels cannot occur. If such a change would appear, then after the rotation *the shaft must be found twisted*, which, obviously, is nonsensical.

7. CONNECTION BETWEEN THE ROTATING DISK AND COUPLED-MIRRORS EXPERIMENTS

Let us suppose (Fig. 7) that our coupled shutters, representing two cog-wheels fixed on a common shaft driven by the electromotor EM, are

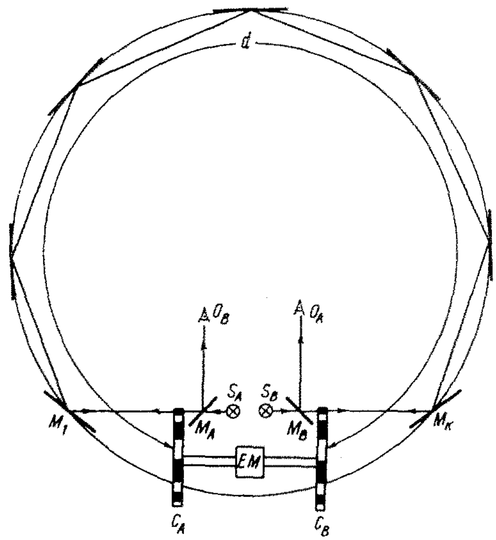

Fig. 7. Coupled shutters mounted on a rotating disk for d near $2\pi R$.

mounted on a rotating disk. Imagine that the distance between the wheels is much less than the circumference of the disk. The direct light beam emitted by the source S_A passes through the semitransparent mirror M_A and, after its chopping by the cog-wheel C_A and reflection by the mirrors M_1 ,..., M_k , arrives at the cog-wheel C_B . If $n = (d/c)f$, where n is an integer, d the path of the direct light beam between the cog-wheels C_A and C_B , and f the chopping frequency, then this chopped beam will pass through the cog-wheel C_B and, being reflected by the semitransparent mirror M_B , will be observed by the observer O_A . The same happens with the opposite light beam.

Let the disk be at rest. If we change the frequency of chopping, the observers O_A and O_B will register together maximum and minimum photon fluxes. However, if we set the disk in rotation, the observer O_A will register a maximum photon flux for the condition[10]

$$\frac{1}{f} n_A = \frac{d}{c} + \int_0^d \frac{\mathbf{v} \cdot d\mathbf{r}}{c^2} = \frac{d}{c}\left(1 + \frac{\Omega R}{c}\right) \tag{29}$$

where R is the radius of the disk, Ω is the angular velocity of rotation, $d\mathbf{r}$ is the differential element of the light path, and we have assumed that the mirrors M_1 ,..., M_k are close to each other, so that we can write $\mathbf{v} \cdot d\mathbf{r} = v\, dr$.

The observer O_B will register a maximum photon flux for

$$n_B = f\frac{d}{c}\left(1 - \frac{\Omega R}{c}\right) \tag{30}$$

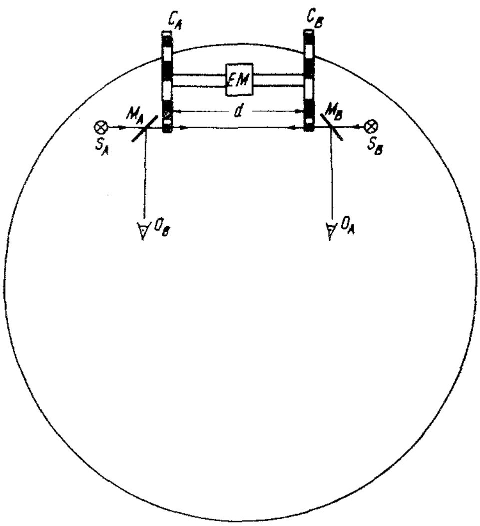

Fig. 8. Coupled shutters mounted on a rotating disk for d much less than $2\pi R$.

Suppose now that the distance d decreases gradually. Formulas (29) and (30), which describe the effect of this disrupted rotating disk experiment, will remain valid. Hence with such a gradually greater and greater disruption we shall come to the situation presented in Fig. 8, where the paths of both light beams are much smaller than the circumference of the disk. Now, for time intervals $t \gg 2\pi R/v = 2\pi/\Omega$ the motion of the coupled shutters can be considered as inertial, and thus we come to the coupled-shutters experiment analyzed in Section 6. Since any component of the Earth's absolute motion —the daily rotation about its axis, the yearly revolution about the Sun, the revolution about the galactic center of mass, etc.—represents some rotational motion, it follows that the coupled-shutters experiment must establish the resultant motion, which, as a matter of fact, we have revealed with the help of our coupled-mirrors experiment.[11,12]

8. CONCLUSIONS

The theoretical analysis and the practical performance of the rotating disk and coupled-mirrors experiments urgently compels the scientific community to recognize the reaccession to the throne of the aether conception and the decline of the principle of relativity. Nevertheless, we must be aware that almost all physical phenomena considered on the one hand in an absolute reference frame and on the other hand in another reference frame that moves inertially with respect to absolute space appear identical. As we have shown in a number of papers, in many of these phenomena *absolute effects do appear*, but they have exactly opposite characters and cancel each other in the final measurable result, so that the principle of relativity is valid there *de jure*. In all experiments where light propagation phenomena do not occur, *absolute effects do not appear at all*, and the principle of relativity is valid *de facto*.

Thus the principle of relativity has a very large realm of validity, but this realm is not infinite. "All pigs are equal, but some pigs are more equal than others," wrote an English novelist in an amusing book. We can say: All intertial frames are equal, but some frames are more equal than others. However, in a contradistinction to the "more equal pigs," which, as experience has shown, are all equally swines, the more equal inertial frame attached to absolute space is the legitimate king of all inertial frames.

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