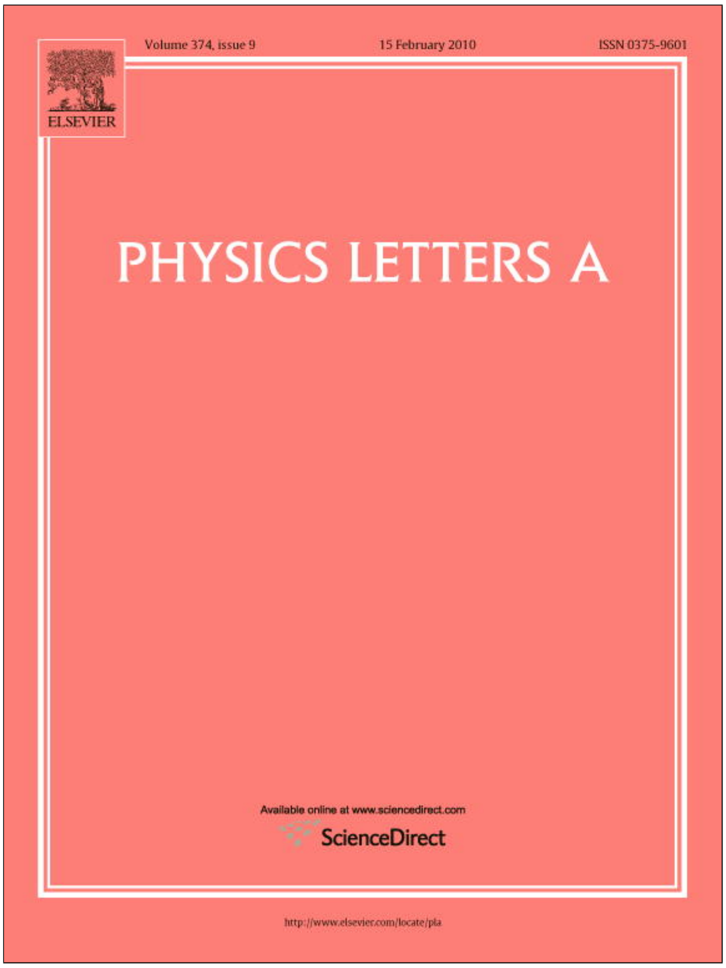
Volume 374, issue 9
15 February 2010
ISSN 0375-9601
ELSEVIER
PHYSICS LETTERS A
Available online at www.sciencedirect.com
ScienceDirect
http://www.elsevier.com/locate/pla

Physics Letters A 374 (2010) 1110–1112

Contents lists available at ScienceDirect

Physics Letters A

www.elsevier.com/locate/pla

Physical interpretation of the fringe shift measured on Michelson interferometer in optical media

V.V. Demjanov

Ushakov Maritime State Academy, Novorossiysk, Russia

ARTICLE INFO

Article history:
Received 3 December 2009
Received in revised form 19 December 2009
Accepted 23 December 2009
Available online 30 December 2009
Communicated by V.M. Agranovich

Keywords:
Michelson experiment
Dielectric media
Fresnel formula
Aether wind

ABSTRACT

The shift of the interference fringe in the Michelson interferometer is absent in vacuum but present in measurements performed in dielectric media with the refractive index greater than unity. This experimental observation induced me to interpret physical processes occurred in the Michelson interferometer in a conceptually new way. I rejected the generally accepted additive rule $c \mp v$ for composition of the velocity v of the inertial body and the speed c of light as inapplicable in principle to non-inertial objects which electromagnetic waves just belong to. I used instead the non-relativistic formula of Fresnel for drag of light by a moving optical medium. This formula, and taking into account the physical effect of Lorentz contraction of the arm of interferometer, enabled me to construct the theoretical model that reproduces in essential features the parabolic dependence of the shift of the interference fringe on the dielectric permittivity of the light-carrying material. The Earth's speed relative to aether found from the experimental curve was estimated as 140–480 km/s. The range of the values refers to the projection of the speed on the horizontal plane of the experimental setup measured at various time of day and night.

1. Michelson experiment and its standard interpretation

By definition, aether is a hypothetical medium that serves to carry over electromagnetic waves and to transmit interactions. Supposedly the Earth moves through the luminiferous aether with a velocity $\mathbf{v}$. In order to detect this motion experimentally Michelson [1,2] measured the time t needed for the light to cover the distance l from the light's source to the rebounding mirror there and back in two directions: $t_\parallel$ is for the propagation path parallel to $\mathbf{v}$ and $t_\perp$ perpendicular to the motion of the experimental setup. The experimental data obtained were interpreted in the following way. By the Michelson's logic we must have:

$$t_\parallel = \frac{l}{c-v} + \frac{l}{c+v}, \qquad (1)$$

$$t_\perp = \frac{2l}{\sqrt{c^2 - v^2}}. \qquad (2)$$

Then measuring the difference of times (2) and (1)

$$\Delta t = t_\perp - t_\parallel \approx -\frac{v^2}{c^2}\frac{l}{c} \qquad (3)$$

we would find the speed v of the "aether wind".

However the measurements of Michelson and later experiments showed that the value of Δt is vanishing. This fact has been explained in the bounds of the physical effect of Lorentz contraction of the length l of a moving with the velocity v body $l' = l\sqrt{1 - v^2/c^2}$ where l' may be the arm of the interferometer in (1). With the account of the latter formula we have the exact equality $t_\parallel = t_\perp$, i.e. $\Delta t = 0$.

2. Michelson experiment in optical media and its non-relativistic interpretation

In 1968–1971 being a scientific researcher at the Obninsk branch of the Karpov Institute of Physical Chemistry I measured [3] Δt on several hand-made interferometers for various transparent dielectric materials used as light's carriers in both arms of the cross-like interferometer. There were employed gas, liquid and solid optical media. The microscopic interference pattern was translated, by means of the vidicon with the optical objective and TV system, on a stationary display, the bandwidth on the kinescope's screen thus being amounted to $X_0 = 90$ mm.

The gas-filled interferometer with the dielectric permittivity lying in the range $1.0003 < \varepsilon < 1.004$ had the arms $l = l_\parallel = l_\perp = 6$ m, and the interferometer with water and solid light carrying materials, $1.5 < \varepsilon < 3$, had the arms $l = 0.3$ m. The harmonic shift of the interference fringe gained in the rotation of the interferometer appeared to be a hundreds times greater for light's carriers with $1.5 < \varepsilon < 3$ than for gas light's carriers. It is the large magnitude of the shift that enabled me to diminish arms of the interferometer to $l = 0.3$ m. For gases measurements were made

E-mail address: demjanov@nsma.ru.

0375-9601/$ – see front matter
doi:10.1016/j.physleta.2009.12.068

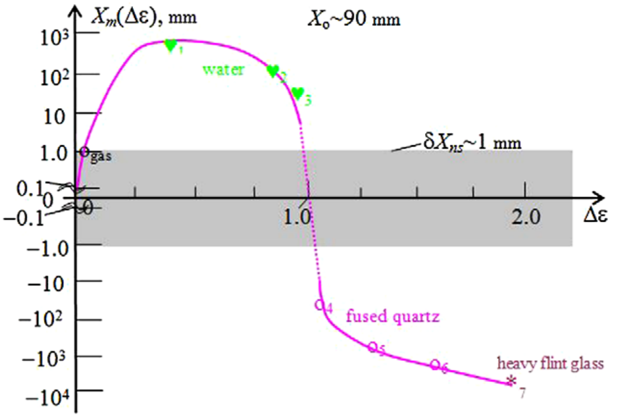

Fig. 1. Dependence of the amplitude X_m of the harmonic shift of the interference fringe on the contribution $\Delta\varepsilon$ of particles to full dielectric permeability $\varepsilon = 1 + \Delta\varepsilon$ of optical media: air, water, fused quartz, heavy flint glass. Measurements were made on various interferometers: with gases for arms $l = l_\parallel = l_\perp = 6$ m, and with water and solid materials as light's carriers for $l = 0.3$ m (all data are reduced to $l = 6$ m). The points 1, 4; 2, 5 and 3, 6, 7 correspond to wave lengths $9 \cdot 10^{-6}$; $9 \cdot 10^{-7}$ and $3 \cdot 10^{-7}$ m, respectively, and for gases the wave length was $6 \cdot 10^{-7}$ m (all data are reduced to $\lambda = 6 \cdot 10^{-7}$ m). X_0 is the interference bandwidth, δX_{ns} the level of the noise.

at the wave length $\lambda = 6 \cdot 10^{-7}$ m. I was able to cover the range $1.5 < \varepsilon < 2$ using the water light's carrier at three different wave lengths $9 \cdot 10^{-6}$, $9 \cdot 10^{-7}$ and $3 \cdot 10^{-7}$ m in the region before the zone of anomalous dielectric dispersion. The range $2 < \varepsilon < 3$ was covered at the same three wave lengths by normal dispersion region of the fused quartz before the zone of anomaly. In order to fit the measurements into a single plot (Fig. 1) they are reduced to a single arm $l = 6$ m and single wave length $\lambda = 6 \cdot 10^{-7}$ m.

In Fig. 1 there is shown the experimental parabolic dependence of the shift X_m of the interference fringe on the difference $\Delta\varepsilon = \varepsilon - 1$ between the dielectric permittivity ε of the optical medium and that of "vacuum". It is proportional to the difference Δt of round-trip times: $X_m = cX_0\Delta t/\lambda$, where X_0 is the bandwidth. As we can see from Fig. 1, the signal/noise ratio considerably improves for media with the refractive index $n > 1$, where $\varepsilon = n^2$. When $\Delta\varepsilon \to 0$ and $\Delta\varepsilon \to 1$ the signal was sunk in the noise. Take notice that measurements made in experiments of previous authors [1,2,4,5] invariably fell into the region near the point o_{gas} (Fig. 1), i.e. sunk or sometimes [4] only slightly raised above the noise.

As before I proceed from the supposition that the Earth, interferometer and hence the optical medium contained in it move translatorily with a velocity v relative to aether. The aim of the present work is to determine v from the experiment. In order to explain the run of the experimental curve shown in Fig. 1, I rejected as inadequate the additive rule $c \mp v$ of the composition of the speed c of light and speed v of the translational motion of the inertial body used in the relation (1). Instead I used the historic formula of Fresnel for the dependence of the light's speed on parameters of a moving optical medium:

$$c_\pm = \frac{c}{n} \pm v\left(1 - \frac{1}{n^2}\right). \tag{4}$$

By the way, formula (4) was recently deduced [6] from Maxwell's equations. We will have instead of (1) in this approach:

$$t_\parallel = \frac{l_\parallel}{c_+} + \frac{l_\parallel}{c_-} \tag{5}$$

where c_+ and c_- are values (4) for the propagation of light along **v** and in the opposite direction respectively. The allowance is made also in formula (5) for the Lorentz effect concerning the length of the moving body. I suppose in this occasion that for media with low optical density used the light resides mostly in aether. Thereby we may assume that in the laboratory reference frame there must be

$$l_\parallel = \frac{l}{\sqrt{1 - v^2/c^2}}. \tag{6}$$

Substituting (6) and respective values of (4) into (5) we obtain for the direction parallel to **v**

$$t_\parallel = \frac{1}{\sqrt{1 - v^2/c^2}}\left[\frac{l}{c_+} + \frac{l}{c_-}\right] \approx \frac{l}{c}2n\left[1 + \frac{v^2}{2c^2} + \frac{v^2}{c^2}\left(\frac{\Delta n^2}{n}\right)^2\right] \tag{7}$$

where $\Delta n^2 = n^2 - 1$. We obtain from (2) and with the account of (4) for the direction of the light's propagation perpendicular to the direction of motion of the light-carrying material:

$$t_\perp = \frac{2l}{\sqrt{c^2/n^2 - v^2}} \approx \frac{l}{c}2n\left(1 + \frac{1}{2}\frac{v^2}{c^2}n^2\right). \tag{8}$$

Subtracting (7) from (8) gives [3]

$$\Delta t \approx \frac{v^2}{c^2}\frac{l}{c\sqrt{\varepsilon}}\Delta\varepsilon(1 - \Delta\varepsilon) \tag{9}$$

where $n = \sqrt{\varepsilon}$ and $\Delta\varepsilon = \Delta n^2$ was used. Formula (9) reproduces in essential features the experimental curve (see Fig. 1). From the curve in Fig. 1 and the theoretical model (9) the speed v of the "aether wind" can be estimated as 140–480 km/s. The range of values refers to the projection of the speed on the horizontal plane of the experimental setup measured at various time of day and night.

It should be noted that the authors [7] realized as well the necessity to perform the Michelson experiment in optical media. Though the linear model $X_m \sim l\Delta\varepsilon$ was obtained by them using too the eclectic form $c/n \mp v$.

3. Discussion and conclusion

On the Michelson-type interferometer there is obtained for optical media with the refractive index greater than unity the shift of the interference fringe that enhances considerably the ratio signal/noise. Thereby there was measured confidently the difference of round-trip times between the paths of propagation of light in parallel and transverse direction to the path of translatory motion of the interferometer. It was found that this difference depends parabolically on the contribution $\Delta\varepsilon$ of particles into the dielectric permittivity ε of light's carrier. Experimental observations are well described by the theoretical model based on the non-relativistic and non-Galilean formula of Fresnel for the drag of light by the moving optical medium. Thus there was shown the inadequacy of the additive rule $c \mp v$ for composition of the light's speed c and the velocity v of a moving inertial body used in the derivation of the Michelson's formula.

It should be stressed that in terms of the interpretation suggested, which is conceptually different from the standard one, all known measurements (see e.g. [1,2,4,5]) on Michelson-type interferometer, where the normal air pressure was maintained (that corresponds to $\Delta\varepsilon \approx 0.0006$), always must exhibited $X_m \neq 0$ and hence $\Delta t \neq 0$. That is why all experimenters reported the signs of nonzero X_m among the noise when measuring in the laboratory air. But Michelson missed $\Delta\varepsilon$ in his formula (3) and thus obtained from his measurements of X_m the badly understated estimation of the absolute speed of the Earth lying within the bounds of the noise, 5–10 km/s. The same estimation was obtained by Miller [4]. I took into account $\Delta\varepsilon$ in my formula (9). That saved from the fatal mistake, which omits the aether wind, and enabled me to detect the motion of the Earth with respect to the stationary aether. The projection of the absolute Earth's speed on the horizontal plane of the interferometer computed by means of (9) was found to be 140–480 km/s at various time of day and night in the Obninsk latitude. Comparing (3) and (9) we see that the accounting for $\Delta\varepsilon$ gives values of the aether wind's speed $\sim 1/\sqrt{\Delta\varepsilon_{\text{air}}} \approx 1/\sqrt{0.0006} \approx 40$ times greater than those obtained by Michelson and Morley [2], Miller [4] and others using (3).

The disregard of $\Delta\varepsilon$ is the reason why famous experiments on vacuumed interferometers and experiments with γ-rays gave negative results: by (9), $\Delta\varepsilon = 0$ implies $\Delta t = 0$. In these experiments there was $\Delta\varepsilon = 0$ either because of vacuum being in the part of interferometer where the light goes or due to vanishing $\Delta\varepsilon_\gamma$, since the dielectric permittivity ε_γ of any optical media in γ-rays equals one, i.e. $\Delta\varepsilon_\gamma = \varepsilon_\gamma - 1 = 0$. And I showed in the experiments [3] that with the air gradually evacuated from the zones where light propagates the interference fringe shift vanishes. Indeed, by (9) $\Delta\varepsilon \to 0$ entails $\Delta t \to 0$, and $X_m \sim \Delta t$.

So, the experimental data obtained and their theoretical interpretation suggested disclose the origin of the common belief in negative results of the Michelson-type experiments. Firstly, it is the inadequacy of the generally accepted additive rule $c \mp v$ for the composition of the speeds of the non-inertial wave and inertial particles of the optical medium where this wave propagates. Secondly, it is the lack of understanding of the fact that the harmonic shift of the interference fringe measured in the experiment is concerned with the presence in the light carrying material of the polarizable by the light particles. The disregard of their contribution $\Delta\varepsilon$ into the full permittivity of light's carriers brought to that the due shift of the interference shift was overestimated in [1] by $\sim 1/\Delta\varepsilon_{\text{air}} = 1600$ times. In other words, in the experiment of 1881 there should be $X_m/X_0 = 0.000025$ but not $X_m/X_0 = 0.04$ as Michelson expected. This means that it must have been clear from the very beginning that the device with the resolution $X_0/40$ [1] is unable to measure the aether wind when $X_m/X_0 = 0.000025$. Had Michelson taken into account formula (4) in his calculations, he would have became aware of that his technique but not the aether failed.

Acknowledgement

The author is grateful to Dr. V.P. Dmitriyev for valuable comments, fruitful discussion and assistance in the preparation of this Letter.

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