Why over 30 years absolute motion was not detected in Michelson-type experiments with resonators

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(Dated: April 5, 2011)

We show that measured by S.Herrmann et al., Phys.Rev.D 80, 105011 (2009) small (but finite) value of relative variation ($\delta\nu/\nu > 0$) of the resonance frequency of an evacuated optical resonator, when changing its orientation in space, can not serve as an indication of the absence of a preferred direction concerned with the absolute motion of the setup. On the contrary, the finiteness $\delta\nu/\nu > 0$ testifies to spatial anisotropy of the velocity of light. In order to detect the absolute motion and determine the value and direction of its velocity, the volume of the resonator should be regarded, at any degree of evacuation, as being an optical medium, with its refractive index $n > 1$ to be necessarily taken into account, irrespective of the extent to be the medium's tenuity. In this event the residual pressure of the evacuated medium should be controlled: that will ensure the magnitude of ¡i¿n¡/i¿ to be known at least to the first significant digit after 1.00000...

If the working body is a gas then, as in the case of the fringe shift in the interferometer, the shift $\delta\nu$ of the resonance frequency of the volume resonator is proportional to $n^2 - 1 = \Delta\varepsilon$ and to the square of the velocity v of absolute motion of the resonator. At sufficiently large values of optical density, $\delta\nu$ is proportional to $\left(n^2-1\right)\left(2-n^2\right) = \Delta\varepsilon(1-\Delta\varepsilon)$, and at $n > 1.5$ it may possess such a great value that there even becomes possible a jump of the automatic laser frequency trimmer from the chosen m-mode of the reference resonator to its adjacent $m \pm 1$ modes. Taking into account the effect of the medium permittivity by introducing in calculation the actual value $n > 1$ in experiments with resonators performed by the scheme of the Michelson experiment enabled us to estimate the absolute speed of the Earth as several hundreds kilometers per second.

PACS numbers: 11.30.Cp, 42.25.Bs, 42.79.Gn, 42.25.Hz, 42.87.Bg, 78.20.-e
Keywords: Michelson experiment, cavity resonators, dielectric media, drag of light, absolute motion

1. INTRODUCTION

The resonance frequency ν of the TEM$_{oom}$-wave in a filled with an optical medium linear resonator, constrained at the ends by reflecting mirrors, is determined by the integer number m of half-waves fit in the sample's length l

$$\nu = \frac{cm}{2nl} \tag{1}$$

where n is the refractive index, and c/n the light speed in the stationary medium. Comparing ν for various orientations of the resonator in space, the authors [1] have found a very small, yet finite, maximal relative shift $\delta\nu/\nu = 10^{-17}$ of the resonance frequency, arising in rotation of vacuumed resonator in a horizontal plane. Then the linear variation of (1) by c in the assumption of other parameters being constant

$$\frac{\delta\nu}{\nu} = \frac{\delta c}{c} \tag{2}$$

has been interpreted by them as actual proof of absence of the light speed anisotropy in the present experiment (though the smallness of measured value $\delta c/c \approx 10^{-17}$ by (2) means the observability and existence of the light's velocity anisotropy).

It is known that stability of the resonance frequency of volume resonators with gas filling is elevated by a deep vacuuming of the cavity. In the air of normal pressure (1 atm) the relative instability $\delta c/c \approx 10^{-8}$ of the resonance frequency can be reduced to $\delta c/c \approx 10^{-17}$ by means of the cavity to be evacuated (e.g. down to the residual pressure $< 10^{-9}$ atm). The apparent "accidental" character of instability $\delta\nu/\nu$ of resonance frequencies, observed in facilities employing volume resonators, is related with the contingency that they are arranged in a particular apparatus and with casual displacements of the devices themselves in the Earth's space. In the current paper this instability is

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partially attributed to registered in [1, 2] regular shift of the resonance frequency ($\delta c/c \approx 10^{-17}$) when the volume resonator with evacuated to $\sim 10^{-9}$ cavity turned in the horizontal plane of the Earth.

I will show below that the adequate interpretation of the experiments with the proper accounting already of first significant digits in the mantissa of $n > 1.00000...$ after 1. leads not to the demonstration of the isotropy of the light's speed in optical media, as the authors [1, 2] think, but on the contrary, it reveals its *regular* anisotropy. The anisotropy of the light's speed is concerned with translational motion of particles of optical media in aether with the velocity v having the order of several hundreds km/s that brings about the dynamical anisotropy of the refractive index ($n_{\parallel} \neq n_{\perp}$) of optical medium in the cavity of resonator.

It is vacuum that is isotropic ($n_{\parallel} = n_{\perp} = 1$), and any moving in it isotropic medium (with $n \neq 1$), which an experimenter deals with, is, in general case, *dynamically* anisotropic for propagation of light (and this anisotropy can be revealed in the reference frame of the moving medium). In experiments of Earth's laboratories one should not identify laboratory vacuum, which always has $n > 1$, with the ideal vacuum, which has $n_{\text{aether}} = 1$. The tendency of experimenters to evacuate the working space, aiming at the rise of their resolution power, leads, as a rule, to decrease of the observed effect (here $\delta\nu/\nu$). The effect is decreased so times as the resolution power of the observed effect increases due to the reduction of the contribution of the source of the effect. In this case, it is because of the concentration of particles contributed by the polarization $n^2 - 1$ to the total permittivity $\varepsilon = n^2$ of the optical medium. As a result, the quantity conveying the physics of the kinetic process (in this case the translational velocity v of the medium in aether), which is calculated as the ratio of the relative shift $\delta\nu/\nu$ of frequency, which is the observed effect, to factor $\Delta\varepsilon = n^2 - 1$, causing this effect, remains unchanged {i.e. $\delta\nu/(\nu\Delta\varepsilon)$=const}; and this will be rigorously proved below in deriving formula (7).

2. SNAP-ANALYZING RESULTS OF MEASURING [1] THE SHIFT OF RESONANCE FREQUENCY IN EVACUATED VOLUME RESONATORS WHEN TURNING THEM IN THE HORIZONTAL PLANE OF THE EARTH

Thus, formula (1) is rather a crude approximation where a possibility is absent to describe effects of the light speed anisotropy through observations of extremely small (of the scale $\delta c/c \approx 10^{-17}$) anisotropic shifts of the resonance frequency. A weak point of (1) is the neglecting of the refractive index $n > 1$ that directly determines the light's speed by the Maxwell's theory. In the series of experimental works [3–5] I exposed the errors in the interpretation of the Michelson type experiments neglecting the refractive index n. The satisfactory results have been attained applying the Fresnel formula describing the entrainment of the light's flow by optical medium with refractive index $n > 1$ moving with the absolute velocity v:

$$\tilde{c}_{\pm} = \frac{c}{n} \pm v\left(1 - \frac{1}{n^2}\right). \tag{3}$$

However, insofar formula (3) is not Lorentz-invariant when taking into account effects of second order of smallness of the ratio v/c, the transfer to the moving with the velocity v inertial reference frame (IRF) required the introducing relativistic corrections to calculations. Since the form of corrections required was not known, in [3–5] I used forms that were known formerly as "Lorentz triangle" accounting for drift of the beam in the arm $l_{\perp}$ and Lorentz contraction of the arm $l_{\parallel}$ containing that or another combination of the key radical $\sqrt{1 - v^2/c^2}$ of the well-known Lorentz transformation. Owing to these corrections I was able to construct a mathematical model which satisfactorily described and explained experimental results of non-zeroth shift of interference fringe obtained by Michelson&Morley [8], Miller [9], Shamir&Fox [11, 13], Trimmer et al. [12, 14] and by me [3–5].

In the first two versions of this article I used another simple approximate means to make out a relativistic correction to the light speed computed by (3) in the moving optical medium, suitable only for light carriers in the form of rarified gases ($1 < n < 1.01$) in the zones of light beams of interferometers and cavities of volume resonators. To this end, in the Lorentz invariant (with respect to parameter c/n) for any velocities $\tilde{c} = c/n$ transformation of velocities:

$$\tilde{c}' = \frac{\tilde{c} + v}{1 + \tilde{c}v/c^2} = \frac{c}{n}$$

I substitute the non-invariant for effects of second order in v/c formula (3), containing in itself explicitly n and v, and obtained invariant value $\tilde{c}' = c/n$ with a small correction in the following form:

$$\tilde{c}' = \frac{\tilde{c}_{\pm} \mp v}{1 \mp \tilde{c}_{\pm}v/c^2} \approx \frac{c}{n}\left[1 + \frac{v^2}{c^2}\left(1 - \frac{1}{n^2}\right)\right]. \tag{4}$$

Obviously, there is added in (4) to the invariant value c/n a small relativistic supplement $\upsilon^2(1-n^{-2})/c^2$ of the second order υ^2/c^2 which even for gases of normal pressure has the magnitude $< 10^{-9}$. Using the form (4) in order to find the relativistic variation of light speed in the reference frame of the Earth yields the following non-zeroth result

$$\left(\frac{\delta c}{c}\right)_{\text{mov.med.}} = \frac{\tilde{c}' - c/n}{c/n} = \frac{\upsilon^2}{c^2}\frac{n^2-1}{n^2}, \tag{5}$$

where $\tilde{c}'$ is the light speed in the direction collinear to $\mathbf{v}$, c/n – in the perpendicular direction, in which $\upsilon_\perp = 0$ (that corresponds to the value c/n inside the stationary in aether resonator). Clearly, that we obtained in principle distinct from [1, 2] result for $\delta c/c$. As we see from (5), $\delta c/c$ is proportional to υ^2/c^2 and explicitly depends on n (for gases it is proportional to n^2-1). Proceeding from that the observed in experiment value is the relative shift $\delta\nu/\nu$ of frequency, after substituting (2) into (5), we obtain

$$\left(\frac{\delta c}{c}\right)_{\text{mov.med.}} = \frac{\upsilon^2}{c^2}\frac{n^2-1}{n^2}. \tag{6}$$

First, we will interpret results of the work [1] where there were compared different orientations of evacuated to pressure $< 10^{-8}$ bar resonance cavities. After the evacuation of resonators authors [1, 2] assumed that the space inside the cavities of resonators is the absolute vacuum ($n = 1$). Actually there is a rarified gas inside the cavities resonators, accounting of whose permittivity is important for interpreting $\delta c/c$ by (5). The permittivity of the gas with rarefaction $< 10^{-8}$ bar is $n^2 < (1 + 6\cdot 10^{-12})$ [6]. The maximal relative shift of resonance frequencies, registered in this experiments is $\delta\nu/\nu = 10^{-17}$. Substituting these values of n^2-1 and $\delta\nu/\nu$ into expression (6) and resolving it with respect to υ we obtain

$$\upsilon \approx c\sqrt{\frac{n^2}{n^2-1}\left(\frac{\delta\nu}{\nu}\right)_{\text{mov.med.}}} = c\sqrt{\frac{10^{-17}}{\leq 6\cdot 10^{-12}}} \geq 400 \text{ km/s}. \tag{7}$$

It is clear from (7) that rarefaction of gas in the cavity of resonators demands a more accurate measuring than it is given in [1, 2] since it determines n^2-1 and the anisotropy of light speed revealed in these experiments. Thus found value of υ agrees, firstly, with obtained by me [3–5] value of υ in the classical Michelson-Morley experiment in gases and other optical media, and, secondly, with results of astronomical observations of Earth's speed relative to stars.

This simplified analysis of experimental results from [1] and [2] was outlined by me in a brief report and directed to the journal EPL. Professor Castberg, reviewing this brief report, noted in a letter sent to me, denying me the right to objection, that my derivation of formula (6) is inaccurate because of using non-invariant speed of light in the form (3) and hence all my interpretation of experiments with Michelson-Morley interferometer [3, 4] and resonator experiments [1, 2] considered after formula (6) is supposedly wrong. Acknowledging that proposed by me the short row (3-6) may appear to be disputable in first reading, I can not agree with his conclusion that after the series of theoretical argumentation (3-6) all is incorrect in my paper. Let us see whether it is right?

The point is that after (3-6) I analyze firmly established experimental facts of non-zeroth shift of interference fringe at Michelson interferometer and non-zeroth shift of resonance frequency of volume resonators. And experimental facts do no depend on their correct or incorrect interpretation. In particular, they do not depend on arguing by Professor Castberg, nor do they depend on my possibly disputable argumentation. Experimental facts are self-sufficient and can be disproved only experimentally. The regular presence in experiments of last 50 years the mentioned shift (of interference fringe or resonance frequency) should be recognized and we must seek their explanation, or they should be disproved by other experiments. Bad arguing of the experimenter can not serve as a reason for rejecting the publication of experimental facts found by him. The fact of detecting traces of anisotropy of light by the shift of resonance frequency are not disproved.

On the contrary, there appear ever new their confirmations. Moreover, they agree with many other experiments (and in particular with my experiments) detecting non-zeroth shift of interference fringe by means of Michelson interferometers. That is why I am looking for their explanation and relate them with the presence in the cavity of resonators of particles in different ways polarizing by light when moving along or transverse the vector of velocity $\mathbf{v}$ of translational motion of optical medium in aether and exciting dynamical spatial dispersion $n(\overleftarrow{\mathbf{v}}\,\overrightarrow{\mathbf{c}})$ of the refractive index of this medium. In its turn, the refractive index, determining the speed of light $\tilde{c} = c/n(\overleftarrow{\mathbf{v}}\,\overrightarrow{\mathbf{c}})$ creates the phenomenon of anisotropy of light speed in translationally moving in aether optical media. The isotropy of light speed is restored in the asymptotic limit of aether without particles $n = 1$.

In the section 3 of the present version v3 I give a more rigorous derivation of formula (6) obtained from first principles of the theory of Lorentz-invariant transforms of the expression of light speed in inertially moving and stationary media. It follows from my analysis that the made by the authors [1] and [2] race for demonstration of

"Lorentz-invariance" in some experimental limit of the existence of zeroth (isotropic) shifts of frequency of volume resonator with deeply vacuumed cavity and advanced Q-factor and resolution of rotary installation has a trivial and quite predictable outcome.

It is such that already without further more complicated experiments it is clear today that isotropy of light in all orientations of TEM_{oom}-wave of volume resonator will be only when $n = 1.$, and with $n > 1$ will be always observed the anisotropy of light speed, whose detection will be more and more expensive in the course of deepening the evacuation of resonator's cavities. But an experimenter who would attain in the cavity of resonator the condition $n = 1.$ never would know why he observes the isotropy of light speed by zeroth shift of resonance frequency of rotary resonator. And shifts of resonance frequencies may be absent by two reasons: the isotropy of light speed and total loss of sensitivity of resonator in the medium with $n = 1$. The choice between two causes can not be resolved experimentally, since the condition $n = 1$ would be realized only in a resonator without walls. The cavity of a real resonator, as a fact, can not be without particles, since they are inevitably emitted by walls.

Now let us return to realities of experiments [1, 2] and show by a rigorous deduction from very well known nowadays first principles of Lorentz-invariant transforms the relevance of formula (6) for media-gases, including rarified media similar to laboratory vacuum.

3. THE RIGOROUS LORENTZ-INVARIANT INTERPRETATION OF THE RESULTS OF MEASUREMENTS [1] ON RESONATORS WITH EVACUATED CAVITIES

It is well known today the rule of Lorentz-invariant addition of light speed c in vacuum (in stationary IRF) with velocity υ of the moving IRF$'$ which gives the following asymptotic value of the speed $\tilde{c}$ of light in IRF$'$:

$$\tilde{c} = c \oplus \upsilon = \frac{c \pm \upsilon}{1 \pm c \cdot \upsilon / c^2} = c. \tag{8}$$

The phenomenon of the magnitudes of light's speed being identical ($c = c'$) testifies to that the kinetic sum $\tilde{c} = c \oplus \upsilon$ is invariant in moving IRF$'$ and stationary IRF$_\circ$. It is important to stress that the value $\tilde{c}$ by (8) always remains the "asymptotic" limit at $n \to 1$. In reality we always deal with light's velocities having magnitudes $c_n = c/n < c$ in stationary media since in Earth conditions everywhere $n > 1$. It is so because optical media include in itself besides stationary aether (where $n = 1.$) also polarizable particles of matter which can be moving or stationary. In the conditions of such reality the rule of relativistic addition is, strictly speaking, given by the expression:

$$\tilde{c}_\pm = c/n \oplus \upsilon = \frac{c/n \pm \upsilon}{1 \pm \dfrac{\upsilon \cdot c/n}{c^2}} = \frac{c/n \pm \upsilon}{1 \pm \upsilon/(cn)}, \tag{9}$$

which just at $n \to 1$ asymptotically tends to (8). Both formula (8) with respect to unitary invariant c and formula (9) with respect to combination c/n for media composed of aether and particles are invariant. This can be easily shown. If the direct (for variation $\delta c = \pm\upsilon \ll c$) transform of velocity c/n of light in *stationary medium* by (9) gives $\tilde{c}_\pm$, then the reverse transform of $\tilde{c}_\pm$ (for opposite variation $\delta c = \mp\upsilon$) gives in IRF$'$ value:

$$\tilde{c}' = \tilde{c}_\pm \oplus \upsilon = \frac{\tilde{c}_\pm \mp \upsilon}{1 \mp \tilde{c}_\pm \upsilon / c^2} = c/n, \tag{10}$$

i.e. gives the same velocity in moving medium. We will find by the above described way the expression for speed of light, invariant in moving and stationary media for proper accounting effects of second order of smallness of the ratio υ/c.

With this end we will expand the right-hand part of (9) by the small parameter $\pm\upsilon/c$ not restricting n by any conditions:

$$\tilde{c} \approx \frac{c}{n}\left[(1 \pm \frac{\upsilon}{c} n \left(1 - \frac{1}{n^2}\right) - \frac{\upsilon^2}{c^2}\left(1 - \frac{1}{n^2}\right) \pm \frac{\upsilon^3}{c^3}\frac{1}{n}\left(1 - \frac{1}{n^2}\right) - \frac{\upsilon^4}{c^4}\frac{1}{n^2}\left(1 - \frac{1}{n^2}\right) \pm ....\right]. \tag{11}$$

The first two terms of this series, as is known [7], give pre-relativistic Fresnel formula $\tilde{c}_\pm = c/n \pm \upsilon(1 - 1/n^2)$ which is not invariant for accounting effects of second order. Its application requires the introduction into calculations of relativistic corrections in transitions from IRF$_\circ$ to IRF and inversely [3–5]. It appears that if we restrict the direct transformation of velocities (11) not by two, but by three terms of the series which include first and second orders of the ratio υ/c

$$\tilde{c} \approx \left[\frac{c}{n} \pm \upsilon\left(1 - \frac{1}{n^2}\right) - \frac{\upsilon^2}{cn}\left(1 - \frac{1}{n^2}\right)\right], \tag{12}$$

then having performed by (10) the reverse of a seemingly approximate expression (12) we will obtain with retaining all terms of second order by v/c the result $\tilde{c} = c/n$ as in a rigorous transform (10). This point to that the "refined" (by keeping terms of second order v^2/c^2) Fresnel formula (12) becomes in description effects of second order approximately (with the accuracy of second order $\sim 10^{-6}$) invariant relative to parameter c/n in moving and stationary media [5].

The time that TEM$_{oom}$-waves run there and back the distance $l_{\parallel}$ between mirrors of the resonator, which is oriented by the m-mode of the oscillation parallel to $\mathbf{v}$, is calculated by means of (12). This calculation gives the following expression for the period of its resonance vibration:

$$mT_{\parallel} = \frac{l_{\parallel}}{\tilde{c}_{+}} + \frac{l_{\parallel}}{\tilde{c}_{-}} = \frac{2l \cdot n}{c}\left[1 - \frac{v^2}{c^2}\frac{\Delta\varepsilon(1-\Delta\varepsilon)}{\varepsilon}\right]. \tag{13}$$

Expression (13) is invariant (with the accuracy accounting effects of second order v^2/c^2) in the inertially moving and stationary optical media. In the work [5] I have shown that using the invariant (12) for determining the times that light propagates in orthogonal arms of Michelson interferometer does not require other relativistic corrections to their geometro-optical calculation. Thus, there is no need to introduce geometric corrections for drift of the perpendicular to $\mathbf{v}$ beam by the "Lorentz triangle", for Lorentz contraction or Lorentz time dilation in the parallel to $\mathbf{v}$ beam, which were euristically introduced formerly for correction calculation based on Lorentz-noninvariant expression (3) of pre-relativistic physics.

Taking into account the above mentioned expression for the period of resonance vibration of the mode with index m, as the time of running by TEM$_{oom}$-wave there and back the distance between mirrors of the resonator oriented by the m-mode of the vibration perpendicular to $\mathbf{v}$ (when the projection of $\mathbf{v}$ at the beam, $v_{\perp} = 0$), will be computed by means of the lorentz-invariant (12) for $v = 0$:

$$mT_{\perp} = \frac{l_{\perp}}{\tilde{c}_{+}} + \frac{l_{\perp}}{\tilde{c}_{-}} = \frac{2l \cdot n}{c}. \tag{14}$$

Subtracting the form (13) from (14), for the difference $m \cdot \delta T = m(T_{\perp} - T_{\parallel})$ of the periods of m-mode of the resonance vibration changing under rotation of the resonator in the horizontal plane of the Earth for the construction $l_{\perp} = l_{\parallel} = l$ (with the account that in volume resonators $2l \cdot n/mc = 1/\nu = T$), we obtain the expression:

$$\delta T = T_{\perp} - T_{\parallel} = \frac{2l \cdot n}{m \cdot c}\frac{v^2}{c^2}\frac{\Delta\varepsilon(1-\Delta\varepsilon)}{\varepsilon}; \quad \delta T/T = \frac{v^2}{c^2}\frac{\Delta\varepsilon(1-\Delta\varepsilon)}{\varepsilon}. \tag{15}$$

The expression for relative change of the resonance frequency of the high Q-factor air-filled resonator with TEM$_{oom}$ wave (if to take into account that $\nu_{\perp} = 1/T_{\perp}$; $\nu_{\perp} = 1/T_{\perp}$; $\delta\nu = \nu_{\parallel} - \nu_{\perp}$; $\delta\nu/\nu \approx \delta T/T$) can be obtained directly from (15)

$$\frac{\delta\nu}{\nu} = \frac{v^2}{c^2}\frac{\Delta\varepsilon(1-\Delta\varepsilon)}{\varepsilon}, \tag{16}$$

where $\nu = \nu_{\perp}$ is the unperturbed value of resonance frequency of the resonator, since vibrations of m-mode of the orthogonal to $\mathbf{v}$ resonator is formed by the light's speed $\tilde{c}(v_{\perp} = 0) = c/n$ which does not depend on $|\mathbf{v}| = v = v_{\parallel}$. Taking into account that in the evacuated cavity $\Delta\varepsilon = (n^2 - 1) \ll 1$, $\Delta\varepsilon^2 \ll \Delta\varepsilon$ from the exact formula (16) immediately follows the approximate formula (6) derived in the previous versions v1 and v2 of this work in a simplified way.

Thus, if we account consistently in the cavity of vacuumed resonator the effect of polarization of the optical medium with the refractive index $n > 1$ then the observed regular shift of resonance frequency under its rotation in the horizontal plane of the Earth will always reveal the anisotropy of light's speed by means of the algorithm (8-16). This sufficiently rigorous interpretation enables us to determine by the shift of resonance frequency of volume resonators with evacuated cavity the velocity of absolute motion of the Earth by means of the approximate formula (7). For solid-body volume resonator, whose resonance cavity is formed by an optical medium with $\Delta\varepsilon > 0.5$, we must use a more accurate formula (16). Under such a correct interpretation of results of measuring non-zeroth shifts of resonance frequency in dependence on the time of performing the measurements in 24-hour cycle of the day-and-night, the processing of them by (7) or (16) always will give the projection of the absolute motion of the Earth in aether at 56° N changing from 140 to 480 km/s [3–5]. The measurements of the shift of resonator's frequency registered in [1] gives after processing them by formula (7) the magnitude of the horizontal projection of the absolute velocity of the Earth $v \sim 400$ km/s.

4. ANALYZING MEASUREMENTS [2] AT SAPPHIRE RESONATOR

In order to calculate velocity v at $n^2 - 1 > 0.5$, we must handle the measurements of the resonance frequency shift with formula (16) which take into account more involved processes of dragging the light by particles of the dense optical medium in the interior cavity of the resonator. Taking into account (16) we obtain the general formula suitable for any value of n:

$$\left(\frac{\delta c}{c}\right)_{\rm mov.med.} = \frac{v^2}{c^2}\frac{(n^2-1)(2-n^2)}{n^2}. \tag{17}$$

As already was mentioned, the observed in the experiments [1, 2] value is the relative shift $\delta\nu/\nu$ of resonance frequency of resonator. After substituting (2) in the left part of (17), we obtain

$$\left(\frac{\delta \nu}{\nu}\right)_{\rm mov.med.} = \frac{v^2}{c^2}\frac{(n^2-1)(2-n^2)}{n^2}. \tag{18}$$

In the measurements at the sapphire resonator with $m = 10000$ the authors [2] noted that they encountered with some difficulties in the observation of the difference $\delta\nu_{\rm saph} = |\nu_{\rm saph.} - \nu_{\rm evac.}|$ of resonance frequencies which they attributed to influence of "small deformations of the breadboard carrying the optics" and other laboratory effects. In my view, these difficulties are concerned with that the experimenters faced with an unexpected by them large shift ($\delta\nu_{\rm saph} \sim 10^9\,$Hz) of the resonance frequency of the sapphire resonator, which can not be registered by the low frequency spectrum analyzer from [2] used for measuring small differences of resonance frequencies of vacuumed resonators ($\delta\nu_{\rm evac.} \sim 0.001 \div 1$ Hz). The shift of the resonance frequency of the sapphire resonator appeared to be 10^{12} times greater than that of vacuumed ones. This is much greater than was expected in [2]. The shift $\delta\nu_{\rm saph.}$ may exceed the distance $\Delta\nu_o = \nu/m$ between adjacent modes of the reference cavity resonator, that we will estimate from (1) with $m = 380000 \pm 1$ as

$$\left(\frac{\Delta \nu_o}{\nu}\right)_{\rm evac.} \approx \frac{1}{m} = \frac{1}{380000} \approx 3\cdot 10^{-6}. \tag{19}$$

Clearly, in this event $(\Delta\nu_o/\nu)_{\rm saph.resonator} = 1/10000 \gg (\Delta\nu_o/\nu)_{\rm evac.resonator}$. Here and further on $\Delta\nu_o = \nu_m - \nu_{m+1}$ designates the difference between frequencies of adjacent modes of the resonator (it will called the frequency band), while $\delta\nu(\varphi)$ – the shift of the resonance frequency under turning the resonator by the angle φ. So, φ characterizes both the shift of a separate m-mode and the frequency shift of the band as a whole.

Thus, part of the reason why the experimenters have not noticed an abnormally high frequency shift could be the use of low-frequency spectrum analyzer from work [1], not designed for observing high frequency beat note in the range $1 < \delta\nu < 10^9$ Hz, arising between the sapphire and vacuum resonator. If my supposition concerning the occurrence of the unnoticed by the experimenters skip in the electronics of trimming the laser frequency (because of the skip in the automatic laser frequency trimmer at 380000±1 mode) is true, then estimating v by (6) we must use the unaccounted in [2] value of relative shift (19), corresponding to 380000±1 mode, but not the artifact value $(\delta\nu/\nu)_{\rm saph.} = 4\cdot 10^{-15}$ measured in [2]. Thus, we assume for the experiment with the sapphire resonator

$$\left(\frac{\delta \nu}{\nu}\right)_{\rm mov.med.} \approx \left(\frac{\Delta \nu_o}{\nu}\right)_{\rm evac.skip}. \tag{20}$$

Using (20) in (18) gives

$$\left(\frac{\Delta \nu_o}{\nu}\right)_{\rm evac.skip} = \frac{v^2}{c^2}\frac{(n^2-1)(2-n^2)}{n^2}. \tag{21}$$

Substituting from (19) the detected in [2] jump of the laser's frequency $(\Delta\nu_o/\nu)_{\rm saph.} \approx 3\cdot 10^{-6}$ supposedly from the mode $m = 380000$ to the mode $m = 380000 \pm 1$ into the left-hand part of (21) and resolving this equation with respect to v, at $n_{\rm saph.} = 1.75$ we obtain the correct estimation of the "aether wind" velocity" measured in [2]:

$$v = c\sqrt{\left|\left(\frac{\Delta \nu_o}{\nu}\right)_{\rm evac.skip}\frac{n^2}{(n^2-1)(2-n^2)}\right|} \approx \sqrt{\frac{1.5}{380000}} \approx 600 \text{ km/s}. \tag{22}$$

This estimation coincides in the order of value with υ computed from (7) from the frequency shift of vacuumed resonators by the above described model of dynamical anisotropy of optical media represented in the form of polarizing mixture of stationary aether (vacuum) and translationally moving in it particles of a specific substance.

The authors [1] may quickly verify this prediction on their experimental setup. General recommendations are reduced to that measurements should be carried out from the achieved low magnitudes of gas pressure, e.g. starting from the values $p = 10^{-8}$ bar, with gradual transition to higher densities up to the air of normal pressure. In this event it should be controlled, e.g. by γ-scale of Fig.1, that the expected frequency shift $\delta\nu$ does not exceed boundaries of measuring facilities (for the normal pressure of the air in the cavity of resonator, according to Fig.1, this boundary should be not less than 1 MHz.

However, if relation of the type (6) remains to be valid in the solid optical medium, as in the case of (18), then for measuring a possible large frequency shift there should be used the scheme of extracting beat note and spectrum analyzer working in a more wide range of frequencies, up to 10^9 Hz (i.e. it is necessary to replace the spectrum analyzer of frequencies $10^{-3} \div 1$ Hz [2] by that in the range $1 \div 10^9$ Hz). In this case, gradually turning the resonator, we can observe a smooth shift of frequency $\delta\nu_{\text{saph.}} = |\nu_{\text{saph.}} - \nu_{\text{evac.}}|$ which is many order greater than $\delta\nu_{\text{evac.}} = |\nu_{\text{evac.}\perp} - \nu_{\text{evac.}\parallel}| = 10^{-3} \div 1$ Hz. Frequency shift may attain, according to estimations by (19), magnitudes $\delta\nu_{\text{saph.}} = \Delta\nu_{o\ \text{evac.skip}} = \nu/m \approx 3\cdot 10^{14}/380000 = 0.79\cdot 10^9$ Hz, where $\nu = 3\cdot 10^{14}$ Hz is the resonance frequency of resonators in [1, 2]. Clear that in this case the electronic system of automatic trimming of laser;s frequency, tuned at 380000 mode may jump to the mode with $m = 380000 \pm 1$.

In order to rise the signal/noise ratio from the sapphire resonator at the output of the frequency converter it would be useful to decrease the amplitude of laser signal at its input below 20 mW, not fearing a dropping of the signal power at the output of the converter below 20 nW, since noises of nonlinearity of the converter may fall in greater times.

To avoid the above described jump of laser's resonance frequency, feeding sapphire resonator, to the adjacent mode of etalon resonator and for more stable work of the automatic trimming the frequency of signal resonator it should be taken etalon resonators with having cavities of lesser dimensions. Then, according to (19), the width $\Delta\nu_o$ of frequency band of reference resonators will become greater and frequency distance between adjacent modes will raise to a value which will be covered by the shift $\delta\nu_{\text{saph.}} = |\nu_{\text{saph.}} - \nu_{\text{evac.}}|$.

5. DISCUSSION

So, we used the Fresnel model (3) of drag of light by the moving medium regarding the medium's velocity υ to be its velocity in the absolute frame of reference. This model has prompted us to take into account the polarization contribution of particles of the medium (laboratory vacuum) where the light propagates. Substituting all the characteristics and result of the experiment [1] in the calculation by formula (6) and (2) or (18) and (2), derived from the Fresnel model, we obtained $\upsilon \neq 0$. This is the consequence of that measurements [1] were performed not in absolute vacuum ($n = 1$) as in aether medium without particles but in the aether medium with particles having the refractive index $n > 1$.

For expected values υ by (18) there was made the prognosis $\delta\nu/\nu = \left(\upsilon^2/c^2\right)\left(n^2 - 1\right)$ of the relative difference between resonance frequencies of orthogonal resonators which supposed verification of the model on media having various optical densities n. Fig.1 basing on measurements of [2] of the relative shift $A_\nu = \delta\nu/\Delta\nu_o$ of the frequency band of the width $\Delta\nu_o = \nu/m$ of vacuumed resonators and measurements in [11, 12] of relative shifts of interference fringes $A_m = X_m/X_o$ at Michelson type interferometers reproduces the linear dependence $A_\nu(\Delta\varepsilon)$ and $A_m(\Delta\varepsilon)$ in the wide range of values $\Delta\varepsilon = n^2 - 1$. It is constructed for lengths of arms of interferometers approximately equal to longitudinal dimensions of cavities of volume resonators ($15 \div 25$ cm). The air pressure from the deep rarefaction ($< 10^8$ bar) to normal pressure $p = 1$ bar were taken by me from description of experimental setups by the authors [1, 11, 12] and were interpreted in a new fashion [13, 14].

The frequency band of the width $\Delta\nu_o$ in resonator experiments, as was above marked, in essence coincides with the width of the interference fringe of the Michelson interferometer. The ratio $\delta\nu/\Delta\nu_o$ of the absolute shift $\delta\nu$ of resonance frequency ν of resonator to the width of frequency band $\Delta\nu_o = \nu/m$ we call here the relative shift of frequency band of the resonator, which is in essence adequate to the relative shift $A_m = X_m/X_o$ of the interferometer's fringe having width X_o.

We take into account the adequacy of such notion comparing at Fig.1 results of measurements of relative shift $A_m = X_m/X_o$ of interference fringe obtained at Michelson interferometers [3–5, 11, 12] with results of the shift of frequency band $\delta\nu/\Delta\nu_o$ at resonators [1, 2]. Comparing shifts (of frequency bands of resonators and interference fringes of interferometers) was made at Fig.1 for identical lengths ($l_\perp = l_\parallel = 15$ cm) of m-cavities of resonators and arms of interferometers. In works [13, 14] I demonstrated that measurements of the shift of high contrast interference fringes in [11, 12] can be made only at parasitic multiple reflections from ends of plexiglas and glass rods in the air and vacuum, respectively. In this event the length of parasitic reflections gaps, playing part of "arms" of interferometers, was $l_\perp = l_\parallel \sim 15 \div 25$ cm. It is this that enabled us to compare at Fig.1 results of registered in [11, 12] non-zeroth shifts of interference fringes with shifts of resonance frequencies of [1, 2] at the same densities of particles in light's carriers: at the deep ($< 10^{-8}$ bar, -•) and usual ($\sim 10^{-2}$ bar, -•) vacuum, and in air of normal pressure (1 bar, -•).

To be exact, I have constructed the straight line in coordinates $\delta\nu(\Delta\varepsilon)$, where $\Delta\varepsilon = n^2 - 1$. The slope of this line was computed by my model with data of [1], the initial point corresponds to parameters of the system studied in [1]: pressure 10^{-8} bar ($\Delta\varepsilon = 6 \cdot 10^{-12}$) and relative frequency shift $\delta\nu/\nu = 10^{-17}$. As we can see from Fig.1, the extrapolation of this line to higher densities runs just through the points of [11, 12], remoulded in terms of $\Delta\nu_o/\nu \sim \Delta X_m/X_o$ with the account of remarks in table I.

The authors [1, 2] may quickly check the validity of this prediction with their experimental setup. The general recommendation is that measurements should be made first for moderate values of the gas pressure, starting from $p = 10^{-8}$ bar and then pass to higher densities. As we approach the normal pressure, the shift $\delta\nu$ of the resonance frequency is expected to increase by 5 orders, from infra-low frequencies to 10^5 Hz, and thus get out the operation limit of measuring instruments of the work [1], $10^{-3} \div 1$ Hz. Therefore, the entire measuring circuit of the installation should be rearranged to a wider range of frequencies.

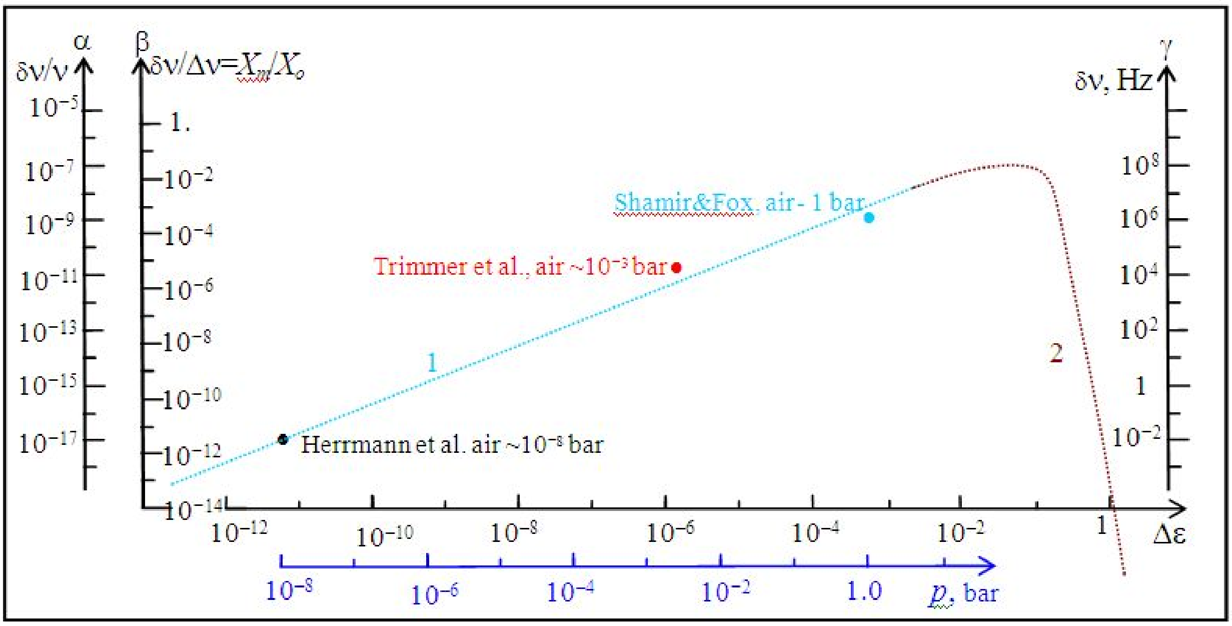

FIG. 1: The dependence of the relative shift $\delta\nu/\nu$ of resonance frequencies (scale α), or relative shift of frequency band (scale β), or absolute shift of resonance frequencies (scale γ) of orthogonal gas-filled resonators or interferometers with short ($15 \div 25$ cm) gas-filled arms, on the contribution $\Delta\varepsilon = n^2 - 1$ of particles into its dielectric permittivity $n^2 = \varepsilon = 1. + \Delta\varepsilon$ of the light's carrier (or on the pressure p of the gas in the zone of the light's carrier). 1 $-$ by measurements [1, 2] of the relative shift of frequency band $\delta\nu/\Delta\nu_o$ of the width $\Delta\nu_o = \nu/m$ between adjacent modes of the resonator; 2 $-$ by my measurements [3–5] of the relative shift of interference fringe X_m/X_o of the width X_o at interferometers of Michelson-Morley type.

Aether and particles are differently polarized by the light in the motion along or transverse the vector of velocity $\mathbf{v}$ of translational motion of the optical medium. Excited in this event dynamical spatial dispersion of the refractive index $n(\overleftrightarrow{\mathbf{vc}})$ of the translationally moving optical media creates the phenomenon of anisotropy of light's speed, since it is the refractive index that determines the light's speed $\tilde{c} = c/n(\overleftrightarrow{\mathbf{vc}})$. The isotropy of the light's speed $\tilde{c} = c$ is restored in asymptotic limit of aether without particles $n = 1$.

From table 1 you can see that the wide spectrum of underestimation ($0 \leq \varepsilon \leq 12$ km/s) of the aether wind velocity in the mentioned works contributed to forming in the last ~ 130 years the "negative" status of experiments of Michelson-Morley type which are supposedly unable to ensure the experimental determination of the absolute motion of the Earth's laboratory in aethereal space. I demonstrate that all experiments on Michelson type interferometers and resonator setups of the same type contain in itself vague signs of presence of the shift of interference fringe or frequency band in resonators, and already by this they are positive. The radical revision of all positive in this sense experiments enabled us, first, to raise the sharpness of the manifestation on the appropriately lowered background noise of the device and, secondly, to give the correct interpretation to the observed non-zeroth shifts of interference fringe and shifts of frequency band in resonators. After correction the errors found in the works cited here, the velocity observed in them will be localized in the relatively narrow interval of values $120 \leq v \leq 600$ km/s (see table 1), that testifies to positiveness of the Michelson-Morley type experiment and observability of absolute motions in the moving inertial reference frame itself.

TABLE I: Published over the past 130 years by various authors the results of measurements of the dynamic anisotropy of the speed of light (speed v of the absolute motion), and removing mistakes in measurements or in interpretation that gives the true value $v \approx 500$ km / sec.

N	Authors	Velocity of absolute motion (anisotropy of light speed)	Refined by me speed of absolute motion after correcting errors or artifacts of experiment	Removing mistakes in experiment or its interpretation
1	Michelson, 1881	not detected	–	It is necessary to enlarge the length of arms of interferometer and raise the resolution of band shift from $\sim 1/40$ [9, 10] up to 1/120 [3–5].
2	Michelson&Morley, 1887	$2 \leq v \leq 6$ km/s	$v \leq 240$ km/s	
3	D.C.Miller, 1926	$3 \leq v \leq 12$ km/s	$120 \leq v \leq 480$ km/s	Revision of physical model correcting 40-fold underestimation of v extracted from experiments.
4	Demjanov, 1968	$140 \leq v \leq 480$ km/s	–	Correct processing measurements proposed [3, 5]
5	Shamir&Fox [11]	$v \leq 6.6$ km/s	$v \sim 400$ km/s	Reflection of beams from straight ends of plexiglas rods taken into account [13]
6	Trimmer et al. [12]	$v \leq 3.8$ cm/s	$v \sim 400$ km/s	Reflection of beams from straight ends of glass rods taken into account [14]
7	Herrmann et al. [1]	$\delta c = 30$ angstrom/s	$v \sim 500$ km/s	Permeability of laboratory vacuum inside resonators taken into account, see (7).
8	Nagel et al. [2]	$\delta c = 0.3$ micron/s	$v \sim 600$ km/s	Fixed omission of skip in electronics of stabilization of laser frequency from 380000 to 380000±1 modes of reference cavity resonator, see (19-22).

Disregarding or incorrect accounting of the effect of the medium at the light's path in the arms of the interferometer or in cavities of resonators is typical for all the history of experiments of Michelson-Morley type. The table I presents data of experiments of various authors and my re-interpretation carried out using the model of dragging the light by the translationally moving in the stationary aether particles of the optical medium. The key phenomenon in this model is the synergy (reactive interrelation) of the polarization processes in aether (creating the aether part $\varepsilon_{\text{aether}} = 1.$ of dielectric permittivity) and in particles (which create its material part $\Delta\varepsilon = 1$) forming that in the Maxwell's theory we call the total dielectric permittivity ($\varepsilon = 1. + \Delta\varepsilon$) of the optical medium. The table 1 presents data of experiments of various authors and my re-calculation performed using the model of light's entrainment by the medium as well as fixing marked flaws of experiments over last ~ 130 years.

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