An interferometer to defeat length contractions

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Abstract

Following the failure of the Michelson-Morley Experiment (MMX) to measure Earth's motion through space, many theories were proposed in an attempt to explain the unexpected results. The more prevalent theory today is that of length contraction effects. This paper proposes a novel use of a Sagnac interferometer to measure an observer's velocity in space. The interferometer was designed in a way that even if Length Contraction effects are present, the interferometer will still be able to produce a measurable result. The interferometer is not as efficient as a Michelson Interferometer, requiring longer mirror distances, but it becomes very simple and practical for high velocities such as the Solar System velocity within the Milky Way galaxy.

Introduction

In 1887, Albert Michelson and Edward Morley [1] performed an experiment intended to measure Earth's motion through space. The interferometer was sensitivity enough for measuring Earth's orbital velocity around the Sun. While there were minor changes in the interference pattern during the experiment, these were too small to be of any significance. The general conclusion is that no motion was detected. A brief discussion is presented here, as well as the prevalent explanation for the null result.

A simplified version of the experimental setup is presented in Figure 1. An incoming light beam 'a' is split into beams 'b' and 'c'. These beams are reflected back as beams 'd' and 'e' and recombined into beam 'f', which forms an interference pattern.

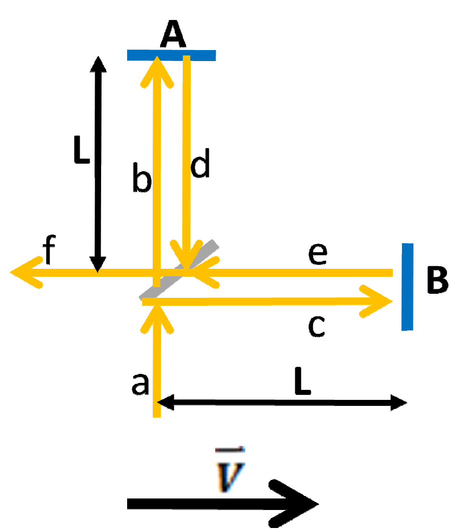

Figure 1. Michelson- Morley experiment setup

When the setup is in motion, as indicated by the vector $\vec{V}$, the time it would take for the beams to complete a round trip is given by the following formulas:

$$t_v = \frac{L}{\sqrt{c^2 - v^2}} + \frac{L}{\sqrt{c^2 - v^2}} = \frac{2\,L}{c\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$t_h = \frac{L}{c - v} + \frac{L}{c + v} = \frac{2\,L}{c\left(1 - \frac{v^2}{c^2}\right)}$$

The number of fringes produced by a 90 degree rotation relative to $\vec{V}$ is given by

$$\#\,fringes = \frac{2\,c\,(t_h - t_v)}{\lambda}$$

Given that

L = 11 meters
v = 30Km/s, (Earth's orbital velocity)
c = $3 \text{ x} 10^8$ (Speed of light)
λ = 550 nm (average wavelength of the light beam used)

The expected fringe shift just on Earth's orbital velocity alone was expected to be ~0.4 fringes.

Since no fringe changes were observed, the Lorentz-FitzGerald length contraction effects hypothesis [2][3] in the direction of motion became the more prevalent explanation; which was later modified and incorporated into Einstein's Special Relativity. The length contraction factor is known as the Lorentz factor and represented by the Greek letter γ.

It is important to note that length contraction effects are used to explain that the times taken by the two beams to make the round trip are the same; and therefore, the interference pattern does not change. While for geometric reasons we can deduce that the times for the vertical beams ('b' and 'd') are equal; this is not the case for the horizontal beams ('c' and 'e'.) It is given that the outgoing beam ('c') will take longer to reach mirror 'B' than the incoming beam ('e') takes to reach the beam splitter; but the sum of the times from both beams ($t_c + t_e$) will be the same as the sum for the vertical beams ($t_b + t_d$).

The purpose of this experiment is to compare one of the vertical beams with only one of the horizontal beams. Would the times be the same? If length contractions are the real explanation for the results of the MMX, then it is clear that the times for individual horizontal beams should not be the same.

Materials and Methods

In 1925, Mr. Michelson did another experiment with the assistance of Henry Gale and their assistant Mr. Pearson[4]. This experiment was intended to measure Earth's surface velocity as it rotates on its axis using a large scale Sagnac interferometer. A simplified version of the interferometer is shown in Figure 2 below.

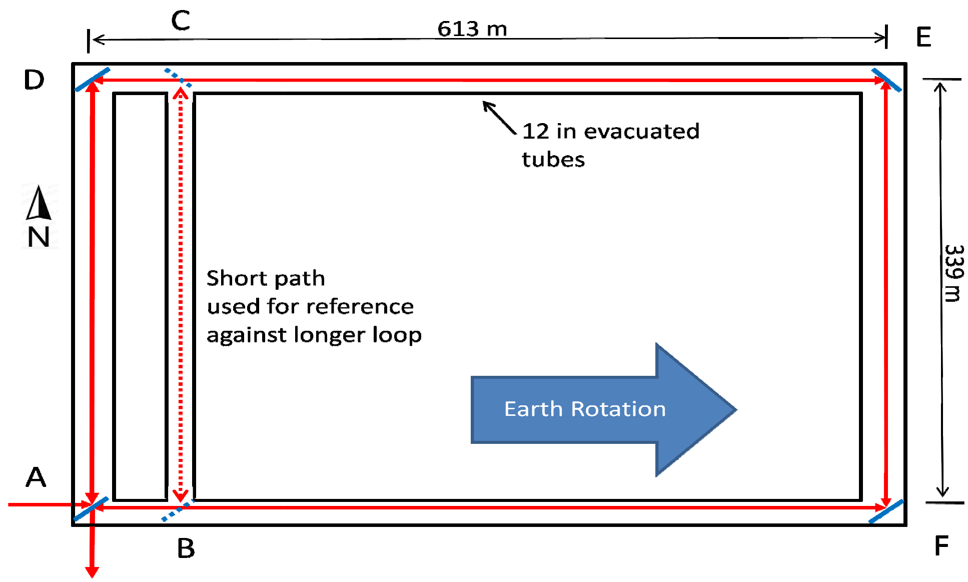

Figure 2. Michelson-Gale-Pearson Experimental setup

This experiment takes advantage of the difference of tangential velocities for Earth's surface at different latitudes. By comparing the difference in time that it takes the two beams to go around the loop, the experiment was able to measure Earth angular velocity; and therefore, verify the difference in tangential velocities.

Inspired by Mr. Michelson's work, and the Martin Hoek experiment[5]; a modified Sagnac interferometer was developed that is capable of measuring an observer's velocity in space, even when length contractions effects are present. This interferometer is shown in Figure 3 below. A Sagnac type interferometer is chosen because they are well known to work, are inherently stable and have low susceptibility to vibration noise.

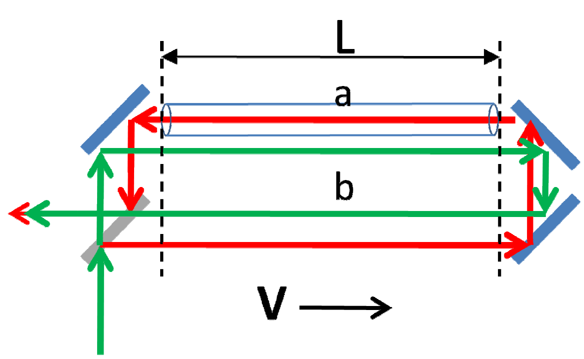

Figure 3

In this interferometer, the two beams do not follow the exact same path in opposite directions as a typical Sagnac interferometer; but are on separate paths in their own loop. The separating distance between beams is about 12 to 15 mm. A green laser beam is aimed at a splitter mirror, resulting in two beams being formed. In Figure 3 above, beams are colored different to make it easier to follow their path. The purpose of separating the beams is to be able to place a glass rod in the path of the top beam labeled ‘a’. The effective length of the interferometer becomes the length of the glass rod. All other paths have no significance. For a detailed description of the setup see Appendix A.

The time that it takes for light to move the length of the path is calculated as follows:

For the red beam (labeled ‘a’) inside the glass rod we use Fresnel formula given that $v \ll c$

$$t_1 = \frac{L}{\frac{c}{n} - v\left(1 - \frac{1}{n^2}\right) + v}$$

For the green beam (labeled ‘b’) in the same direction as beam ‘a’

$$t_2 = \frac{L}{c + v}$$

When we rotate the fixture 90 degrees from vector $\vec{\boldsymbol{V}}$, then for beam ‘a’

$$t_3 \approx \frac{L}{\sqrt{\left(\frac{c}{n}\right)^2 - v^2}}$$

For beam ‘b’ in the same direction as beam ‘a’

$$t_4 = \frac{L}{\sqrt{c^2 - v^2}}$$

From these equations, we can determine Δt for ‘L’ non-length contracted

$$\Delta t = (t_3 - t_1) - (t_4 - t_2)$$

For a length contracted ‘L’

$$\Delta t_c = (t_3 - t_1/\gamma) - (t_4 - t_2/\gamma)$$

Given that

n ≈ 1.5 (glass refraction index)
c = 3×10^8 (Speed of light)
λ = 530 nm (average wavelength of a green laser source)

We can now solve for the expected number of fringe shifts as a function of $\vec{\boldsymbol{V}}$ given ‘L’.

The number of fringes is calculated as before:

$$\# \; of \; fringes = \frac{c \, \Delta t}{\lambda} \; or \; \frac{c \, \Delta t_c}{\lambda}$$

Shown below is Table 1 with the calculated number of fringes when a 0.44 meters glass rod is used. 'L' is both length-contracted and non-length contracted in the calculations.

v	t1	t1/γ	t2	t2/γ	t3	t4	Δt	Δtc	# fringes L not-LC	# fringes L L-C
30000	2.20E-09	2.20E-09	1.47E-09	1.47E-09	2.20E-09	1.47E-09	2.23E-17	2.60E-17	0.013	0.015
217000	2.20E-09	2.20E-09	1.47E-09	1.47E-09	2.20E-09	1.47E-09	1.17E-15	1.36E-15	0.660	0.769
370000	2.20E-09	2.20E-09	1.46E-09	1.46E-09	2.20E-09	1.47E-09	3.39E-15	3.95E-15	1.920	2.235

Table 1

Three different velocities are considered in the table in this order:

1. Earth's orbital velocity around the sun. In this case, the interferometer would produce only 1/100th of a fringe, which is hard to observe.
2. The solar system velocity around the Milky Way galaxy. This would produce more than half a fringe shift. This would be observable.
3. The estimated solar system velocity relative to the CMB. The interferometer would produce about two fringe shift or better.

The next step is to determine the direction where to aim the interferometer. The solar system motion around the Milky Way galaxy is in the direction of the constellation Cygnus (the swan); and the solar system motion relative to CMB is in the direction of the constellation Leo. At some point during the day in the United States south, the star Deneb in the constellation Cygnus, and the star Regulus in the constellation Leo are just above the horizon. This is shown in Figure 4 below. Note that it does not have to happen at night; any time of the day is good, as long as we point in the right direction. Given the high fringe shift expected of the interferometer, an exact calculation of direction is not necessary.

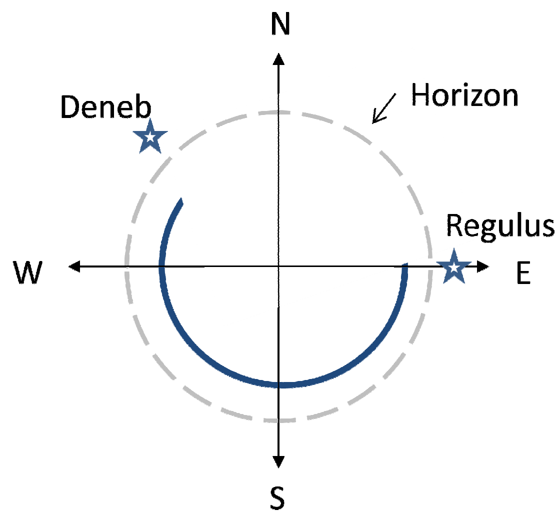

Figure 4

The interferometer was rotated along the path indicated by the solid blue arc in Figure 4, or about 225 degrees. Note that the Solar System velocity in the galaxy and the velocity relative to the CMB are not the same magnitude, or in exact opposite directions; therefore, there is no cancellation of velocities. If both motions are present, then, we should expect a total motion of about 265 Km/s due NE; well within the sensitivity of the Interferometer, and in the path of the experiment. We would expect about one fringe shift if that is the case.

Results and discussion

The interference pattern did not change; no fringe shifts were observed during the experiment after repeated trials. The author recruited the assistance of Mr. Alberto Mancia to perform the experiment.

Sagnac interferometers are well known for being able to measure motion according with defined mathematical calculations; the interferometer used for this experiment can be equally expected to work according to the calculated values.

The conclusion from this experiment is that length contraction effects are not the explanation for the results of the Michelson-Morley experiment; and it puts into question whether length contractions really exists. The reason for the failure to measure any velocity relative to space (consistent with the results of MMX) very well may be because there is none to be measured.

It is important to note that there were no attempts to determine motion in any other direction than what is stated in Table 1; as no other motion has been documented. The author does not expect that the solar system motion can be measured on Earth using interferometry.

While there are many sources of error in the setup (such as the true refraction index of the glass, the exact direction of motion in the galaxy and relative to the CMB, and many others), these would only play a role if motion had been detected. There was no reason to quantify these effects.

Appendix A

Interferometer construction

The interferometer was constructed on a single wood board with 3-D printed parts. Mirrors are first face mirrors. Shown below in Figure A-1 is a picture of the interferometer; Figure A-2 shows the experimental setup with the interferometer mounted on a tripod. Figure A-3 and A-4 shows some of the basic 3-D printed parts. An adjustable voltage regulator was used to control power to the laser source.

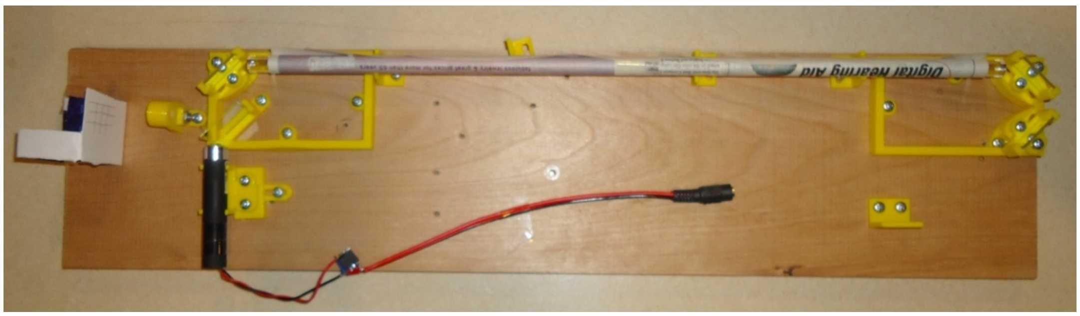

Figure A-1 – Interferometer construction

Figure A-2 - Experiment setup on tripod mount

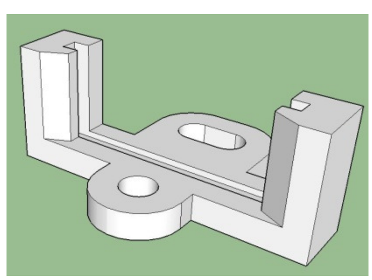

Figure A-3 - Mirror housing block

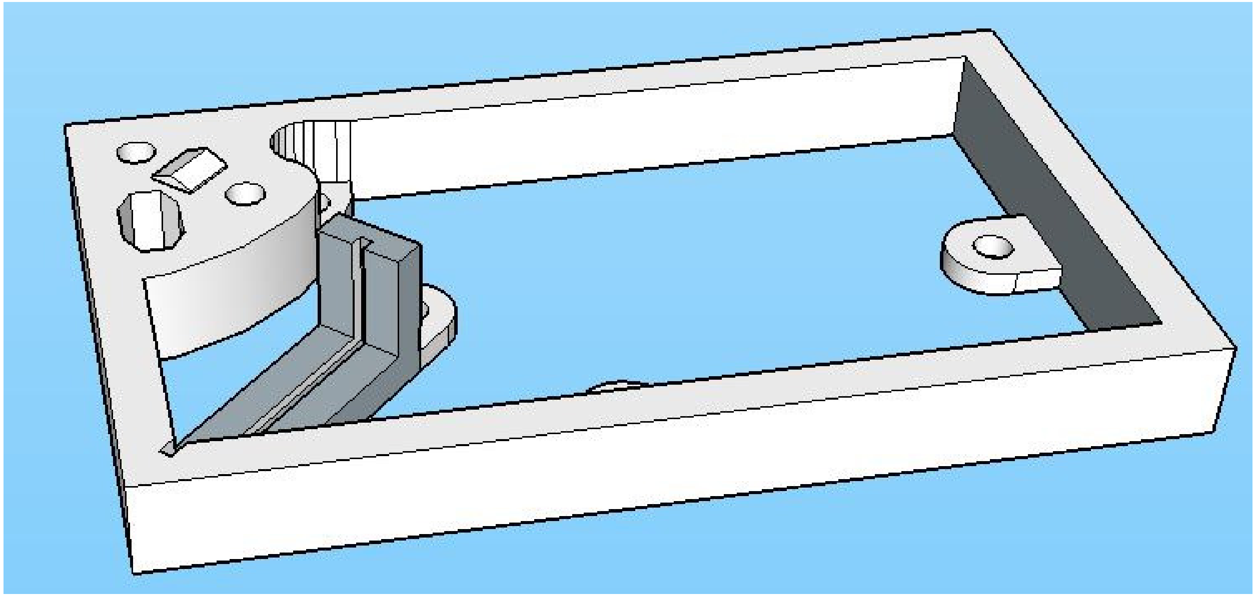

Figure A-4 Beam Splitter housing

References

[1] *Michelson, Albert A.; Morley, Edward W. (1887). "On the Relative Motion of the Earth and the Luminiferous Ether" .*

[2] *FitzGerald, George Francis (1889), "The Ether and the Earth's Atmosphere"*

[3] *Lorentz, Hendrik Antoon (1892), "The Relative Motion of the Earth and the Aether"*

[4] *Michelson, A. A.; Gale, Henry G. (1925). "The Effect of the Earth's Rotation on the Velocity of Light, II".*

[5] *Hoek, M. (1868). "Determination de la vitesse avec laquelle est entrainée une onde lumineuse traversant un milieu en mouvement"*