FROM CURRENT LITERATURE

EXPERIMENTAL VERIFICATION OF THE POSTULATES OF THE SPECIAL THEORY OF RELATIVITY

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As is well known [1], the special theory of relativity is based on two postulates—on the postulate (principle) of relativity and on the postulate of the independence of the velocity of light of the velocity of the source of the radiation. The experimental verification of the first postulate, starting with the Michelson-Morley experiment, has been carried out with ever increasing accuracy in numerous experiments which have proved the nonexistence of a privileged reference system for electromagnetic phenomena [2]. At the same time, until very recently there have been no sufficiently reliable experiments verifying the second postulate [3-5]. A recent result of Kantor's experiment [6] which cast some doubt on the second postulate has increased the general interest in providing an experimental basis for this postulate. All this has led to the result that lately there has appeared a number of experimental papers [3,7-10] in which the fact that the velocity of light is independent of the velocity of the source of radiation has been checked by various methods. Among these investigations only one [3] has utilized an extraterrestrial source of radiation. In it values of the velocity of light emitted by different equatorial edges of the sun's disc were compared by a phase method. A statistical treatment of the results of observations led to complete agreement with the second postulate.

However, it should be noted that results of experiments with extraterrestrial sources of radiation encounter difficulties of interpretation due to the interaction of light with the medium situated between the source and the point of observation [5]. The same is also true of experiments carried out under terrestrial conditions when light is propagated through air as, for example, in the case of Kantor's experiment. We shall discuss this experiment which has attracted widespread attention.

In this experiment a comparison was made of the optical path lengths of two light beams passing through thin glass plates mounted on a rotating disc. The direction of propagation of one of the beams coincided with the direction of motion of the plates, while the other beam was propagated in the opposite direction. As a result of the motion of the glass plates an interference shift of 0.5 fringe was observed which was interpreted by the author as a violation of the validity of the second postulate. A number of authors [11-15] gave different explanations of this result within the framework of Einstein's theory, but in subsequent similar experiments [7,8] the shift of interference fringes noted above was not observed at all. Thus, it was established that the shift of interference fringes observed by Kantor had no direct bearing on the second postulate.

In addition to the experiments referred to above it appeared to be of interest to carry out independent experiments which do not utilize the interference properties of light. Two such experiments have been carried out recently. In one of them [9] use was made of the method of measuring the time of flight of γ quanta emitted by moving and by stationary nuclei, while in the other one [10] use was made of annihilation of positrons and electrons in flight.

In the experiment on the measurement of the time of flight of γ quanta the moving source of radiation was the excited nucleus C^{*12}, obtained as a result of the inelastic scattering of α particles in the reaction $C^{12}(\alpha, \alpha')C^{*12}$. The lifetime of the excited state (4.43 Mev) of C^{*12} is equal to 6.5×10^{-14} sec, and the nucleus has time to emit a γ quantum before it comes to rest (after scattering the α particle the C^{*12} nucleus has a recoil velocity). The stationary source in this experiment was the O^{*16} nucleus (the 6.13-Mev level) obtained in the analogous reaction $O^{16}(\alpha, \alpha')O^{*16}$. The lifetime of this nucleus in the excited state is equal to 1.2×10^{-11} sec, and the nucleus has time to come to rest before emitting the γ quantum. Measurements of the Doppler shift have shown that at the moment of emission the C^{*12} nucleus has on the average a velocity equal to $(1.8 \pm 0.2) \times 10^{-2}c$, where c is the velocity of light in vacuo, while the velocity of the O^{*16} nucleus at the moment of emission is on the average actually equal to zero.

In the experiment under discussion a periodic sequence of pulses consisting of α particles coming from a cyclotron was made to fall on two targets situated along the direction of motion of the α-particle beam. The distance between the targets one of which contained C^{12} nuclei, and the other one O^{16} nuclei was equal to 30 cm.

The resultant sequence of pulses of γ quanta was recorded by a detector situated at a distance of ~ 5 m from the targets close to the axis of the α-particle beam. If the time interval between the recorded pulses of γ-quanta coming from both targets is denoted by τ_1 in the case when the α-particles first fall on the target containing C^{12} nuclei, while the same time interval is denoted by τ_2 in the case when the targets have been interchanged, then in accordance with the second postulate the relation $\Delta\tau = \tau_1 - \tau_2 = 0$ should hold. If the velocity of light and the velocity of the source were additive, then in such a case $\Delta\tau$ would have been equal to 0.5×10^{-9} sec. However, preliminary results of the experiment have shown that $\Delta\tau = (-0.2 \pm 0.2) \times 10^{-9}$ sec. Thus, this experiment has verified the second postulate.

In another experiment utilizing the annihilation of positrons in flight the velocity of the source emitting the γ quanta coincided with that of the center of mass of the electron and the positron. The electron-positron annihilation with the emission of two γ quanta took place in a thin plate of organic glass (cf., diagram). Two detectors recording the two γ

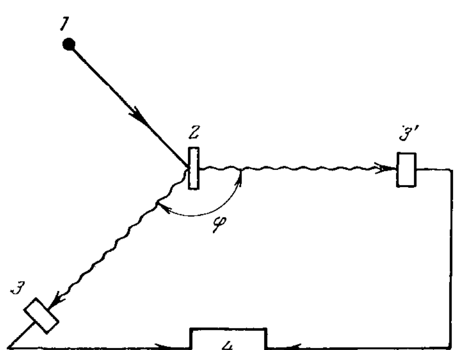

Diagram of experiment utilizing annihilation in flight. 1 – Positron source (Cu^{64}); 2 – plate of organic glass; 3, 3′ – detectors of γ quanta; 4 – coincidence circuit.

quanta were placed at the same distance from the plate. In the center of mass system the two γ quanta are emitted in opposite directions ($\varphi = 180°$). In the laboratory coordinate system this angle will be less than 180°, while the directions of emission of the two γ quanta will, generally speaking, be asymmetric with respect to the direction of motion of the positrons.

In this experiment the times of flight of the two γ quanta were compared (by a coincidence method) in two cases: in cases of annihilation at rest and in flight. In the case of annihilation at rest the detectors of radiation and the point of annihilation were situated along the same straight line ($\varphi = 180°$). In the case of annihilation in flight the components of the vector velocity of the source of radiation (the center of mass of the electron and the positron) along the directions of motion of the two γ quanta were not equal to one another, and if the velocities of the source and of the γ quanta were additive this could have led to unequal times of flight for the two γ quanta. However, measurements have shown that with an accuracy of up to 10% the times of flight, and consequently the velocities of the γ quanta, turned out to be equal for all the angles of emission that were investigated in complete agreement with the second postulate of the special theory of relativity.

A further increase in accuracy in similar experiments can be attained by increasing the velocity of the source of radiation, for example, by utilizing the decay of π^0 mesons into two γ quanta [16]. Such an increase in experimental accuracy would be desirable considering the important role played by the second postulate not only in the special theory of relativity, but also in the general theory since the fact that the velocity of light is independent of the velocity of the source of radiation is assumed also in the general theory of relativity (cf. [17]).

As regards the accuracy with which the first postulate has been verified, recently utilization of beats between two identical masers with molecular beams directed oppositely[18] and at right angles [19] to one another has made it possible to establish that the velocity of the "ether" with respect to the earth cannot exceed 30 m/sec (0.001 of the earth's orbital velocity). This result is by a factor of 45 more accurate than previous experiments of the Michelson-Morley type [20]. An even greater accuracy can be attained in experiments utilizing the Mössbauer effect [2,21].

Thus, in spite of ever increasing accuracy all the experiments available at the present time confirm both postulates of the special theory of relativity.

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