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1. INTRODUCTION

In recent years there is frequently discussed the question of the one-way velocity of light and the closely connected question of the definition of simultaneity of remoted events[1]. The statement of the isotropy of light velocity is the part of the postulate of the Special Theory of Relativity (STR). Therefore it seems strange that it is still rigorously discussed. Really, Poincare[2] emphasized the conventionality of simultaneity of remoted events already in 1898, Reichenbach[3] studied this question in detail in 1928. And Robb in his book[4] of 1921 demonstrated that only the absolute coordination of events founded by the possibility of signal exchange has sense. On the basis of this work[4] one can already conclude that only the terms "later" or "earlier" in relation to remoted events are important, while their "simultaneity" does not matter. But the captivating simplicity of the formalism of STR promoted to some extent the neglection of these subjects and the dissimination of the belief in light velocity isotropy.

In the STR, the concept of light velocity is introduced before the definition of simultaneity of remoted events (before the synchronization convention), but one, traditionally, accepts the velocity as the ratio of the path to the time taken to cover it. This concept of velocity when applied to the light signal used for the synchronization leads one to the vicious circle. And, in fact, the one-way light velocity is not defined in the STR. All these hinders the analysis of the proposed experiments to proove the isotropy of light velocity and explains the long term discussion of this problem.

The recently arised interest in the considered question is partly explained by the wish to verify the STR postulates with better accuracy using the advancing experimental possibilities. And, besides, it is interesting because of the anisotropy of the universe along short (solar, galactic) and, possibly, very long (inhomogenety of the distribution of quasars[5]) distances. This incites the search for different kinds of anisotropy[6]. Such propositions and experiments on search for the anisotropy connected with EMW cannot be interpreted within the STR. Therefore, they are often analysed in terms of the ether wind (for a lack of something better). But there does not exist any experimental operational definition both of the ether wind velocity and of the one-way velocity of the synchronization signal. (Such situation with the velocity of light c_0 makes one anxious about the definition of the EM wavelength, $\lambda = c_0 T$, which is the basis for the present standard of length). One of the purposes of the present paper is to find a possibility to analyse the above - mentioned questions without the quantities having no operational definition.

Usually, in the STR one deals with the light signals in general. Indeed, it is enough for the synchronization to have the signals from some restricted frequency range. At present the experiment [7-9] allows one to compare the properties of EMW (in particular, velocity) in different frequency ranges. Therefore, it is high time to set a question about a choice of the standard EM signals (γ), necessary for the coordination of the events (of events of EMW also).

In connection with the above-mentioned questions we shall consider the kinematic properties of EMW using as the measuring instruments only standard clocks and γ-signals. In order to avoid conventions the operational principle is applied, i.e., the principal definitions and concepts are introduced on consideration of the experimental procedure with which the corresponding values can be measured.

2. COORDINATION OF EVENTS AND ONE-WAY VELOCITY

2.1. The relative kinematics can be built up [10] without the concept of one-way velocity of the standard EM-signal (γ-signal). This means that the statement about the isotropy or anisotropy of this signal velocity is not necessary for the description of kinematical experiments. It must be just so, if this statement is conventional [10]. Within this approach the readings of standard clocks are the only measured quantities. The events are coordinated by γ-signal exchanges between the point of the events and the points of the standard clocks (atoms can serve as a basis for such clocks). The shape of γ-signal (the wave superposition from the standard frequency range) must not be changed while signal propogation, thus one may select experimentally the γ-signal from other EM signals

The absolute time interval $\tau_{12}(O)$ is the difference of clock readings for the events 1 and 2 taking place at the clock site only (point O). If events a and b occur at different sites, then the experimental connection between them and a given clock can be established only with the help of signals. This connection is characterized by two events of γ-signal departures from the clock of point O towards the points of events a and b and by two events of γ-signal arrivals at clock site being reflected from points in which events a and b occur. Let us introduce the denotions: $r^{-}_{ab}(O)$ is the time interval by the clock at O between the departures and $r^{+}_{ab}(O)$ - between the arrivals of γ-signals at O. (These denotions are also used, if only one of the two events occur in the clock point).

Imagine two close points A and O in relative motion. Point A moves throught (event 1) and away from point O (event 2 in point A about immediately follows event 1). By the clock of p. O only $r^{-}_{12}(O), r^{+}_{12}(O)$ can be measured. The quantities

$$\ell_{12}(O) = \frac{r^{+}_{12} - r^{-}_{12}}{2}, \quad v_A(O) = \frac{r^{+}_{12} - r^{-}_{12}}{r^{+}_{12} + r^{-}_{12}}, \tag{1}$$
$$\ell = \frac{v}{1+v} r^{+} = \frac{v}{1-v} r^{-} = v \frac{r^{+} + r^{-}}{2}$$

are called the location coordinate and velocity, respectively. The velocity characterizes not only the motion of the object (p.A) with respect to p.O, but also the motion of γ-signal. The numerical value of $v_A(O)$ coincides with the value of v/c_0 ratio in the STR, but here /10/ $v_A(O)$ is not interpreted as the path went during the time unit. The numerical value of the location coordinate (measured in seconds as r) coincides with the ratio of the distance to the velocity of the synchronization signal in the STR (r/c_0, here the velocity c_0 is measured (in m/s) along a closed trajectory).Thus the velocity of the subject along the trajectory in one direction is measured by comparing the propagation of the subject and of the γ-signal. But it has no sense to speak about the γ-signal velocity (though its being equal to unity formally follows from the definition of v and γ), since the propagation of the γ-signal cannot be compared with the propagation itself. The concepts of the one-way velocity of the synchronization signal as well as of the velocity with respect to the ether are just the products of mental invention, and without the measuring operations defining these concepts, one can interprete no experiments with the help of these quantities.

The muddle around the one-way velocity of light is due not only to the vague definition of the velocity, but also to the separation of the clock synchronization from the measuring of time by the clocks when one calculates the time coordinate in the STR. Such single-time synchronization could be possible, if one is sure that the clocks are at rest after the synchronization. But the latter may be proved only with the help of many repeated exchanges of signals between the clocks (it is impossible to define the points at rest only with the help of the rigid body). In particular, it must be proved that the relative location coordinate of the clocks does not change with time, i.e., one must measure r^+, r^- for a set of events. But then the clock synchronization using some convention does not give any advantage and, in principle, the STR time coordinate $t=(r^+ + r^-)/2$ is not preferable by the nature among other possible coordinates [1,10] (indeed, one needs to measure r^+, r^- and then, one may calculate t or other time coordinate).

The situation with the one-way light velocity and the velocity of ether emphasizes the importance of the classification of theoretical quantities with respect to the experiment. The properties of some of them are conventional (under convention I understand a theoretical statement, which can be replaced without contradiction with experiment by another statement inconsistent with the first one). The values of others are fixed by definitions (e.g. units of standards). And the numerical values of the third group may be measured only in the experiment.

2.2. Let us see how the above situation with the one-way velocity is reflected in the relationship for the EMW phases. Let the wave be generated in point O and events 1 and 2 occur in the centre of the sphere with radius r_{12} and on its surface, respectively. The usual relationship for the differences of the wave phases (between the two events 1 and 2 with coordinates t_{12} and r_{12}) is

$$\phi_{12} = 2\pi\left(\frac{t_{12}}{T} - \frac{r_{12}}{\lambda}\right), \quad \lambda = c_0 T . \tag{2}$$

In the suggestions on the measurement of the one-way velocity of light the quantity c_0 in (2) is replaced by $c(\theta)$ (here θ is the space angle). And the t and r coordinates and the T and λ parameters are supposed to be independent (i.e., four measured quantities). Here one does not take into consideration that the relation (2) should change under the assumption of the anisotropy of $c(\theta)$, and that the quantities in (2) are connected through their definitions (e.g., by the convention of simultaneity of remoted events). Indeed, if the wave belongs to the standard frequency range of γ-signal, then $r_{12}/c_0 = (r^+_{12} - r^-_{12})/2$, $t_{12} = (r^+_{12} + r^-_{12})/2$ since r^+ and r^- are the directly measured quantities, while t and r/c_0 are their derivatives. Therefore, from eq. (2) it follows that

$$\phi^{\bullet}_{12} = 2\pi \frac{r^-_{12}(O)}{T} \tag{3}$$

(for the converging spherical wave $\phi_{12} = 2\pi r^+_{12}(O)/T$). Thus for this wave c_0, r_{12}, t_{12} are rigidly bound and the phase difference is expressed through one signal coordinate τ^- and the period T. But, if the wave does not belong to the standard frequency range, then the phase velocity c is the measured quantity and from the empirical point of view is not necessarily equal to c_0. One has for it:

$$\phi_{12} = \frac{\pi}{T}[\tau^+_{12} + \tau^-_{12} - \frac{1}{u}(\tau^+_{12} - \tau^-_{12})], \quad u = \frac{c}{c_0}. \tag{4}$$

Eq. (4) (differently from eq. (3)) actually coincides with eq. (2), but they make use of different coordinates. After this preliminary consideration we shall formulate in the next section some operational postulates, which will lead to (3) and (4) without using (2).

3. MEASUREMENTS OF KINEMATIC PROPERTIES OF EMW

3.1. Since the γ-signal is so necessary for the construction of the kinematics, one should start with the investigation of its properties. (The introduction of concepts by consequent approaches can bring one to the vicious circle and it is much desired to avoid this). Let be measured the time intervals $\tau(O)$ between the departures of two signals from point O and between their arrivals at p.A $\tau(A)$. If $\tau(O) = \tau(A)$ then these points are called [10] to be at rest under the given signal exchange. The exchange can be also performed with the help of the monochromatic EMW. In this case one needs to measure the wave period in both points.

The principal property of EMW is connected with the possibility to find the points at rest. In such points the wave phase changes according to the expression $2\pi\tau/T$, which is one and the same for all these points (postulate A). Of course, this property has a relation to the wave as well as the points at rest. Therefore, one cannot build a system of references (s.r.) using only EMW (or ether). Furthermore it should be noted that though it is convenient to use the γ-signal for the definition of the points at rest, but one can also use the signal, which changes its shape with propogation.

So having for the experiment the same s.r. as that introduced [10] on the basis of the points at rest, let us formulate the criterion for the selection of the standard frequency range. Let some generator produce (at least) two waves with different periods. The shape of the superposition of them can be measured in different points of the s.r. If it does not change from point to point, then the aperiodic superposition of the similar to the above-mentioned waves can be used as the γ-signal, and the waves themselves can be considered as standard EMW(postulate B). As a consequence of the B postulate: if the standard wave and γ-signal propogate between the points at rest, then the wave phases measured at these points at the moments of γ-signal arrivals in the points are equal. If the wave is out of the standard range, then its phase delays along the ℓ distance by $2\pi\ell(n-1)/T$ with respect to γ-arrival (n is equal to unity for the standard EMW). This is the generalization of the B postulate.

3.2. The procedure described above can be the basis for the introduction of the wave phase velocity. Let the wave "hill" and the γ-signal appear in the point O in the moment of ev.1; in p.A the γ-signal comes in the moment of ev.2 and the "hill" nearest to ev.2 appears in p.A in the moment of ev.3, $r_{23}(A) = \ell\,(n-1)$. We can introduce the parameter $u = [r^{+}_{13}(O) - r^{-}_{13}(O)]/[r^{+}_{13}(O) + r^{-}_{13}(O)]$ and analogously to (1) it can be called the phase velocity ($u = n^{-1}$, i.e., n formally corresponds to the refractive index). Note that u and n are rigidly bound and here it is not necessary to introduce them both. But in the refraction n has the status of the quantity measured independently of u.

One can search for this or that anisotropy of some properties only with respect to a certain standard, while there is no sense of speaking about the check of isotropy of the standard. In the present paper and within the operational approach to kinematics /10/ the standard clock and γ-signals are those standards. Relative to them we can measure the one-way $u(\theta)$ for the nonstandard EMW. Generally speaking u and n can be dependent on the direction and the position in the space. Therefore for some trajectory of length ℓ one can measure the average over the trajectory values of $\bar{u}$ and $\bar{n}$ ($\bar{n}\ell = \int n d\ell$ see i.3.1).

For the purpose of the theory of measurements one should not accept the postulates restricting strongly the properties of EMW. Therefore, the postulates in i. 3.1 were formulated so that the EMW properties necessary to enable the measurements followed from them. This, for example, allows one to demonstrate that the usually accepted isotropy of the EMW properties does not always have the experimental foundation and that there is no need in this isotropy in STR. Besides, without the postulate about the isotropy of EMW properties one can easily interpret the many experiments /6/ that are presently considered within the ether ideology.

3.3. The present standard of length is realized under the condition of the two-way propogation of EMW. Therefore, in order to define the wavelength let us consider the following:

along a closed trajectory both the γ-signal and the wave return to the initial point O; the signal comes there after $r(O)=\ell$ (see i.2.1); during this time the phase of the oscillations in p.O is changed by $\phi_1 = 2\pi\ell/T$ and the phase of the returning wave delays by $\phi_2 = 2\pi\ell(\bar{n}-1)/T$ with respect to the time of γ-signal arrival; therefore, the phase difference between the oscillations in p.O and the returned wave equals

$$\phi_1 + \phi_2 = 2\pi \frac{\ell\bar{n}}{T} = 2\pi\frac{\ell}{\lambda}. \tag{5}$$

The latter relationship defines the wavelength $\lambda = \bar{u}T = T/\bar{n}$ along the closed trajectory. (When the two coherent waves go between the two points along different trajectories they accumulate the phase difference $2\pi(\bar{n}_1\ell_1 - \bar{n}_2\ell_2)/T$). The definition of λ (as $\lambda = uT$) along a not closed trajectory does not give anything new in comparison with $u\cdot T$. On the opposite, for the closed trajectory there arises a possibility (see (5)) to measure λ without measuring $\bar{u}$ and T. (For a linear resonator used in the Kr meter, the relationship between λ and one-way velocities is: $\lambda = \bar{u}T$, $2\bar{u}^{-1} = u_1^{-1} + u_2^{-1}$, $\bar{n} = (n_1 + n_2)/2$. Here the indices 1 and 2 correspond to opposite directions).

Thus the refusal from the concept of the simultaneity of remoted events does not prevent one to make any kinetical measurements with EMW as well as other kinematical measurements /10/. And the space picture of EMW at some time moment (in particular, the imaginary distance between the adjacent hills usually defined as λ) is only, strictly speaking, the tribute to our visual perseption. It was just this that led one to accepting the convention about the simultaneity of remoted events.

4. LOCATION COORDINATE AND STANDARDS OF LENGTH

4.1 The interpretation of the experiments is much dependent on the system of the measuring operations accepted for the definition of the quantities. Not accurately formulated definitions lead to not very definite statements. And often the discussions of the above-mentioned STR aspects are hindered by the fact that the opposite sides use different definitions. (For example, one can speak about a search for the contraction of the Michelson's interferometer base, if the length is measured in λ of EMW. But it is nearly out of sense, if one uses a rigid rod as the standard of length).

Since, within the considered here approach, the clock and γ-signal are taken as standards, so other existing standards of length must be considered as the secondary ones. And one needs to consider the relations between the method of distance measurements with the help of γ-signal and other methods, such as: 1) the interferomentry method (using λ of Kr atom), 2) the method of the rigid rod.

In the STR one uses the measuring rods. But it is a pity that the STR includes the definitions in the following way: there exists a system of reference, clocks and measuring rods, for which the STR laws hold. But the real solid bodies are far from always can be used as the measuring rods in the STR (it cannot define strictly the rest with the help of rigid rods). But within the empirical approach it is possible to consider the meter rod as the standard for the measurement of the "rod distance" between the points of rigid bodies (without speaking about the points at rest). Here I use the term the "rod distance" to distinguish it from the term "distance" used in the present paper and measured by the clocks and γ-signals. These two quantities are essentially different (e.g., if a rotating disk and rods are made from the same material, then one cannot notice the rotation by measuring the rod distances on the disk). Therefore, one can measure the ratio between the distances of the two kinds under a change of orientation and the site of the measured rigid body in the space (this ratio changes on the rotating disk). Thus the meter rod is the standard for the rod distance. Of course, the dynamics must connect the distances of these two kinds, but I think the metrology must distinguish these concepts.

The count of the interference stripes between the edging points is, in particular, similar to counting the number of rigid rods put between the edges. The edging points (which the interferometer mirror coincides with) must be at rest during the measuring procedure. Their being at rest can be proved only with the help of the exchange of γ-signals or EMW (the mirrors are at rest, if the pattern does not change with time). But the use of γ-signals allows one to perform the measurements also with the points not at rest. And the signal coordinates (r^+, r^- see i.2.1) measured in this way give us both the location and time coordinates of events (the distance is the particular case of the location coordinate (i.2), when the latter does not change with time /10/). Therefore, it seems natural to accept the signal method of coordination as a basic one, including the interference method as a particular case of the measurement of distance. Indeed, the interference of a standard EMW allows one to measure the time of γ-signal propogation along a closed base (from i.3.3 $l = r(0) = \frac{\phi_1 + \phi_2}{2\pi} T$) with the accuracy of T. Thus, if in the interference method one uses the EMW from the standard frequency range, then there exists the rigid connection (since $n = 1$, $\lambda = T$) between the signal method and the interference method. And the space periodicity of the standard EMW is fully determined by the time periodicity. (In order to notice the analogy between these two methods it is convenient to imagine instead of the lonely measuring γ-signal the use of the periodic sequence of γ-signals). The interference method may be considered independent only, if there are used the EMW with $n \neq 1$. Then one can speak about the measurement of λ of these non-standard EMW in seconds (as well as the length of the rigid meter in seconds).

4.2. If one measures λ (in interference meters, i.e., as compared with λ_k of the krypton atom) and T (in seconds) of the laser EMW /15/, and if the EMW occurs in the frequency range of γ-signal $(\lambda(s) = T(s))$, then we have in result a value of the conversion coefficient $c_0(m/s) = \lambda(m)/\lambda(s)$ which is fixed by the definitions of the interference meter and the second. As far as the similar to the above experiments are concerned one may speak about the average phase velocity $c(\frac{m}{s})$ along a closed trajectory, if the EMW is out of standard frequency range:

$$\lambda(m) = \lambda(s) \cdot c_0(\frac{m}{s}) = \bar{u} \cdot c_0(\frac{m}{s}) \cdot T(s) = c(\frac{m}{s}) \cdot T(s) .$$

The similar experiments can result in the restriction of the possible difference $\Delta\bar{u}$ of the average velocities of EMW for different frequencies with a precision of one part in 10^9. About other experiments having better precision for Δu will be mentioned in i.5.3. These experiments allow one to choose the standard frequency range for γ-signals.

Before the defining of the meter the number c_0 could be taken arbitrary. But at present c_0 is restricted within extreme deviations of the kripton meter. By the recomendation of the Committee Consultatif pour la Definition du Metre /16/ the value c was fixed (partly basing on ref. /15/). In fact, it should have been supposed that c is equal to c_0. But, indeed, the experimental base (with sufficient precision) for such supposition exists only in the case of the visual light, where one can be sure that $\Delta u < 10^{-16}$ (see i.5.3). Therefore this frequency range could be taken as a standard range. And value $c = c_0$ (at $\bar{n} = 1$) must be fixed only in this standard range. All these would lead to the new determination of the interference meter with an uncertainty of the frequency standard (since for the standard EMW $\lambda(s) = T(s)$, $\lambda(m) = c_0(\frac{m}{s})T(s)$).

Note that in the present paper the ratio of the rod distance of the closed trajectory to the propagation time of EMW signal was not used as an average velocity, since it was necessary. The peculiarity of such velocity is determined by the ratio of the rod distance to the γ-signal distance (see i.4.1).

5. SOME KINEMATIC EXPERIMENTS WITH EMW

5.1. The possible in principle measuring operations considered in i.3 and corresponding to the accepted postulates can be realized only in the radio wave range. More often, in the experiments performed, one compares the phase difference of two waves going along their trajectories (e.g., the experiments by Michelson). In the present paper the results of Michelson's experiments performed with the nonstandard waves must be interpreted by the constancy of the ratio of the interferometer base to the wavelength (achieved accuracy is 1 part in 10^{11} (see ref. /12/). But using the standard waves one can speak only about the constancy of base length (since $n = 1$ at any orientation of the base). The experiment made with both types of waves would set some restrictions for the anisotropy of $\lambda(\theta) = 2T/[n(\theta) + n(\theta+\pi)]$ (see i.3.3) of the nonstandard waves. The similar experiment, but with the basic and doubled frequency has been proposed and made by Silvertuth /9/ and was interpreted within the ideology of the ether wind. The zero effect obtained in this experiment, from my point of view, showed that

$$\frac{\ell}{T}\,[2n'(\theta) - n(\theta) - 2n'(\theta+\pi) + n(\theta+\pi)] < 1\,,$$

where n and n' are the refractive indices of the basic wave and the doublet frequency one, respectively. If $n(\theta) = n(\theta+\pi)$ then ref. /9/ results in:

$$n'(\theta) - n'(\theta+\pi) < 10^{-6}, \quad u'(\theta) - u'(\theta+\pi) < 10^{-6}.$$

5.2. The experiment on the interference of the waves from the two nonsinchronized lasers has been proposed in ref. /11/ to prove the isotropy of the one-way EMW velocity. But this experiment in the initial proposal cannot be used for this. In order to clarify the principal aspects of such an experiment let us assume that both lasers move uniformly along a circumference in some system of reference and the interference pattern is observed in its centre. First of all one should make it sure with the help of γ-signals that the lasers rotate uniformly. Only then, one can make an attempt to search for the anisotropy of $n(\theta)$ for the nonstandard waves according to their interference pattern.

In general, the search for the anisotropy of the EMW properties requires the measuring of the change in location coordinates of different parts of the apparatus with the help of γ-signals. This notion is in direct connection (see ref.[10]) with the very precise Mossbauer experiments with rotor [13] (interpreted in ref.[13] within the ideology of the ether wind) and with similar proposals [14].

5.3. Another type of experiments, we are interested in, is the comparison of velocities of EMW from different spectral ranges. From them one obtains the information about the dependence of u on T. The observation of flashes from pulsers [8] gave the following restrictions for Δu of the EMW in the interstellar space: 10^{-10}, 10^{-16}, 10^{-14}, 10^{-3} for the ratio, visible, roentgen and gamma range, respectively. Similar observations of the pulsers in different directions can help to prove the isotropy of $u(\theta)$. The fact of the absence of the dependence of u on T in the interstellar space, which was established with the accuracy yet not possible under the earthly conditions, did not mean that such experiments should not be performed on the Earth. In general, the near earth vacuum can have different properties (e.g., due to the motion of the Earth with respect to the Universe). Therefore, the experiment with the interferometer with doubling of frequency [9] ($\Delta U < 10^{-6}$) and the experiment on the comparison of the propogation of the visible 10 eV light and of the 10 GeV gamma-rays ($\Delta u < 10^{-6}$)[7] have their special interest.

6. CONCLUSIONS

6.1. Thus for the coordination of the events we need to find the standard signal (γ-signal), which according to the definition has no concept of velocity. This definition is the sufficient condition for the simplest (though fundamental) measurements. And we do not need to introduce the parameters u for γ-signals. For the nonstandard EMW the quantities u, n, λ are not fixed by the definition, but measured, in particular, along the one-way trajectory. The properties of the nonstandard EMW are generally speaking not restricted within the theory of the coordination of events (i.e., within the relative kinematics).

Thus the widely accepted statement about the experimentally proved isotropy of the one-way light velocity (as well as of its wavelength) is not right. And the assertion about the necessary conventionality of the above statements is not exact, since, first, the use of the convention in the STR may be restricted to standard frequency EMW range and, second, there is no need in it in kinematics if differently formulated[10].

6.2. At a certain stage of the development of the measuring method and our understanding of its role, there arises a need in standards. Earlier it was sufficient to speak about the EM-signal for the synchronization. At present it is necessary to choose the standard frequency range for the coordination signals. It seems convenient to make this simultaneously with the change of the frequency and wavelength standards those become obsolete. The stabilized laser can serve as a basis for the rigidly bound standards of frequency and wavelength, if the frequency is in the frequency range of the standard coordinating γ-signal (the latter in principle can be obtained by using the same transition).

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