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 (18.5) from the first,

$$\Delta t = t_A - t_B = \frac{d\,v}{c^2} . \qquad (18.7)$$

This formula shows that if before rotation the « phase difference » between both pairs of shutters is equal to zero, then after rotation the shutter S^1_B will open with a delay Δt relative to the shutter S^1_A, while the shutter S^2_A will open with the same anticipation relative to the shutter S^2_B. 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 rigid shaft. The relations between the absolute time and the proper times elapsed on two clocks moving with velocities v_A and v_B are given by formulas (18.5) only if the clocks are independent. If we consider both rotating cog-wheels as clocks, we do not have the right to use formulas (18.5) 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 appeared, then after the rotation *the shaft would be found to be twisted,* which, obviously, is nonsensical.

Thus the « coupled-shutters » experiment can « work » only when for shutters two cog-wheels fixed on a common shaft are used. In such a case a Newtonian time synchronization is realized, but the axis which one has to use to obtain a registrable effect must be so long that it cannot be practically constructed.

§ 19. THE QUASI-FOUCAULT « COUPLED-MIRRORS » EXPERIMENT

With the aim of shortening the basis in Fizeau's rotating cog-wheel experiment, Foucault developed his rotating mirror experiment. Our « coupled-mirrors » experiment represents a modification of this historical Foucault experiment with whose help for the first time in history we have measured the Earth's absolute velocity.

19.1. THE DEVIATIVE « COUPLED-MIRRORS » EXPERIMENT

In the summer of 1973 we carried out the deviative variant of the « coupled-mirrors » experiment. The report on its performance is given in Marinov (1974b).

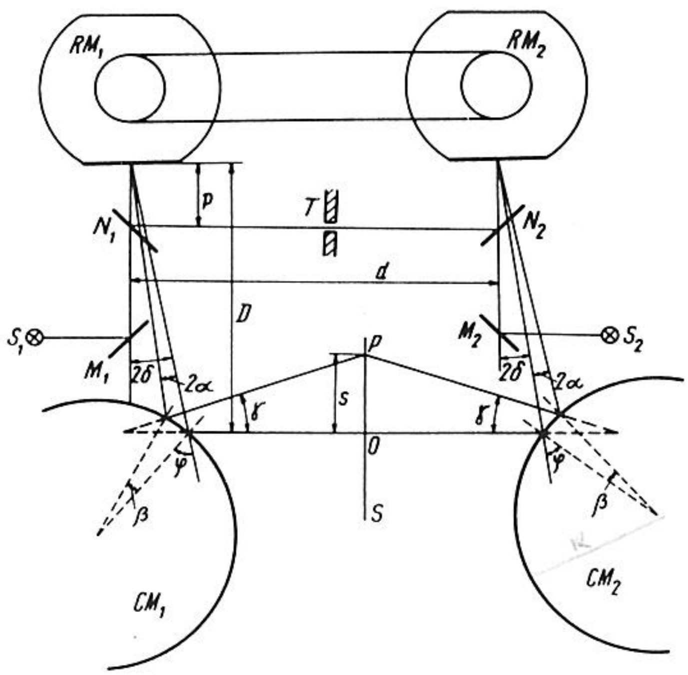

Fig. 19-1

In fig. 19-1 we give the scheme of this experiment. Let us have two disks driven always *exactly* with the same phase difference (imagine the wheels of a bicycle). On each disk two antipodal facets are cut and one is made a mirror, while the other and the rest of the disk's rim are not light reflecting. The distance between both disks, called the rotating mirrors RM_1 and RM_2, is d. Intensive light from the source S_1 (or S_2) is reflected by the semi-transparent mirror M_1 (M_2) and, after passing through the semi-transparent mirror N_1 (N_2), is incident on the mirror facet of RM_1 (RM_2). The light beam then reflected by the semi-transparent mirrors N_1 and N_2 (N_2 and N_1) whose distance from the rotating mirror is p, is incident on the mirror facet of RM_2 (RM_1). If the rotating mirrors are at rest, the light beam reflected by the cylindrical mirror CM_2 (CM_1) will illuminate screen S from the right (from the left) at a certain point. The light path from the rotating mirrors to the cylindrical mirrors is D and from the cylindrical mirrors to the screen is $d/2$.

If the rotating mirrors are set in motion, then, because of the slit T, only the light which is reflected by RM_1 (RM_2) when the latter is perpendicular to the incident beam will reach RM_2 (RM_1). However, for the time spent by light to cover the distance $d + 2p$, the facet of RM_2 (RM_1) which is parallel (an exact parallelism is not necessary !) to the corresponding facet of RM_1 (RM_2) will rotate by a certain angle

$$\delta = \frac{d + 2p}{c} \Omega , \qquad (19.1)$$

where Ω is the angular velocity of the rotating mirrors.

Suppose now that light velocity along the direction from RM_1 to RM_2 (which we call « direct ») is $c - v$ and along the direction from RM_2 to RM_1 (which we call « opposite ») is $c + v$. In such a case during the time in which the light pulse reflected by RM_1 will reach RM_2 the latter will rotate to an angle $\delta + \alpha$, while during the time in which the light pulse reflected by RM_2 will reach RM_1, the latter will rotate to an angle $\delta - \alpha$, and we shall have

$$\delta \pm \alpha = \left(\frac{d}{c \mp v} + \frac{2p}{c} \right) \Omega , \qquad (19.2)$$

from where (assuming $v \ll c$) we get

$$\alpha = \Omega \, d \, v / c^2 . \qquad (19.3)$$

Our apparatus takes part in the diurnal rotation of the Earth and in 24 hours it will make all possible angles with the component of the Earth's absolute velocity in the plane determined by the different positions of the apparatus during the day; this component we shall refer to as the Earth's absolute velocity and designate by v.

Suppose first that the unit vector along the « direct » direction $\boldsymbol{n}$ is perpendicular to $\boldsymbol{v}$, and let us adjust the cylindrical mirrors so that the chopped light beams will illuminate the same point O on the screen S. Now, if $\boldsymbol{n}$ becomes parallel to $\boldsymbol{v}$, both light beams will illuminate point P, and for the distance between O and P we shall have (suppose $\varphi = \pi/4$)

$$s = \gamma \frac{d}{2} + 2 \alpha \, D , \qquad (19.4)$$

where $\gamma = 2 (\alpha + \beta)$ and $\beta = 2 \alpha (D/R) \sec \varphi$; angles β, γ, and φ are shown in fig. 19-1 and R is the radius of the cylindrical mirrors. Thus we have

$$s = \frac{\Omega}{c^2} d^2 v \left[1 + 2 D \left(\frac{1}{d} + \frac{\sec \varphi}{R} \right) \right] . \qquad (19.5)$$

The establishment of velocity v is to be performed as follows : In regular intervals of time during a whole day we maintain such a rotational velocity Ω

that the chopped light beam from the left will always illuminate point O. Then the light beam from the right will illuminate point O when $\boldsymbol{n}$ is perpendicular to $\boldsymbol{v}$; it will be displaced over a distance $2s$ upwards when $\boldsymbol{n} \uparrow\uparrow \boldsymbol{v}$ and over the same distance downwards when $\boldsymbol{n} \uparrow\downarrow \boldsymbol{v}$.

In our factual set-up, both rotating disks were fixed on a common shaft because the most important requirement of the « coupled-mirrors » experiment is the maintaining of an *equal phase difference* between both rotating mirrors during the Earth's rotation. Two He-Ne lasers were used as light sources. We used three cylindrical mirrors for each beam and such a combination of cylindrical mirrors which increases enormously the « arm » of a light beam is called by us the « cylindrical mirrors indicator ». The light spots were observed over two different screens because in our factual experiment both rotating mirrors lay in two different parallel planes. According to the calculation for our real adjustment it must be $s = 0{,}62$ mm for $v = 100$ km/s. This displacement is large enough to be reliably registered. However the inconstancy of the cylindrical mirrors radii and the trembling of the images were too considerable, and our experiment could not lead to an accurate quantitative measurement of v. The observed displacement was maximum 3 ± 2 hours after midnight and after noon and corresponded to a velocity $v = 130 \pm 100$ km/s, the « direct » direction being the one after midnight. The distance between both rotating mirrors was 7,2 m, the radius of the cylindrical mirrors was $R = 8$ cm, and the velocity of rotation of the shaft, taken from an old torpedo-boat, was $\Omega/2\pi = 80$ rev/s. The azimuth of the apparatus was 84° and the observations were performed in July-August in Sofia.

The error $\pm$ 100 km/s was established in the following manner : An observer maintained for 2-3 minutes one of the light spots in a certain position, adjusting by hand a corresponding tension of a *dc* electromotor which drives the shaft. Another observer registered the diapason of trembling of the other light spot which was normally 2-3 mm. If this diapason is $\Delta s = 2.48$ mm, then the fluctuation error is $\pm$ 100 km/s.

19.2. THE INTERFEROMETRIC « COUPLED-MIRRORS » EXPERIMENT

The result obtained with our deviative « coupled-mirrors » experiment was very inaccurate and the scientific community remained sceptical whether we really registered the Earth's absolute motion. For this reason, in the summer of 1975 we carried out the interferometric « coupled-mirrors » experiment, obtaining a very sure and reliable value for the Earth's absolute velocity. The report on its performance is given in Marinov (1978c).

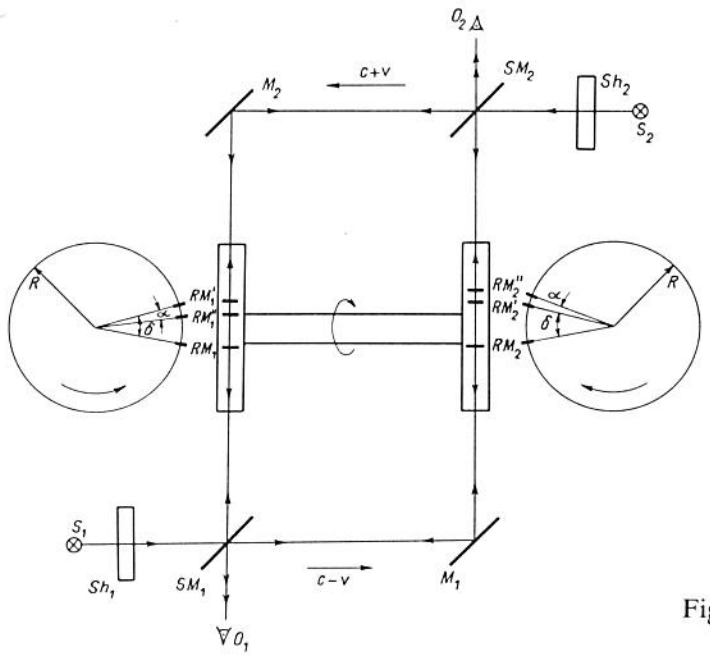

Fig 19-2

Let us have (fig. 19-2) a shaft with length d on whose ends there are two disks with radius R. On the rims of the disks, two mirrors RM_1 and RM_2 are fixed which we call the rotating mirrors. Monochromatic parallel light emitted by the source S_1 (or S_2) is partially reflected and partially refracted by the semi-transparent mirror SM_1 (SM_2). The « refracted » beam is then reflected successively by the mirror M_1 (M_2), by the rotating mirror RM_2 (RM_1), again by M_1, SM_1 (M_2, SM_2), and the observer O_1 (O_2) registers the interference which the « refracted » beam makes with the « reflected » beam, the last one being reflected by the rotating mirror RM_1 (RM_2) and refracted by SM_1 (SM_2). We call the direction from RM_1 to RM_2 « direct » and from RM_2 to RM_1 « opposite ».

Let us now set the shaft in rotation with angular velocity Ω and let us put in action the shutters Sh_1 and Sh_2 which should allow light to pass through them only when the rotating mirrors RM_1 and RM_2 are perpendicular to the incident beams. This synchronization is performed by making the opening of the shutters ($\cong 10^{-6}$ s) to be governed by the rotating shaft itself. Instead of shutters, we also used simple slits placed along the light paths to the rotating mirrors. If the « reflected » light pulse reaches RM_1 (RM_2) when the second mirror is in the position RM_2 (RM_1), then, in the case of rotating shaft, the « refracted » pulse will reach the second rotating mirror in the position RM_2' (RM_1') when the velocity of light is equal to c, and in the position RM_2''

(RM_1'') when the velocity of light is equal to $c - v$ ($c + v$). Denoting by δ the angle between the radii of RM_2 and RM_2' (RM_1 and RM_1') and by α the angle between the radii of RM_2' and RM_2'' (RM_1' and RM_1''), we shall have

$$\delta \pm \alpha = \frac{d}{c \mp v} \Omega , \qquad (19.6)$$

from where (assuming $v \ll c$) we get the result (19.3).

The difference in the optical paths of the « refracted » and « reflected » light pulses in the cases of availability and non-availability of an « aether wind » will be

$$\Delta = 2 \alpha R = 2 \frac{d R \Omega}{c^2} v = 2 d \frac{v_r v}{c^2} , \qquad (19.7)$$

where v_r is the linear velocity of the rotating mirrors.

If the wavelength of the used light is λ and we maintain such an angular velocity $\Omega = 2 \pi N$ (N is the number of revolutions per second) that the observer O_2 should always register the same interference picture, then, during the rotation of the apparatus over 360° in a plane parallel to the direction of the absolute velocity v, the observer O_1 should register a change in his interference picture within

$$z = 2 \frac{\Delta}{\lambda} = 8 \pi \frac{d R N}{\lambda c^2} v \qquad (19.8)$$

wavelengths.

In our factual set-up, the « direct » beams are tangent to the *upper* parts of the rotating disks, while the « opposite » light beams are tangent to their *lower* parts. Thus the reflection of the « direct » and « opposite » beams proceeds on the same planes of the mirrors. The « observers » in our factual set-up represent two photoresistors which are put in the « arms » of a Wheatstone bridge. The changes in both interference pictures are *exactly opposite*. Thus in our apparatus the mirrors RM_1 and RM_2 are exactly parallel and the photoresistors are illuminated *not* by a pattern of interference fringes but *uniformly*.

A very important difference between the deviative and interferometric « coupled-mirrors » experiments is that the effect registered in the latter is *independent* of small variations in the rotational velocity. In the interferometric variant one *need not* keep the illumination over one of the photoresistors constant by changing the velocity of rotation when rotating the axis of the apparatus about the direction of its absolute motion, but need merely to register the *difference* in the illuminations over the photoresistors during the rotation. This (together with the high resolution of the interferometric method) is the most important advantage of the interferometric « coupled-mirrors » experiment.

Since the illumination over the photoresistors changes with the change of the difference in the optical paths of the « refracted » and « reflected » beams according to the sine law, then the apparatus has the highest sensitivity when the illumination over the photoresistors is average (for maximum and minimum illuminations the sensitivity falls to zero). Hence a change in the velocity of rotation can lead only to a change in the sensitivity.

Let us consider this problem in detail. We suppose that the electric intensities of the « reflected » and « refracted » beams when they meet again on the semi-transparent mirror SM_1 (or SM_2) are, respectively,

$$E_1 = E_{max} \sin(\omega t), \qquad E_2 = E_{max} \sin(\omega t + \varphi), \tag{19.9}$$

where E_{max} is the maximum electric intensity which is equal for both beams, ω is the angular frequency of the radiation and φ is the difference between the phases of the intensities in the « reflected » and « refracted » beams.

The resultant electric intensity after the interference will be

$$E = E_1 + E_2 = 2 E_{max} \sin(\omega t + \frac{\varphi}{2}) \cos \frac{\varphi}{2} = E_{ampl} \sin(\omega t + \frac{\varphi}{2}), \tag{19.10}$$

where $E_{ampl} = 2 E_{max} \cos(\varphi/2)$ is the maximum electric intensity (the amplitude) of the resultant beam.

The energy flux density which will fall on the photoresistors will be

$$I = \frac{c}{8\pi} E^2_{ampl} = \frac{c}{2\pi} E^2_{max} \cos^2 \frac{\varphi}{2} = I_{max} \cos^2 \frac{\varphi}{2} = \frac{I_{max}}{2} (1 + \cos\varphi), \tag{19.11}$$

where I_{max} is the maximum possible energy flux density.

The sensitivity is

$$\frac{dI}{d\varphi} = - \frac{I_{max}}{2} \sin\varphi \tag{19.12}$$

and is highest for $\varphi = \pi/2, 3\pi/2$, i.e., when the difference in the optical paths of the « reflected » and « refracted » beams is $(2n + 1)(\lambda/4)$, n being an integer. The sensitivity falls to zero for $\varphi = 0, \pi$, i.e., when this difference is $n(\lambda/2)$.

If the resistance of the photoresistors changes *linearly* with the change in the illumination (as was the case in our set-up), then to a small change dI in the energy flux density a change

$$dR = k\, dI = -k \frac{I_{max}}{2} \sin\varphi \, d\varphi \tag{19.13}$$

in the resistance of the photoresistors will correspond, k being a constant. For a change $\Delta\varphi = \pi$ the resistance will change with $R = -k\, I_{max}$, as it follows after the integration of (19.13).

Since it is $\Delta\varphi = 2\pi\Delta/\lambda$, then *for* $\varphi = \pi/2$, where the sensitivity is the highest, we shall have

$$\frac{\Delta R}{R} = \pi \frac{\Delta}{\lambda} . \qquad (19.14)$$

Substituting this into (19.8), we obtain

$$v = \frac{\lambda c^2}{4\pi^2 d R N} \frac{\Delta R}{R} . \qquad (19.15)$$

The measuring method is : First, we make the axis of the apparatus to be perpendicular to the absolute velocity v of the laboratory. We set such a rotational rate N_1 that the illumination over the photoresistors to be minimum. Let us denote the resistance of the photoresistors under such a condition by R_1 and R_2 (it must be $R_1 = R_2$). We put the same constant resistances in the other two arms of the bridge, so that the same current J_0 (called the initial current) will flow through the arms of the photoresistors, as well as through the arms of the constant resistors, and no current will flow through the galvanometer in the bridge's diagonal. Then we set such a rotational rate N_2 that the illumination over the photoresistors is maximum and we connect in series with them two variable resistors, R, so that again the intial current, J_0, has to flow through all arms of the bridge. After that we make the illumination average, setting a rotational rate $N = (N_1 + N_2)/2$, and we diminish correspondingly the variable resistors, R, so that again the same initial current has to flow through all arms of the bridge and no current through the diagonal galvanometer. Now, we make the axis of the apparatus parallel to the absolute velocity v and we transfer resistance ΔR from the arm where the illumination over the photoresistor has decreased to the arm where it has increased, so again the same initial current will flow through all arms and no current through the diagonal galvanometer. The absolute velocity is to be calculated from (19.15).

When the illuminations over the photoresistors were average a change $\delta R = 8.10^{-4} R$ in any of the arms of the photoresistors (positive in the one and negative in the other) could be discerned from the fluctuation of the bridge's galvanometer and thus the resolution was

$$\delta v = \frac{\lambda c^2}{4\pi^2 d R N} \frac{\delta R}{R} = \pm\ 17 \text{ km/s} . \qquad (19.16)$$

The errors which can be introduced from the imprecise values of $d = 140$ cm, $R = 40{,}0$ cm, and $N = 120$ rev/s are substantially smaller than the resolution and can be ignored. To guarantee sufficient certainty we take $\delta v = \pm 20$ km/s.

The experiment was not performed in vacuum.

The room was not temperature-controlled, but it is easy to see that thermic disturbances cannot introduce errors because of the complete *symmetry* of the method and of its rapid performance.

The whole apparatus is mounted on a platform which can rotate in the horizontal plane and the measurement can be performed in a couple of seconds.

The magnitude and the apex of the Earth's absolute velocity have been established as follows :

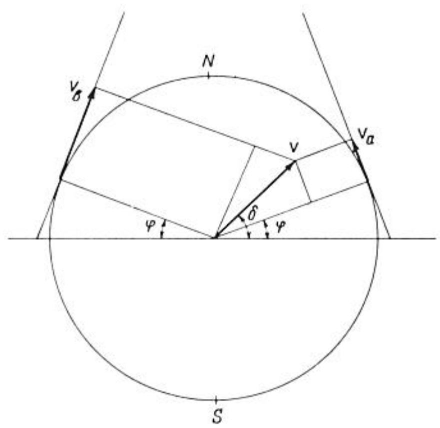

Fig. 19-3

During a whole day we search for the moment when the Wheatstone bridge is in equilibrium if the axis of the apparatus points east-west. At this moment the Earth's absolute velocity lies in the plane of the laboratory's meridian. Thus turning the axis of the apparatus north-south, we can measure v in the horizontal plane of the laboratory. The same is to be made after 12 hours. As can be seen from fig. 19-3, the components of the Earth's absolute velocity in the horizontal plane of the laboratory for these two moments are

$$v_a = v \sin(\delta - \varphi), \qquad v_b = v \sin(\delta + \varphi), \tag{19.17}$$

where φ is the latitude of the laboratory and δ is the declination of the apex. From these we obtain

$$v = \frac{[v_a^2 + v_b^2 - 2 v_a v_b (\cos^2\varphi - \sin^2\varphi)]^{1/2}}{2 \sin\varphi \cos\varphi},$$

$$\tan\delta = \frac{v_b + v_a}{v_b - v_a} \tan\varphi . \qquad (19.18)$$

We take v_a and v_b as positive when they point to the north and as negative when they point to the south. Obviously, the apex of the absolute velocity points to the meridian of this component whose *algebraic* value is smaller. Thus we shall always assume $v_a < v_b$ and then the right ascension α of the apex will be equal to the local sideral time of registration of v_a. We could establish this moment within a precision of about 30 minutes. Thus we can calculate (with an inaccuracy not larger than $\pm$ 5 min) the sideral time t_{si} for the meridian where the local time is the same as the standard time t_{st} of registration, taking into account that sideral time at a middle midnight is as follows :

22 September	— 0^h	23 March	— 12^h
22 October	— 2^h	23 April	— 14^h
22 November	— 4^h	23 May	— 16^h
22 December	— 6^h	22 June	— 18^h
21 January	— 8^h	23 July	— 20^h
21 February	— 10^h	22 August	— 22^h

Our first measurement of the Earth's absolute velocity by the help of the interferometric « coupled-mirrors » experiment was performed on 12 July 1975 in Sofia ($\varphi = 42°41'$, $\lambda = 23°21'$). We registered

$$v_a = -260 \pm 20 \text{ km/s}, \qquad (t_{st})_a = 18^h\,37^m \pm 15^m,$$
$$v_b = +\ 80 \pm 20 \text{ km/s}, \qquad (t_{st})_b = 6^h\,31^m \pm 15^m. \qquad (19.19)$$

Thus

$$v = 279 \pm 20 \text{ km/s},$$

$$\delta = -26° \pm 4°, \qquad \alpha = (t_{si})_a = 14^h\,23^m \pm 20^m. \qquad (19.20)$$

We repeated the measurement exactly six months later on 11 January 1976 when the Earth's rotational velocity about the Sun was oppositely directed. We registered

$$v_a = -293 \pm 20 \text{ km/s}, \qquad (t_{st})_a = 6^h\,24^m \pm 15^m,$$
$$v_b = +121 \pm 20 \text{ km/s}, \qquad (t_{st})_b = 18^h\,23^m \pm 15^m. \qquad (19.21)$$

Thus

$$v = 327 \pm 20 \text{ km/s},$$

$$\delta = -21^{\circ} \pm 4^{\circ}, \qquad \alpha = (t_{si})_a = 14^h\, 11^m \pm 20^m. \qquad (19.22)$$

For v and δ we have taken the r.m.s. error, supposing for simplicity $\varphi \cong 45^{\circ}$. The right ascension is calculated from the moment when v_a is registered, i.e., from $(t_{st})_a$, since for this case ($|v_a| > |v_b|$) the sensitivity is better. If our experiment is accurate enough, then t_{st} which is taken as the second must differ with $11^h\, 58^m$ from t_{st} which is taken as the first, because of the difference between solar and sideral days.

The magnitude and the equatorial coordinates of the apex of the Sun's absolute velocity will be given by the arithmetical means of the figures obtained for the Earth's absolute velocity in July and January :

$$v = 303 \pm 20 \text{ km/s},$$

$$\delta = -22^{\circ},5 \pm 4^{\circ}, \qquad \alpha = 14^h\, 17^m \pm 20^m. \qquad (19.23)$$

§ 20. THE ACCELERATED « COUPLED-MIRRORS » EXPERIMENT

Since the masses of the material points are a measure of their kinetic energy as well as of the gravitational energy to which they contribute, the so-called **principle of equivalence** can be formulated, this asserts : Any gravitational field in a small region around a given space point can be replaced by a suitable non-inertial frame of reference (and *vice versa*), so that the behaviour of material points in an inertial frame of reference in the presence of a gravitational field would be indistinguishable from their behaviour in a suitable non-inertial frame without the gravitational field.

Einstein generalized and made absolute this « mechanical » (or Galilean) principle of equivalence (as he has done with the Galilean principle of relativity — see §21), postulating that it is by no means possible to establish whether the acceleration which is exerted on material points in a laboratory has a kinematic (mechanic) character (thus being due to the accelerated motion of the laboratory, for example, by thrust of a space ship) or a dynamic (gravitational) character (thus being generated by the action of nearby masses, for example, by the Earth's attraction).

According to our absolute space-time conceptions, such a generalization of the principle of equivalence contradicts physical reality. The accelerated « coupled-mirrors » experiment proposed in Marinov (1978t) can immediately reveal the invalidity of Einstein's principle of equivalence. Its essence is as follows :