Reenactments of the Michelson-Morley Experiment in Non-Vacuum Media

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Abstract

Alternative explanations to the Michelson-Morley exist and continue to be produced. In the current paper we will deal with a relatively recent reinterpretation[1] of the experiment. The authors of the paper in cause claim that the original data of the experiment has been misinterpreted by generations of physicists due to overlooking the effect of immersing the interferometer in a medium with a refractive index n>1. Our paper is organized as follows: in the background section we will give the correct expressions for the relativistic light speed in arbitrary media. We will follow by explaining the correct equations of the Michelson-Morley experiment in medium with n>1. In the third section we will outline the errors in [1] .

Keywords: Alternative theories to Special Relativity, Michelson_Morley experiment, Fizeau equations, refractive index

1. Background

Using the STR formula for speed composition we get the speed of light propagating in a moving medium as follows: let the refraction index be n, the speed of light in the medium is c/n , if the speed of the moving medium with respect to CMBR v then the light speed with respect to CMBR is:

$$c_{\|+} = \frac{\frac{c}{n}+v}{1+\frac{v*c/n}{c^2}} = \frac{c}{n} + \frac{v}{1+\frac{v}{cn}}(1-\frac{1}{n^2}) \approx \frac{c}{n} + v(1-\frac{1}{n^2}) \tag{1.1}$$

when c/n and v have the same direction and sense and:

$$c_{\|-} = \frac{\frac{c}{n}-v}{1-\frac{v*c/n}{c^2}} \tag{1.2}$$

when c/n and v have opposite senses.

For the case when v and c/n are orthogonal:

$$c_{\perp} = \frac{1}{\gamma} \frac{\frac{c}{n}}{1 + \frac{v * c / n}{c^2}} \tag{1.3}$$

where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

In the following we will use the notation $c_0 = c/n$. Expressions (1.1-1.3) become:

$$c_{\|\pm} = \frac{c_0 \pm v}{1 \pm \frac{v * c_0}{c^2}} \tag{1.4}$$

$$c_{\perp} = \frac{1}{\gamma} \frac{c_0}{1 + \frac{v * c_0}{c^2}} \tag{1.5}$$

We will attach two reference systems, S_1 to the horizontal arm of the interferometer and S_2 to the vertical arm.

In S_1 the components of the light speed are :

$$u_{x(1)} = c_0, u_{y(1)} = 0 \tag{1.6}$$

It follows that in CMBR:

$$u'_{x(1)} = \frac{c_0 + v}{1 + \frac{c_0 v}{c^2}} = c_{\|+} \tag{1.7}$$

$$u'_{y(1)} = 0 \tag{1.8}$$

In S_2 the situation is rotated 90 degrees:

$$u_{y(2)} = c_0, u_{x(2)} = 0 \tag{1.9}$$

such that in CMBR:

$$u'_{x(2)} = v$$
$$u'_{y(2)} = c_0 / \gamma \tag{1.10}$$

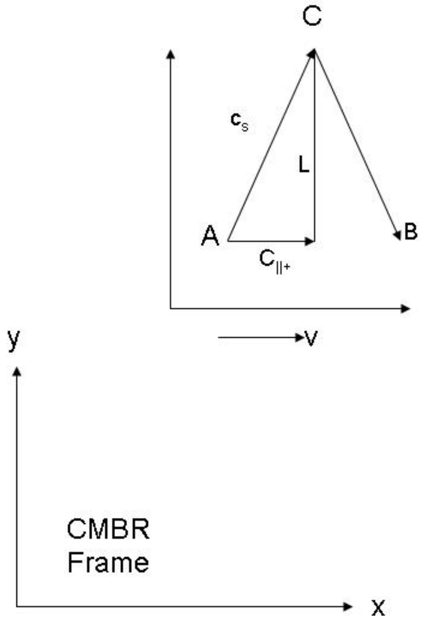

Fig. 1 The Michelson-Morley Experiment

2. The equations for the Michelson-Morley experiment in a medium with n>1

From figure 1. we derive the well known equations for the Michelson Morley experiment. All computations are done from the perspective of the CMBR frame of reference.
The light path along the horizontal arm of the interferometer:

$$c_{\|+} t_{AB} = L_{\|} + v t_{AB} \tag{2.1}$$

$$c_{\|-} t_{BA} = L_{\|} - v t_{BA} \tag{2.2}$$

Due to length contraction:

$$L_{\|} = L / \gamma \tag{2.3}$$

where L is the proper length of the interferometer arm.
From (2.1-2.3) we obtain:

$$t_{\|} = t_{AB} + t_{BA} = \frac{L}{\gamma}\left(\frac{1}{c_{\|+} - v} + \frac{1}{c_{\|-} + v}\right) = \frac{2L\gamma}{c_0} \tag{2.4}$$

For the slanted path of light:

$$t_S = t_{AC} + t_{CB} \tag{2.5}$$

$$(c_S t_{AC})^2 = (L_\perp)^2 + (vt_{AC})^2 = L^2 + (vt_{AC})^2 \tag{2.6}$$

$$(c_S t_{CB})^2 = L^2 + (vt_{CB})^2 \tag{2.7}$$

$$t_{AC} = t_{CB} = \frac{L}{\sqrt{c_s{}^2 - v^2}} \tag{2.8}$$

Since $$c_S{}^2 = u'^2_{x(2)} + u'^2_{y(2)} \tag{2.9}$$

where, according to the speed transformations :

$$\begin{aligned} u'_{x(2)} &= v \\ u'_{y(2)} &= c_0 / \gamma \end{aligned} \tag{2.10}$$

$$c_S{}^2 - v^2 = \frac{c_0{}^2}{\gamma^2} \tag{2.11}$$

$$t_S = 2t_{AC} = \frac{2L\gamma}{c_0} \tag{2.12}$$

The path differential is :

$$\Delta t = t_S - t_{||} = 0 \tag{2.13}$$

exactly as in the case of the vacuum experiments! The presence of the refractive material cancels out when the equations of special relativity is applied correctly. The theoretical result from (2.13) agrees very well with the experimental result from[2] which is a repetition of the MMX experiment with the optical paths in perspex (n = 1.49), and a laser-based optics sensitive to ~0.00003 fringe. They report a null result with an upper limit on V_{aether} of 6.64 km/s.

3. Discussion

It is interesting to mention that it is interesting to set up an asymmetric experiment having only one of the interferometer's legs in a highly refractive material. An example is [3,4], using a triangle interferometer with one leg in glass. They set an upper limit on the anisotropy of 0.025 m/s. This is about one-millionth of the earth's orbital velocity and about 1/10,000 of its rotational velocity. Indeed, if we revisit (2.13) in this particular case we obtain:

$$\Delta t = \frac{2L\gamma}{c}(n_1 - n_2) \tag{3.1}$$

In the lab frame time appears dilated:

$$\Delta t' = \frac{2L\gamma^2}{c}(n_1 - n_2) \tag{3.2}$$

Formula (3.2) allows for immediate calculation of v from the fringe shift. As shown in [3], the method allows for setting very tight limits on the speed v.

4. Conclusion

We have shown that correct usage of relativistic equations restores the order in the interpretation of several two way light speed measurements.

References

1. M. Consoli and E. Costanzo “From classical to modern ether-drift experiments: the narrow window for a preferred frame” Phys.Lett A , **333** (2004), p355.

2. Shamir and Fox, N. Cim. **62B** no. 2 (1969), p258.

3. Trimmer et al., Phys. Rev. **D8**, (1973), p3321.

4. Trimmer et al., Phys. Rev. **D9** (1974), p2489.