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ON THE MEASUREMENT OF THE VELOCITY OF LIGHT EMITTED BY AN ULTRARELATIVISTIC SOURCE

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By analytical calculations it has been shown that in papers on the measurement of the velocity of light published in 2011 in the journals Uspekhi Fizicheskikh Nauk [Physics–Uspekhi] and Pis'ma v ZhETF [JRTP Letters], in actual fact the velocity of a light pulse from a relativistic clot of electrons was not measured. All that was done was to compare the velocity of light emitted by an ultrarelativistic source with the velocity of light from a fixed source, i.e., both in the first and second variants (one independent quantity was compared with another), in essence, it was simply postulated. In the first variant a glass plate was used as the fixed light source, and in the second variants, a synchrotron pulse was used as the reference signal. The velocity of light was calculated using a calculated time based on the postulate of the special theory of relativity (STR) on the invariance of the velocity of light. This, of course, contradicts the Newton–Ritz hypothesis on ballistic addition of velocities, but at the present time this idea is not taken seriously. Practically none of the serious contemporary critics of STR, apart, of course, from amateurs, holds this point of view. The result cannot be considered as a direct experimental confirmation of the second postulate of Einstein's special theory of relativity, i.e., its main part, which speaks of the constancy of the velocity of light in all inertial reference frames, but only of that part which speaks of the independence of the velocity of light on motion of the source. Moreover, this same result stands as equal proof of the so-called theory of the luminiferous ether, which held sway up to the creation of the special theory of relativity and which has now been revived, i.e., it does not distinguish between these two theories. It is fundamentally impossible in principle to measure the velocity of light by the proposed method, it is only possible to postulate it.

Keywords: ultrarelativistic source, Newton–Ritz hypothesis on ballistic addition of velocities, independence of the velocity of light of the velocity of the source, absolute synchronization of clocks, impossibility of absolute synchronization of clocks with the help of signals of an electromagnetic nature and measurement of the velocity of light.

Aleksandrov *et al*. [1, 2], regarding the measurement of the velocity of light, announced that they had carried out a comparison for the first time of the velocity of light from an ultrarelativistic source (here we are talking about a relativistic electron moving with near-light velocity) and from a fixed source (a glass plate). This result contradicts the Newton–Ritz ballistic hypothesis which assumes Galilean addition of the velocity of light from a source and the velocity of the source itself. They also asserted [1, 2] that they had performed a first-of-its-kind direct measurement of the velocity of light emitted by an ultrarelativistic source and that the result can be considered as the most direct (and final) proof of the validity of the second postulate of the special theory of relativity (STR).

As for the incompatibility of their results with the Newton–Ritz ballistic hypothesis, they of course made no pretensions to the contrary. This direction of research is at the present time generally not held to be worth pursuing – practically none of the serious present-day critics of STR hold this point of view, except, of course, amateurs. It was of

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interest 50–100 years ago. But as for their assertion of a direct measurement of the velocity of light emitted by an ultrarelativistic source and the idea that their measurements should be considered as the most direct (and final) proof of the validity of the second postulate of STR, this is not entirely so.

Indeed, as follows from [1, 2], it was not a direct measurement of the velocity of light emitted by an ultrarelativistic source (i.e., the velocity of synchrotron radiation) that was made, but only a comparison of the velocity of light emitted by an ultrarelativistic source with the velocity of light from a fixed source (one unknown quantity was compared with another unknown quantity), both in the first variant, where a fixed glass plate served as the fixed source, and in the second variant, where a synchrotron pulse in the cable served as the reference signal (this velocity is of the same order of magnitude as the velocity of light in vacuum). But the measurement of the velocity of light used simply a calculated time based on the postulate of STR on the invariance of the velocity of light. But since the first experiment showed that the velocity of light from a moving source does not add together with the velocity of the source, i.e., it is equal to the velocity of light, and that the Newton–Ritz ballistic hypothesis is invalid, the whole point of the second experiment generally falls to the wayside since it is already known that the velocity of light from a moving source and the velocity of light from a fixed source coincide.

That means the second experiment, in essence, is the same experiment as the first, only now the role of a fixed source is played by the source of the synchrotron pulse (reference signal) and adds some new element to the calculation based on the postulate of STR. But this experiment is absolutely worthless, senseless, and useless as was proven by Michelson around 100 years ago, who forbade any consideration of such experiments or even that they be carried out.

In order to measure the velocity of light, as in the situation considered in [1, 2], i.e., from the point of emission of synchrotron radiation to the sapphire output window (l = 7.2 m), it is necessary to know the transit time of light across this segment. And in order to know this time, it is necessary to know *a priori* the velocity of propagation of light on the other segments, and also the velocity of propagation of signals in the cables. It is also necessary to know the velocity of propagation of electrons in the storage ring, etc., etc. Albeit, for example, that the authors of [1, 2] write that to eliminate the error associated with phase shifts of the signals and to achieve transport of the useful signal and the synchronization signal (i.e., the reference signal) they used cables of one type and the same length (8 m). But this again is valid only in the case when their propagation velocity is known in advance, i.e., *a priori*.

But we do not know this *a priori*, since in all experiments on measuring the velocity of light (measuring a signal) what is being measured is the two-way velocity of light (of the signal), i.e., there and back, which is conserved. This is an experimental fact. And all the rest, as they say, is a trick. For example, this condition (except, of course, for the Lorentz transformation) is also satisfied by the Tangherlini transformation [3–6] although in the latter case the one-way velocity of light in an inertial reference frame (IRF) S' moving with velocity V relative to absolute space is anisotropic and equal to

$$c' = \frac{c}{1 + \dfrac{V}{c}\cos\theta}, \tag{1}$$

where θ is the angle at which the light propagates in the IRF S' relative to the x' axis (the vector $\boldsymbol{V}$) and, as experiments show [7], most probably this is indeed the case. Correspondingly, in a medium with refractive index n the velocity of light is equal to

$$c' = \frac{c}{n + \dfrac{V}{c}\cos\theta}. \tag{2}$$

But nevertheless, the experiment [1, 2] is absolutely insensitive to this since it is based on a comparison of signals (the useful signal and the reference signal), having a common electromagnetic nature.

But to calculate the transit time of light from the emission point of the synchrotron radiation to the sapphire output window (l = 7.2 m), Aleksandrov *et al.* [1, 2] used simply a calculated time in which the velocity of light, and also the velocity of the electrons in the beam and the velocity of the signals in the cable were postulated in advance, *a priori*.

For example, to calculate the time of flight of an electron clot from the accelerating gap in the resonator to the emission point in the magnet M3 ($L = 5.61$ m) they assumed that the velocity of the electrons in the storage ring is equal to the constant c. In fact, the velocity of the electrons is unknown, as is also the velocity of light, and it is necessary to denote it by the variable quantity c', in order not to confuse it with the constant c (most likely, the electrons also move around the ring with variable velocity). This would not be the case, for example, if the electron beam returned to the initial point. Then the average velocity of the electrons in the storage ring after a full round-trip would be equal to the constant c (in fact, due to the rotation of the Earth this velocity will be a bit corrupted by the Sagnac effect) and in the calculations it would be possible to use this constant. But then it would be necessary to modify the scheme of the experiment, i.e., to move the output channel of the synchrotron radiation closer to the resonator, for example, tangent to the equilibrium orbit in the magnet M4. But, all the same, in this case the velocity of light on the other segments would remain unknown, and likewise the velocity of the signals in the cables.

It is exactly the same, for example, with the time measured from the sapphire output window to the detector, which was calculated using the same constant c, although it too was subjected to measurement, etc. And it is like this everywhere in all the calculations. Thus, the velocity of light is postulated everywhere out front, *a priori*, and this desired quantity is therewith served up as the actual quantity. But one cannot prove a postulate with the help of this same postulate. Thus, in the final count, for the transit time of light from the emission point to the sapphire output window ($l = 7.2$ m) Aleksandrov *et al*. [1, 2] obtained a calculated time equal to 24.1 ns. It is obvious that dividing l by this time will give a velocity equal to the constant c. But this is not a measurement, this is a postulation.

For example, working through exactly the same calculations, but within the framework of the Tangherlini transformation, it is possible to obtain a different result, etc. And thus every time, all the time, a new result. However, the experiment [1, 2] does not distinguish this, the phase difference of the signals (useful and reference) does not change. The experiment in [1, 2] is absolutely worthless, useless, and devoid of meaning (an analytical calculation of the fundamental impossibility of measuring the velocity of light by the proposed method is given in the Appendix at the end of this paper).

A change in the velocity of light if such a thing could take place in reality, could be measured, for example, using the scheme proposed by Torr and Kolen [7]. In this case, synchronization of clocks is not required. And it would be specifically for such experiments, i.e., to manifest differences in the one-way velocity of light in different directions, in my opinion, that it would be worth for the Russian Foundation for Basic Research to spend money on it.

It is possible to measure the absolute velocity of light only with clocks that are absolutely synchronized, for example, with the help of infinite signals if such existed, but not by Einstein's method. For example, in Malykin's opinion [6], it would be possible to realize an absolute synchronization of clocks with the help of the so-called light spot having a superluminal velocity, which was considered for the first time by Ginzburg and Bolotovskii about 40 years ago [8, 9]. (In these works they considered motion along a screen of a projector beam rotating with angular velocity Ω. If A and B are equidistant from the projector at a sufficiently large distance r, then for linear velocity v of the light spot, the condition $v = r\Omega >> c$ is fulfilled.)

However, in actual fact such a method of synchronization of clocks with the help of a light spot does not permit the absolute synchronization of clocks even for $\Omega = \infty$ and is entirely the same method of synchronization of clocks with the help of light signals considered by Einstein more than 100 years ago. Einstein simply considered the limiting case ($\Omega = \infty$), i.e., when from the point O (e.g., from the middle of the interval AB in Fig. 1) light waves are simultaneously emitted in opposite directions. Einstein assumed *a priori* that a spherical light wave emitted from the point O, reaches the equidistant points A and B simultaneously, which in the situation described in [6] would imply infinite phase velocity of the light spot around a sphere of radius r. However, such is not the case.

Indeed, let the velocity of light in the IRF S' be anisotropic and let formula (1) be valid. In this case, the phase velocity of the light spot around this sphere of radius r would be equal to [10]

$$v_{\text{proj}}(t) = \frac{r\Omega}{1 - r\Omega \dfrac{V}{c^2} \sin \Omega t}.$$

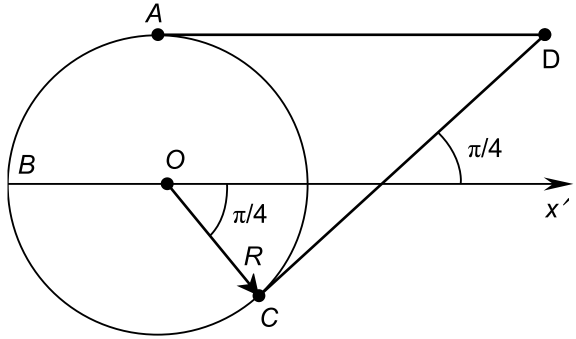

Fig. 1

Thus, in the direction of the x' axis (e.g., in the direction of the point B) the velocity of light c' will be equal to $c/(1+\beta)$, where $\beta = V/c$, and in the direction of the point A: $c/(1-\beta)$. It is entirely obvious that the signal from the point O to the point A arrives earlier than to the point B, i.e., the mean phase velocity of the light spot over the sphere along the path AB will be finite. Thus, even such a method of synchronization of clocks with the help of a light spot does not permit an absolute synchronization of clocks even for $\Omega = \infty$ and is entirely the same method of synchronization of clocks proposed by Einstein 100 years ago.

Next, in regard to a supposedly final proof of the validity of the second postulate of STR, the second postulate of STR does not state exactly what is asserted. According to the second postulate of STR, the velocity of light (in vacuum) is the same in all IRFs and does not depend on the motion of sources and receivers. Thus, the results of [1, 2] prove only the second part of this postulate, namely that part of it that is also valid in the so-called theory of the luminiferous ether, which prevailed up to the creation of STR and which now is being given a new lease on life, i.e., without making a distinction between these two theories. The main part of this postulate, regarding the constancy of the velocity of light in all IRFs, has still not been proven. For example, the experiments in [7] show that the velocity of light is most likely different in different directions.

The Appendix below presents an analytical proof of the impossibility of measuring the velocity of light using the method proposed by Aleksandrov *et al*. [1, 2].

APPENDIX

Thus, we assume, once again, that in the IRF S' the velocity of light is anisotropic and formulas (1) and (2) are valid. We reproduce, setting aside all nuances and details, the approximate scheme of measurement of the velocity of light considered in [1, 2] (Fig. 1).

We assume for definiteness that the line segment AD (cable with reference signal with refractive index n) is parallel to the x' axis and feeds into one of the inputs to an oscilloscope. The velocity of the reference signal in the cable is obviously equal to $c' = \dfrac{c}{n + \dfrac{V}{c}}$.

For simplicity, let the electron beam in the storage ring move around the circle $ABCA$ of radius R in sync with the synchrotron pulse. The velocity of the electrons is obviously equal to Eq. (1) and, note, different along different segments. For definiteness, at the distance $ABC = 2.5\dfrac{\pi}{2}R$ at the point C, let electrons emit light (synchrotron radiation) in the direction of the point D $\left(\text{here } CD = AD = R\Big/\tan\dfrac{\pi}{8}\right)$ at the angle $\theta = \dfrac{\pi}{4}$ to the x' axis.

This radiation is incident upon a radiation detector located at the point D, to which, we assume is attached a cable (with the useful signal) of the same length and type as the cable with the reference signal and is fed to the other input of the oscilloscope after making a loop and returning to the same point. Obviously, the average velocity of the signal in the cable is equal to $c' = \frac{c}{n}$. The velocity of light on the segment CD is obviously equal to $c' = \frac{c}{1+\frac{V}{c}\cos\frac{\pi}{4}}$. It is required to show that the difference between propagation times of the signals does not depend on the parameter V, i.e., to show that $\Delta t = t_{ABC} + t_{CD} + t_{DD} - t_{AD} = \text{const}$. It is obvious that

$$t_{ABC} = \int_0^{2,5\frac{\pi}{2}} \frac{R}{c}\left(1+\frac{V}{c}\cos(\varphi+\pi)\right)d\varphi,\ t_{CD} = \frac{R}{c\tan\frac{\pi}{8}}\left(1+\frac{V}{c}\cos\frac{\pi}{4}\right),\ t_{DD} = \frac{Rn}{c\tan\frac{\pi}{8}},\ t_{AD} = \frac{R}{c\tan\frac{\pi}{8}}\left(n+\frac{V}{c}\right).$$

Now, substituting all of this into the previous expression, we find that $\Delta t = 6.3412043793603365971\frac{R}{c}$ (the same result, as calculation shows, is obtained within the framework of STR), i.e., Δt does not depend on the parameter V. The experiment, thus, is absolutely senseless and completely useless, as was required to be shown. The velocity of light can only be postulated.

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