ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E2-97-233

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NATURE OF RELATIVISTIC EFFECTS AND DELAYED CLOCK SYNCHRONIZATION

Submitted to the Proceedings of the International Conference «Relativistic Physics and Some Its Applications», June 1997, Athens, Greece

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1997

1 Introduction

As it is known, at present there are two principally different views on the nature of relativistic effects. A part of physicists, following Poincaré and Lorentz, consider them as a consequence of deformations experienced by bodies moving relative to the preferred (ether) reference frame. Other physicists, like Einstein, consider these effects as a pure kinematic consequence of the simultaneity in moving and motionless frames.

Our aim is to try to distinguish these two viewpoints observing a possible change of an interference of an incoming and the refracted laser rays depending on the reference frame velocity.

Einsteinean theory says that such a dependence is not to be present since otherwise one would be able to discover the fact of an inertial motion being inside a isolated system. However, from the viewpoint of those who share the Lorentz's idea about the existance of some preferred reference frame, in the considered experiment one can measure an interference fringe displacement owing to a time delay in the process of the ray refraction.

In addition, one more question remains undecided. The special relativity is based on the purely classical principle of the time synchronization which, in one's turn, assumes an instantaneous, without any delay, reflection of the sent signal. At first sight we encouter here a contradiction with the fact of a finite duration of excitation and deexcitation processes of atoms inside mirrors due to which the refraction is realized. Nevertheless, we shall show that the known Lorentz transformations conserve their form even if the time delay is explicitly taken into account.

In the next Section the interference experiment and its results are described. Sect. 3 is devoted to a theoretical consideration of the Lorentz transformations with a time delay. In Sect. 4 we discuss the results.

2 Experiment with the delayed refraction

Now our goal is to check up the velocity dependence of an interference of two laser rays. The principal idea of such a check-up can be explained by the following gedanken experiment. Let as imagine two parallel coherent light beams in a reference frame moving with a velocity v. One of these beams gets immediately into an interferometer but the other beam encountering a mirror is absorbed, i. e. is detained for a some time t_0 and then is emitted into the interferometer. If the Lorentz's idea on the preferred reference frame is true, than turning the plate where a light beam source and the interferometer are located perpendicularly to the frame velocity vector v will results in a relative phase shift of light beams φ and, therefore, the fringes in the interferometer will be displaced.

According to the Lorentz's idea the light velocity in the moving frame is $c+v$, so the times during which two mentioned above rays run from their common source up to the interferometer

$$t_1 = x/(c+v), \quad t_2 = t_0 + (x - v\tau)/(c+v) \qquad (1),$$

and the corresponding time delay $\tau = t_2 - t_1$. In the case of the perpendicular disposition of the installation

$$t_1{}' = x/c, \quad t_2{}' = t_0 + x/c \qquad (2)$$

with the delay $\tau' = t_2{}' - t_1{}'$.

The time difference, determining the interference picture changes in the process of the transition from an initial disposition to the perpendicular one, is

$$\Delta\tau = \tau' - \tau = vt_0/(v+c) \simeq t_0\beta \qquad (3)$$

with the exactness to within quadratic terms $\sim \beta^2 = (v/c)^2$ stipulated by the Lorentz contraction of lenghses. Unlike the well known Michelson-Morley and other measurements, where the developments of light in two opposite directions compensate any linear terms, in the considered experiment with a single-directed light development these terms are conserved and can be investigated.

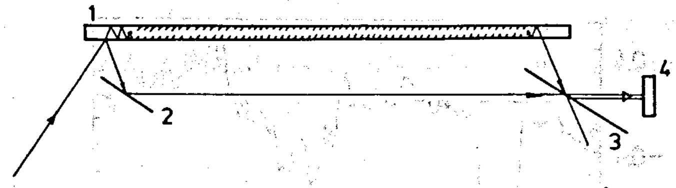

Figure 1: Scheme of the interference experiment. 1 — plate-parallel slab, 2 and 3 — mirrors, 4 — photodetector.

The corresponding phase shift of sinusoidal light waves

$$\varphi = \pi v \Delta\tau/\lambda, \qquad (4)$$

creates the fringe displacement in photodetector

$$\Delta\ell = \varphi\lambda/2\pi. \qquad (5)$$

Measuring this displacement we may get

$$\Delta\tau = \varphi\lambda/v = 2\pi\Delta\ell/v \qquad (6)$$

and the time delay

$$t_0 \simeq \Delta\tau/\beta = 2\pi\Delta\ell/\beta^2 c. \qquad (7)$$

The real experiment differs from the considered one only by the substitution of a mirror for a Mach-Zander interferometer with 125-multiple reflections of the light beam between two plane-parallel silvered plates (see Fig. 1) what allows to enlarge essentially the time delay. The fringe displacement is recorded by a photodetector and the results are accumulated in a computer. To lower a random noise level all details placing on a turning plate are pasted after a process of correction to this plate which, in one's turn, is appended to a massive base plate by means of a small-area contact. As a transfer velocity v we exploited the Earth velocity ($\simeq 300 km/s$).

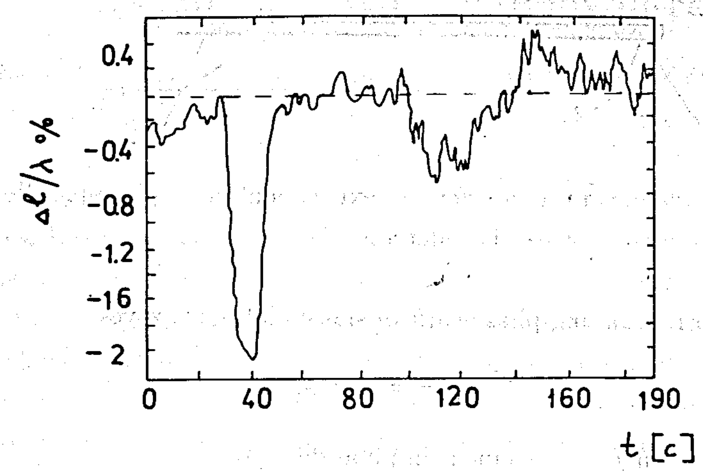

Figure 2: Displacement of the interference fringes $\Delta\ell/\lambda$ as a function of time.

The arrangement is calibrated by means of the introducing of a plate-parallel slab with the precisely known thickness and the refraction coefficient, i. e. producing known time delay, into the free arm of the interferometer (the low arm in Fig. 1). In Fig. 2 where the results of our measurement are plotted, one can see such a calibration peak corresponding to the interference fringe displacement $\Delta\ell/\lambda = 0.02$ (in the case $\lambda = 63\mathring{A}$).

In Fig. 2 the 360°-turning of the arrangement corresponds to the time interval $\Delta t = [90s, 190s]$ inside which $\delta\ell/\lambda = 0 \pm 0.006$, i. e. $t_O = (0 \pm 3.6)10^{-17}s$ [1]. The observed oscillations of $\Delta\ell/\lambda$ are errors due to small deformations of the turning plate. The corresponding error Δt_0 is much smaller than the duration of light refraction from metal mirror $t_0 \sim 10^{-14}s$ measured in direct experiments [(1)], and this fact allows

[1] We took into account that t_0 in (7) must be devided by the number of refractions inside the interferometr $n = 125$.

to claim that the Lorentz's hypothesis about existence of a preferred reference frame and the dependence of light velocity on the frame speed v is wrong.

1 Delayed synchronization of clocks

The Einsteinean synchronization method assumes that if at the time instant t_1 any observer sends a light signal towards some event and the signal after a reflection at the position of the event comes back to the same observer at the instant of time t_2 then the clock located at the event at the moment of the refraction should show up the time instant t which satisfies the following synchronization condition

$$c(t - t_1) = c(t_2 - t) \tag{8}$$

where c is the vacuum light velocity. Such an assumption is quite clear in the domain of macroscopic physics but needs an additional discussion on the microscopic level.

To simulate the excitation and the subsequent deexcitation of atomic processes close to the mirror surface we modify the Einsteinean synchronization condition into the form

$$c(t - t_1) = ct(t_2 - t - \tau) \tag{9}$$

where τ is the delay time which is the macroscopic parameter due to quantum phenomena in the mirror [2]. From this condition we get the

[2] It should be noted that the customary relativistic energy-momentum relation considered usually as the most evident test of applicability of the Einsteinean theory of relativity to microscopic processes is not changed for the considered more general synchronization procedure. The modification introduced by the condition (9) is some kind of additional translations whose do not influence the definition of four-vectors because in this definition only the homogeneous part of space-time transformations is involved. The energy-momentum four vector P_μ has therefore exactly the same properties as in theories with the customary Einstein time synchronization

synchronized time

$$t = (t_2 + t_1 - \tau)/2 \tag{10}$$

and the distance to the event

$$x = c(t_2 - t_1 - \tau)/2. \tag{11}$$

Another observer operating with times t'_1 and t'_2 to synchronize clocks and to compute distances ascribes to the same event co-ordinates

$$t' = (t'_2 + t'_1 - \tau')/2 \tag{12}$$

and

$$x' = c(t'_2 - t'_1 - \tau')/2 \tag{13}$$

where the same invariant light velocity c is present and other delay time τ' is used since this quantity does not to be the same for all observers.

The relations between times used by different observers are given by Lorentz transformations

$$t'_1 = \lambda t_1, \quad t'_2 = \lambda^{-1} t_2 \tag{14}$$

where λ is a dimensionless parameter determined by the relation between the observers in question. The transformation rules (14) are the same as in the usual Einsteinean synchronization because they are characteristics of the light frequencies and are therefore independent on the interaction of light with the matter of the mirrors.

The relations (14) can be rewritten in terms of the space-time co-ordinates as

$$x' = \left[(\lambda^2 + 1)x - c(\lambda^2 - 1)t + \lambda\tau' - \tau\right]/2\lambda, \tag{15}$$

$$t' = \left[(\lambda^2 + 1)t - (\lambda^2 - 1)(x/c) + \lambda\tau' - \tau\right]/2\lambda. \tag{16}$$

These formulae coincide with the standard Lorentz transformations if the delay time transforms also according to the Lorentz rule as the times t_i:

$$\tau' = \lambda^{-1}\tau = [(1-\beta)/(1+\beta]^{-1/2}\tau = \gamma(1 - v/c)\tau = \gamma(\tau - \chi/c), \tag{17}$$

where $\gamma = (1 - v^2/c^2)^{-1/2}$, $\chi = v\tau$, v is the velocity of the moving observer.

So, we see that the delayed synchronization of clocks doesn't disturb the known form of the Lorentz transformations.

2 Concluding remarks

The obtained above results convince in the impossibility to link any singled-out reference frame with vacuum. In its uniformity there is nothing, neither kinematic nor dynamic, peculiarities which can be used as an "anchor" for such a frame. Nevertheless, the concept of vacuum cannot be completely waived, as it was proposed by Einstein. The both experiment and quantum theory prove that it is a specific material media though all attempts to decribe it in modern notions encounter a great number of contradictions. Construction of an edequate theory of vacuum is now the main problem of physics.

We should like to stress also that althought the Einsteinean synchronization of time doesn't contradict any known experimental data, it is a macroscopic procedure. At small space-time intervals Δx and Δt the concept of vacuum is incomprehensible. It is not clear also, in what a sense one can speak about lenghses inside elementary particles where the modern interpretation of form-factors describing the particle internal structure encounters difficulties and the usual image of an extended particle all spatial points of which have the same time t becomes relativistic non-invariant [(2)].

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Received by Publishing Department on July 24, 1997.