Michelson and Morley Experiment Does not Validate Length Contraction (version 1.1)

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25 April 2017[1]

Abstract

The theory of length contraction was initially proposed to uphold the existence of aether after the surprise null result from Michelson and Morley (M&M) experiment. The theory claimed that any physical object shrinks in the direction of its movement through aether. The theory is accepted by special relativity. It is, however, redefined as the shortening of any physical object in the direction of its movement relative to an observer.

This article shows that M&M experiment does not support length contraction, and time dilation, as the theory was not based on all-inclusive analysis of the experiment. In fact, the distance travelled by the half-silvered mirror was not examined in the experiment to find out it does not agree with length contraction. Subsequently, the constancy of the speed of light becomes uncorroborated by the experiment.

1 - Introduction

M&M Experiment [1] carried out in 1887 to verify the existence of aether and to measure the velocity of the earth through it, following its predicted effect on the speed of light. The unexpected null result was interpreted with various theories including length contraction of any physical object in the direction of its movement through aether which was assumed to be a universal stationary medium. Later, special relativity (SR) rightly dismissed the theory of aether. Yet, it accepted the idea of length contraction along with time dilation. SR also assumed that the speed of light in a vacuum is measured the same by all observers who are moving relative to the source of light with any constant speed at any direction.

One should, however, note a very important point that one-way measurement of the speed of light in vacuum, c, has not yet been possible. All measurements of c, so far, are two-way measurements [2], including M&M experiment[2] and certainly not in vacuum.

[1] The first version of this article was created on 17 Sep. 2017.

[2] See *An Inquiry into the Speed of Light (Version 2)* for a brief analysis of two-way measurement [7]

2 - Vector Presentation

Equipped with SR, modern physics accepts that any non-accelerating movement of the source of light does not affect the magnitude of the speed of light measurement. Mathematically, it means that vector operations do not apply to the speed of light. Figure 1 depicts two cases in which the movement of the source is in line or opposite to the direction of the ray of light. The emphasis is that the quantity and direction of the speed of the source parallel to the direction of light has no effect on the measurement of c.

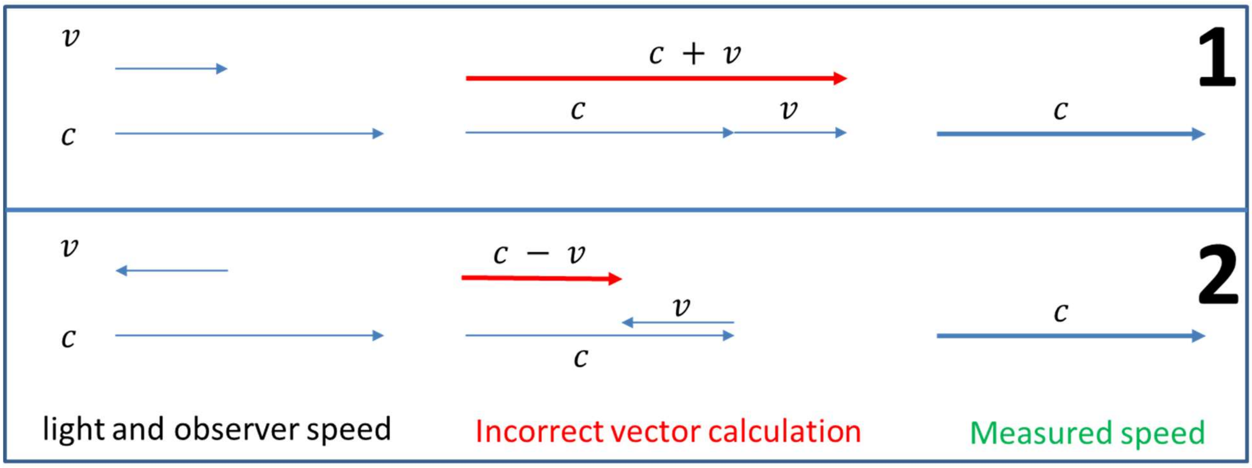

Figure 1 – Vector Presentation of the Speed of Light Measurement

But what about the effect of the source movement on the direction of light for non-parallel cases? Mathematically, the movement of the light source also should have no effect. However, based on SR, for an outside observer the direction of light is affected by the speed of the source. The accepted effect is depicted in Figure 2.

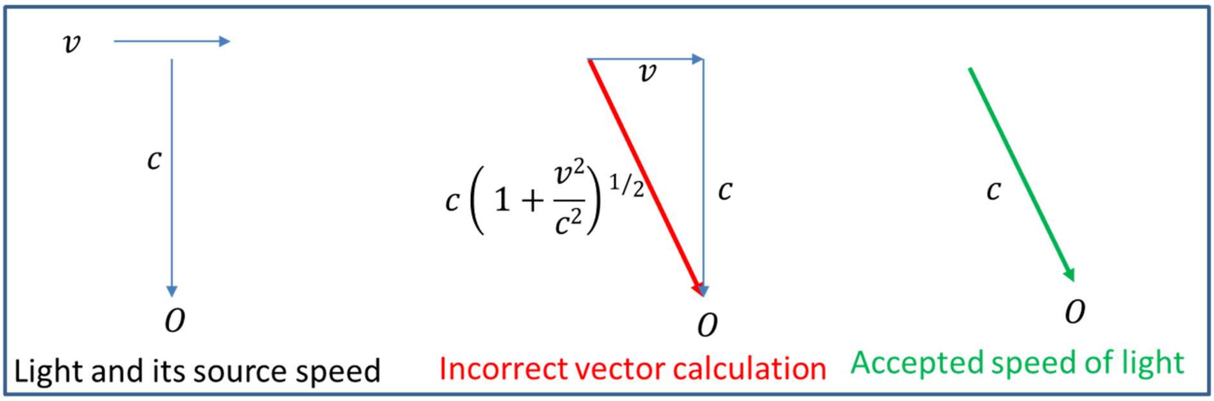

Figure 2 – The Accepted Effect of the Movement of the Source on the Direction of Light

This is different from classical mechanics. For comparison, suppose a ball is thrown vertically up and travels with constant speed to the ceiling of a space wagon and is bounced back with the same speed.

If the effect of the constant speed of the wagon on the speed of the ball is studied by an outside observer, it is concluded that both magnitude and direction of the speed of the ball are affected. In this case vector algebra is honoured for both magnitude and direction.

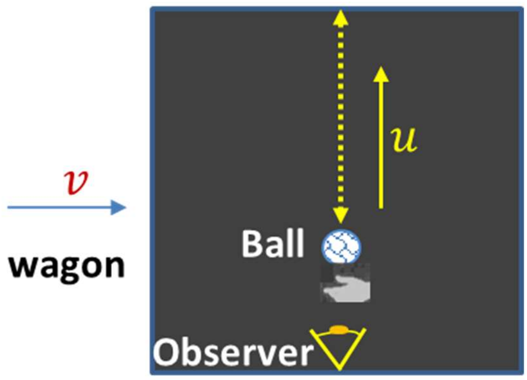

Figure 3 – The Movement of a Ball within a Non-Accelerating Wagon

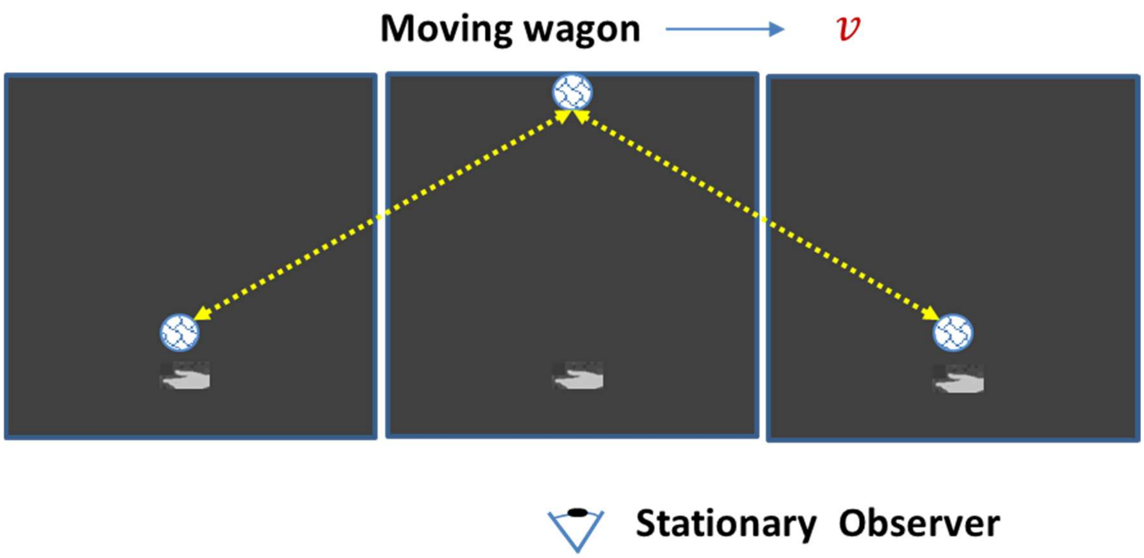

Figure 4 – The Movement of the Ball According to an External Observer

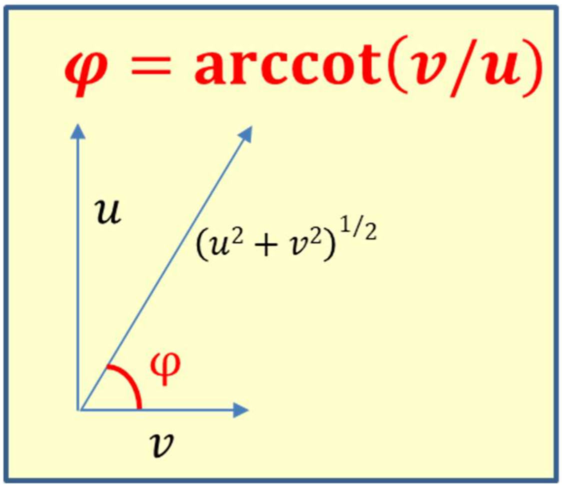

Figure 5 – Vector Presentation of the Speed of the Ball According to an External Observer

3 - The Reason for the Directional Effect on Light

One major reason and at the same time a vital application for this effect is Einstein's light clock which is in fact a theoretical instrument[3]. The unit of time in a stationary clock is T_0 which is the time interval for a round trip of the pulse of light from the top or bottom mirrors[4].

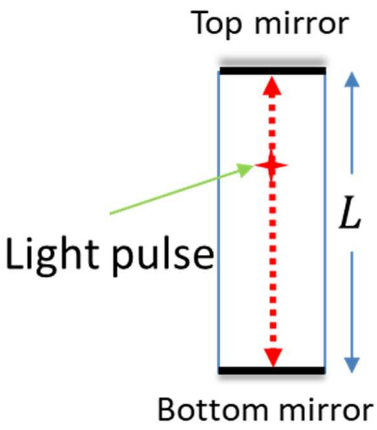

Figure 6 – A Light Clock

In SR, the movement of a light pulse within a moving light clock when observed by a stationary observer is accepted to be the same as the movement of the light pulse within a stationary light clock when observed by a moving observer. Accepted travel path of light for stationary and moving clocks are depicted in Figure 7[3], [4]. Key conclusions of SR are based on the analysis of the accepted working assumption of the clock in various thought experiments.

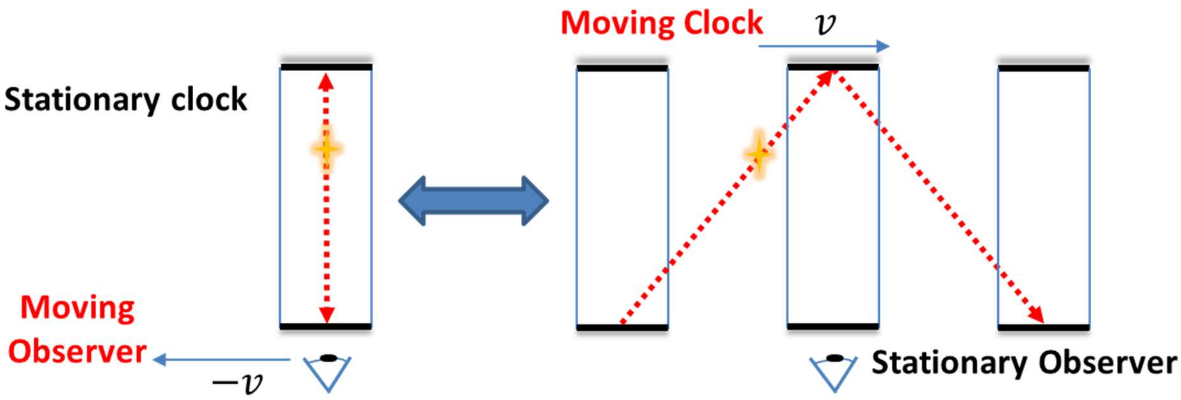

Figure 7 – Accepted Travel Path of Light Beam in Stationary and Moving Clock

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[3] See An Inquiry into the Speed of Light (Version 2), for stellar aberration effect [7]

[4] See Tuning Einstein's light clock for more details [6]

In absence of an experiment this admission is the reason for the directional acceptance. There is, however, one more problem.

As the magnitude of c is not affected by the speed of the moving clock, $\boldsymbol{v}$, the angle between light and the speed of the clock, θ, cannot be calculated the same as the angle between the speed of the wagon and the ball movements, φ, when they are observed externally. The angle is calculated by $\mathbf{arccos}(\boldsymbol{v}/\boldsymbol{c})$ and not by $\mathbf{arccot}(\boldsymbol{v}/\boldsymbol{c})$, omitting time and constants for simplicity. Again, the same law of classical mechanics does not apply for light if nothing else is changed.

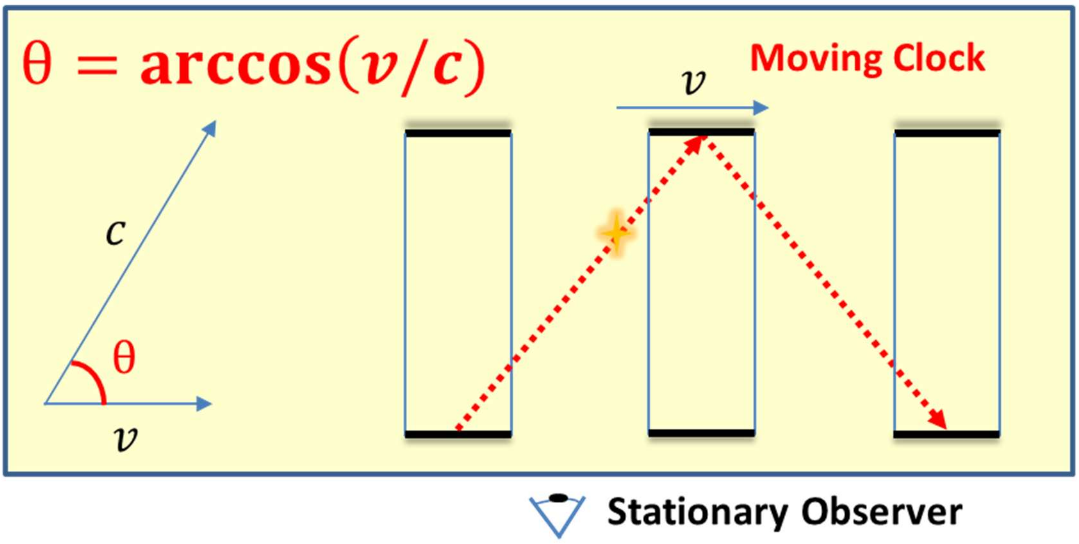

Figure 8 – A Different Rule for Calculating Light Direction

If the magnitude of c was affected by the speed of the moving clock, the angle β in Figure 9 was greater than θ for any $v > 0$. One way to correct this problem, make θ to be equal to β and consequently the movement of light to tie with classical mechanics, is to adjust the adjacent leg by a factor $\boldsymbol{x}$.

$$\frac{v}{c} = \frac{vx}{(c^2 - v^2)^{½}}$$

$$x = \left(1 - {v^2}/{c^2}\right)^{1/2}$$

$$x = 1/\gamma$$

Meaning that the adjacent leg needs to be shortened by a factor of $1/\gamma$, where γ is Lorentz factor. This solution is the reason for acceptance of length contraction in SR.

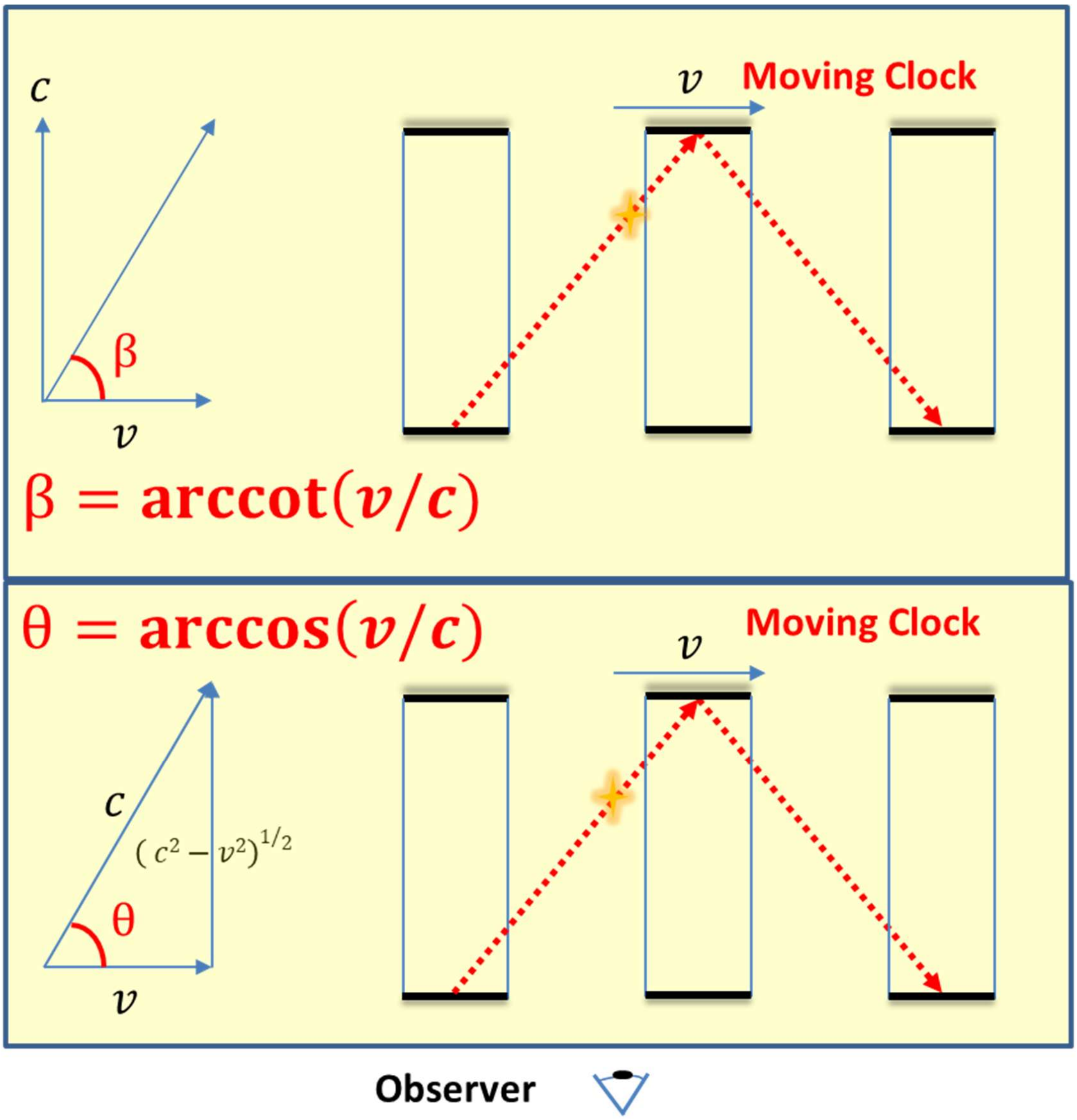

Figure 9 – Analytical Reason for Length Contraction

4 - Michelson and Morley Experiment

So far, the contraction of a physical object in the direction of relative movement in relation to an observer seems justified based on the working assumption of the light clock. Does M&M experiment support this theory. The concern, thus, is not with the existence of aether but solely validation of length contraction using M&M experiment.

M&M split a beam of light by a half-silvered mirror and sent them multiple times to two perpendicular directions using several mirrors and then reflected them back towards an interferometer to verify any effect while rotating the whole platform [1], [5].

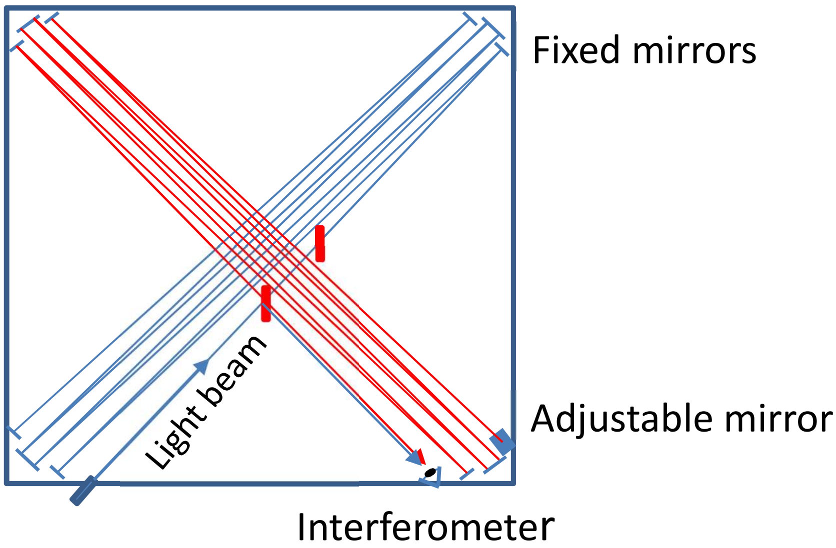

Figure 10 – M&M Experiment Schematic

The simplified version of experiment for analytical study is shown in Figure 11. The experiment can be considered as putting two light clocks perpendicular to each other on the platform. In the Figure, one clock is shown to be in the direction of the movement of the frame and the second one is perpendicular to it.

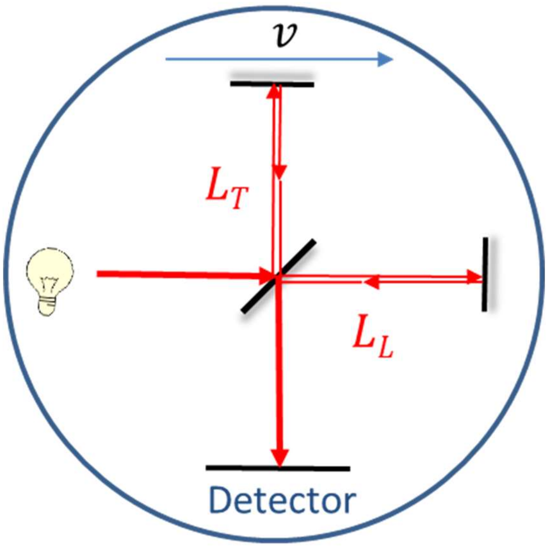

Figure 11 – Simplified M&M Experiment Concept

If the overall speed of the two light beams or the distances they travel changes slightly its effect could be detected in the interferometer. M&M did not observe the expected change with rotation of the whole frame and disregarded slight averaged changes, attributing them to experimental errors. It means that the initial longitudinal, L_L, and transverse, L_T, round trips of light do not change from the initial setting or change with exactly the same amount.

The result of light travel calculation for each arm, while the whole frame is moving with the constant speed of $\boldsymbol{v}$ is shown in Figure 12 [3][6]. One conclusion from the null result, as acknowledged by SR and is mathematically acceptable is that the frame is contracted by a factor of $\mathbf{1}/\gamma$ in the direction of frame movement or $\boldsymbol{v}$. This is highlighted in Figure 12. Detail calculations are in Appendix A.

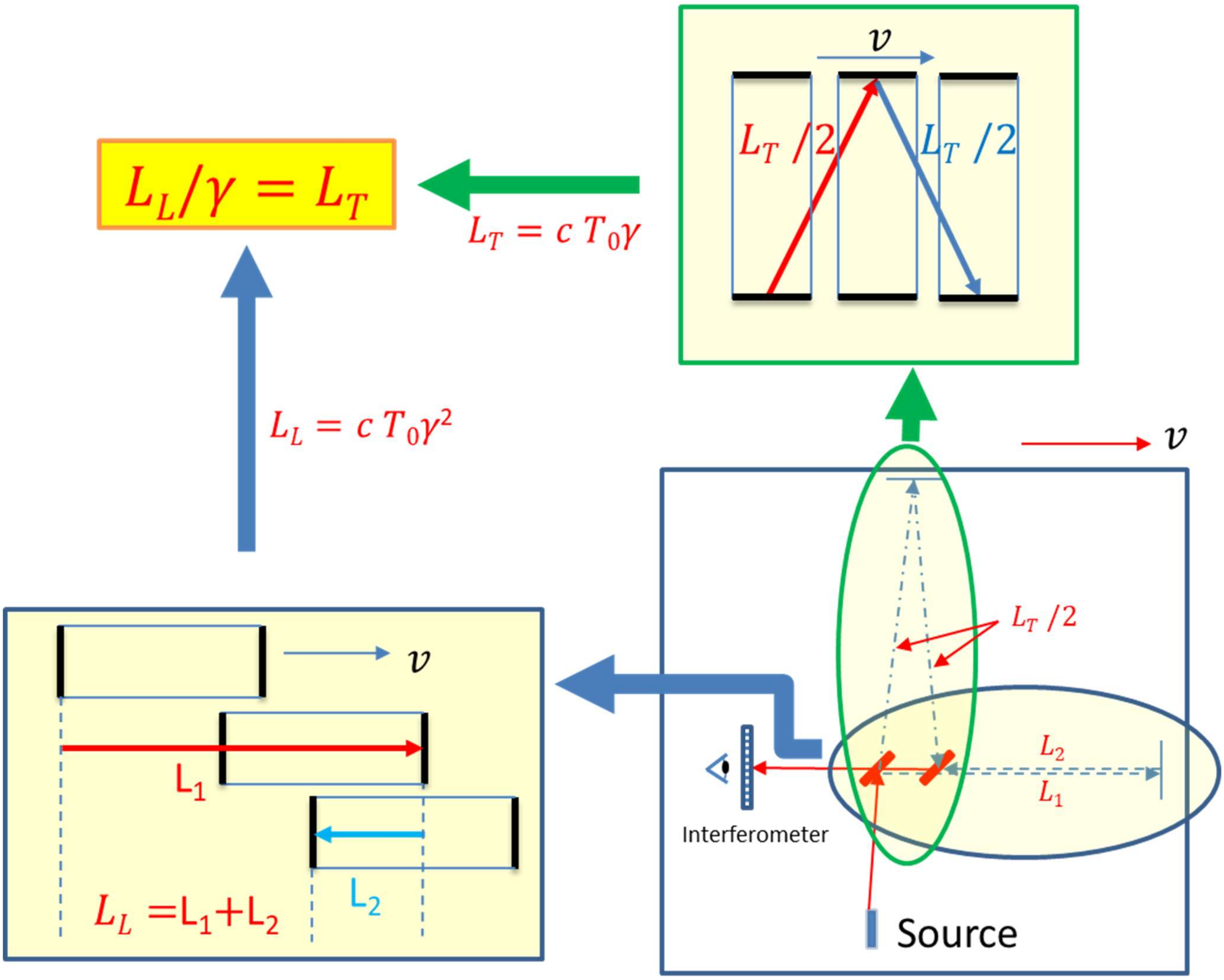

Figure 12 – Distances the Light Beams travel at perpendicular and parallel directions

5 – Just a Simple Oversight

So far so good. But, one should also note that the longitudinal travel of the half-silver mirror must be the same, calculated either way. The problem is that we are as well left with two unequal calculations for the travel of the mirror [3][6], shown in Figure 13. We cannot arbitrarily reduce the outcome of one calculation by $1/\gamma$ as both distances are calculated for the same longitudinal travel of the mirror. Obviously, this discrepancy in the travel of half-silvered mirror calculation should be enough to refute length contraction and time dilation theory. The refutation of time dilation is now obvious. It is enough to divide both sides of the equations by $\boldsymbol{v}$.

The inconsistency stems from the variation of the unit of time with the physical directions of the light clock relative to $\boldsymbol{v}$ [5].

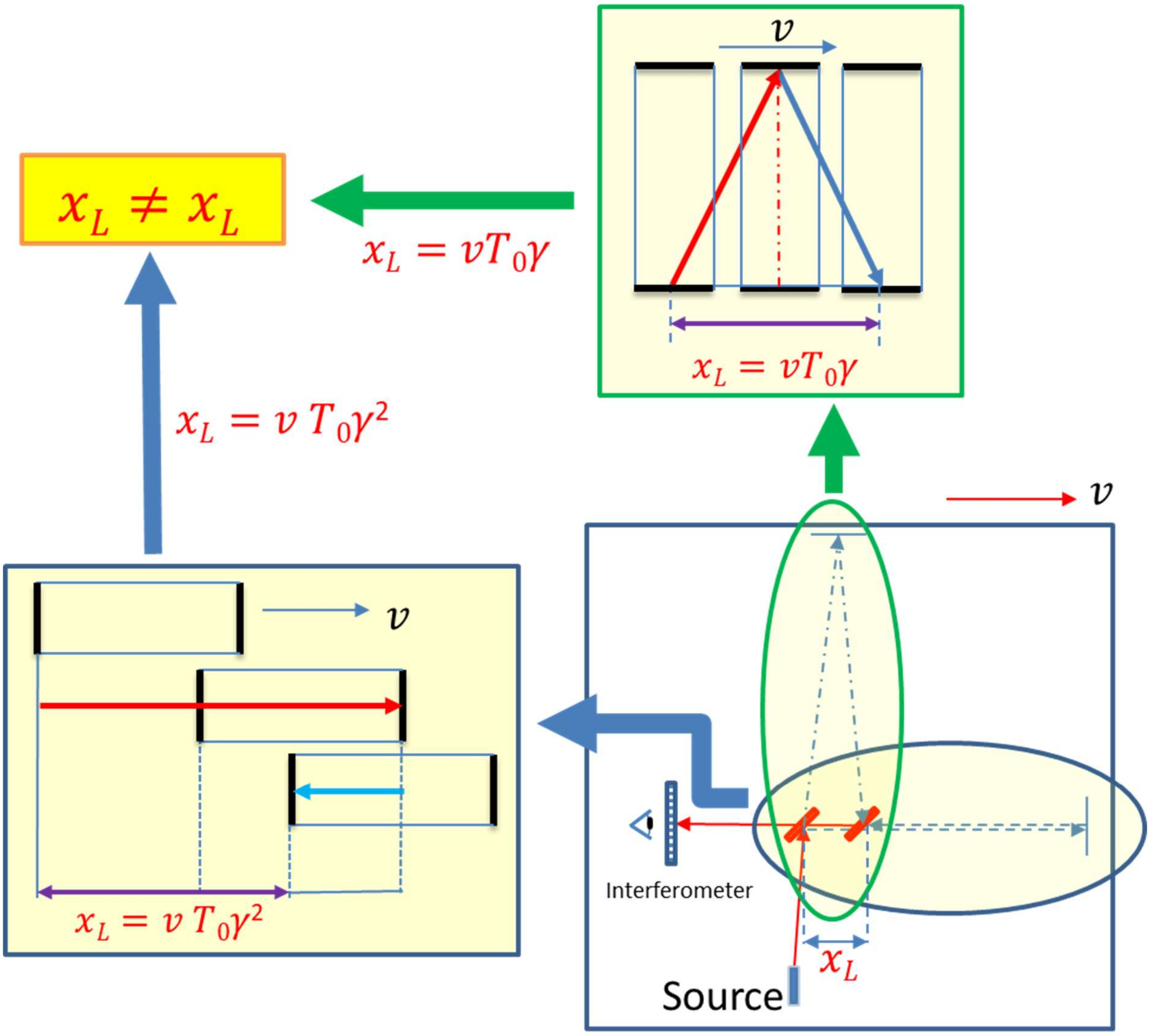

Figure 13 – Two Distances for the Travel of Half-Silvered Mirror!?

[5] See Tuning Einstein's light clock for more details [6]

6 – Does M&M experiment support the constancy of the Speed of Light?

In absence of any one-way measurement of the speed of light, c, M&M have provided us with the only experiment which can be examined for the idea of the constancy of c.

The inconsistency in the calculation of half-silvered mirror also brings the constancy of c under serious scrutiny. Length contraction and constancy of c work hand in glove as was demonstrated in section 3. If length contraction is not defendable by M&M experiment the same goes for the constancy of c.

The experiment in fact suggests that both magnitude and direction of light is affected by the speed of the source similar to the wagon and ball case in classical mechanics.

7 – Conclusion

In this article, the movement of half-silvered mirror in M&M experiment is examined. If we accept the constancy of c then there are two different calculations for the displacement of the mirror. This inconsistency not only refutes the theory of length contraction but also the constancy of the speed of light. Simply, Michelson and Morley experiment does not validate the following three renowned ideas:

- length contraction
- time dilation
- constancy of the speed of light

8 – References

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3. A.P. French, *Special Relativity*, the MIT Introductory Physics Series, 1968.
4. D. Cassidy, G. Holton, J. Rutherford, *Understanding Physics*, Springer Verlag, 2002.
5. S. Adams, *Relativity: An Introduction to Spacetime Physics*, Taylor & Francis,1997.
6. Z. Shafiei, Special Relativity Project: Tuning Einstein's Light Clock, ResearchGate, 2015.
7. Z. Shafiei, Special Relativity Project: An Inquiry into the Speed of Light (Version 2), ResearchGate, 2017.

Appendix A

This appendix gives details of the calculations for light and the half-silvered mirror travels in M&M experiment for a unit of time.

$(cT_v/2)^2 = (vT_v/2)^2 + L^2$

$(cT_v/2)^2 = (vT_v/2)^2 + (cT_0/2)^2$

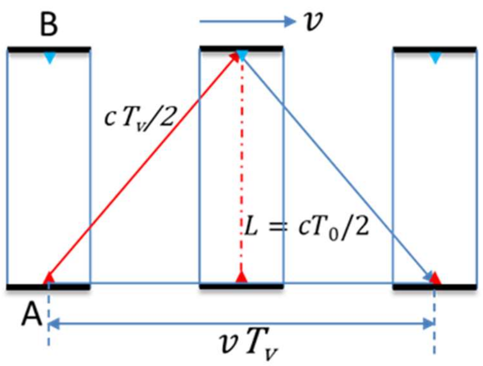
$c^2T_v^2 = v^2T_v^2 + c^2T_0^2$

$c^2T_v^2 - v^2T_v^2 = c^2T_0^2$

$T_v^2(1 - v^2/c^2) = T_0^2$

$T_v = T_0/(1 - v^2/c^2)^{½}$

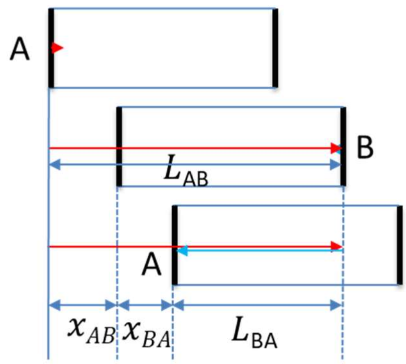
$\boldsymbol{T_v = T_0\ \gamma}$ **(Time dilation)**



$$\boldsymbol{L_T = cT_v = c\,T_0\gamma}$$ (Distance travelled by light)

$$\boldsymbol{vT_v = vT_0\,\gamma}$$ (Distance travelled by half-silvered mirror)

From A to B we can write the following equation.



$L_{AB} - x_{AB} = L$

$T_{AB}c - T_{AB}v = cT_0\,/2$

Therefore, the time interval for light to go from A to B is

$$T_{AB} = \frac{cT_0}{2(c-v)}$$

From B to A we can write the following equation.

$L_{BA} + x_{BA} = L$

$T_{BA}c + T_{BA}v = cT_0\,/2$

and thus, the time interval for light to go from B to A is

$$T_{BA} = \frac{cT_0}{2(c+v)}$$

The total time interval for the round trip of light then is

$$T_v = T_{AB} + T_{BA} = T_0/(1 - {v^2}/{c^2})$$

$$\boldsymbol{T_v = T_0\gamma^2}$$