Physical Science International Journal
12(4): 1-5, 2016; Article no.PSIJ.29643
ISSN: 2348-0130

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The Wonderful World of Hammar's Experiment

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/PSIJ/2016/29643
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Complete Peer review History: http://www.sciencedomain.org/review-history/16896

Original Research Article

Received 22nd September 2016
Accepted 3rd November 2016
Published 14th November 2016

ABSTRACT

In a rather terse note, published in 1935, G.W. Hammar explained his brilliant experiment destined to put away, once and for all, the notion of "aether entrainment". Certain physicists, such as Dayton Miller, insisted that the null result of the Michelson-Morley experiment and its repetitions could be explained in the framework of Galilean relativity as an artifact of the lab (and the interferometers) "dragging" with them the medium ("aether") necessary for light propagation. Today, this very clever experiment is almost forgotten, taking a backseat to the more famous pillars of special relativity tests: Michelson-Morley, Kennedy-Thorndike and Ives-Stilwell. Maybe the stark parsimony of Hammar's note (one page, no figures, no calculations) is the reason for overlooking this wonderful experiment.

Keywords: Galilean mechanics; aether entrainment; Hammar experiment.

PACS: 03.30.+p.

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1. INTRODUCTION

In the opening of his note Hammar [1] tells us:

"D. C. Miller explains in his report [2] that the difference between his results and those of other experimenters in the field may be due to entrapping of the ether in the heavily enclosed apparatus of the other investigators, while his own apparatus is quite open to the outside atmosphere. If this explanation be correct, it should be possible to detect a differential light velocity between a light beam in a heavily wa1led tube with stopped ends held in the direction of the earth's velocity and a light beam just outside and parallel to the tube."

Hammar reasons that if he could show that there is no "aether entrapment" in the closed arm of the instrument then Dayton Miller's explanation of his "aether wind detection" can be shown to be invalid [3,4]. An instrument capable of "trapping" the aether such that its presence will influence the speed of light in a differential way would be needed for this task. Hammar then proceeds to explain the very clever setup of his experiment (Fig. 1) whereby the arm CD has been encased in a lead tube (represented in blue):

"An apparatus was therefore constructed in which an unpolarized beam of white light was divided by means of a half-silvered mirror into two beams of approximately equal intensities. One beam, entered transversely a heavy walled steel tube with lead plugged ends through a small hole near one end, was reflected by means of a fully silvered mirror a distance of 89.4 centimeters along the axis of the tube, then encountered another fully silvered mirror which reflected the beam out through a small lateral hole near the other end of the tube. Outside the second hole was another fully silvered mirror which projected the beam parallel to the tube toward the originally encountered half silvered mirror through which a portion of the half beam passed a second time, but now at right angles to its original direction. The second of the original half-beams traversed the same path indicated above but in the opposite direction from the half-beam first considered.

Since the two half-beams partly reunited after passing through the half-silvered mirror for the second time, a pattern of interference fringes was seen in the field of the half-silvered mirror."

2. EXPERIMENTAL DETAILS

The "aether wind", if it existed, would affect the speed of light differently for the shielded arm (where the "aether wind speed" is assumed to be w) and the unshielded arm (where the "wind speed is assumed to be $v \neq w$). Hammar uses the symbol $"u"$ for the "aether wind" speed and the symbol $"D"$ for the interferometer arm length, we use $"w"$ and respectively $"L"$. If that is true, the time for traversing the instrument in opposing directions will be different resulting into a fringe displacement. Once the instrument is rotated, as in the Michelson-Morley experiment, the roles of the arms are exchanged, resulting into the fringes of interference shifting by what Hammar predicted to be an observable amount. If, on the other hand, there would be no fringe shift observed, that would mean that the "aether wind" does not affect the speed of light, contradicting D. Miller's claims about why his results differed from the other experimenters. Miller's claim that he detected "motion with respect to the aether" would be invalidated, and the hypothesis of "partial entrainment" for aether would also be rendered invalid. Two (very big) birds knocked off with Hammar's stone.

All calculations in this note are made from the point of view of the "aether frame" and all employ Galilean relativity. The clockwise (t_{CW}) and counterclockwise (t_{CCW}) time of light propagation are (see Fig. 1):

$$t_{CW} = \frac{AB}{c-v} + t_{BC} + \frac{CD}{c+w} + t_{DA}$$
$$t_{CCW} = t_{AD} + \frac{DC}{c-w} + t_{CB} + \frac{BA}{c+v} \quad (1)$$

In (1) AB, CD DC and DA are the light paths and $t_{BC}, t_{DA}, t_{AD}, t_{CB}$ are the times necessary to traverse the paths BC, DA, AD and CB respectively and "c" is the speed of light in vacuum. The "aether wind speed" is assumed to be w in the shielded arm CD and $v \neq w$ in the unshielded arms AB, BC, DA.

Obviously, the times in the arms moving perpendicular on the "aether wind" do not depend on the traversal sense:

$$t_{DA} = t_{AD}$$
$$t_{BC} = t_{CB} \quad (2)$$
$$AB = BA = CD = DC = L$$

Hammar does not mention anything about the FitzGerald contraction. He doesn't need to, all that is needed is for the "aether wind" to affect the lengths of the parallel arms the same way. It is only the speed of light that is affected differently, due to the presence of the shield. So, the time differential between the clockwise and the counterclockwise paths is:

$$\Delta t = t_{CW} - t_{CCW} = \frac{L}{c-v} - \frac{L}{c+v} + \frac{L}{c+w} - \frac{L}{c-w} = \frac{2L}{c^2}\left(\frac{v}{1-\frac{v^2}{c^2}} - \frac{w}{1-\frac{w^2}{c^2}}\right) \quad (3)$$

According to Hammar:

"If any differential velocity existed between the light inside the tube and that: outside, the position of the interference pattern should depend on this differential velocity."

Given that $v << c, w << c, w \neq v$ one recovers Hammar's result:

"The velocity difference should yield an apparent path difference of 2VD/c^2, where V is the difference in the ether drifts outside and inside the tube"

$$\Delta t \approx \frac{2L}{c^2}(v - w) \quad (4)$$

We are not done yet: when the instrument is rotated such that the shielded arm is moving perpendicular to the "aether wind" (see Fig. 2), the shield no longer "contributes" any difference in the total elapsed times:

$$t'_{CW} = \frac{AB}{c} + t_{BC} + \frac{CD}{c} + t_{DA}$$
$$t'_{CCW} = t_{AD} + \frac{DC}{c} + t_{CB} + \frac{BA}{c} \quad (5)$$

So:

$$\Delta t' = t'_{CW} - t'_{CCW} = 0 \quad (6)$$

The total fringe shift through a 90^0 rotation of the instrument is therefore:

$$\Delta\lambda = c\Delta t = \frac{2L}{c}(v - w) \quad (7)$$

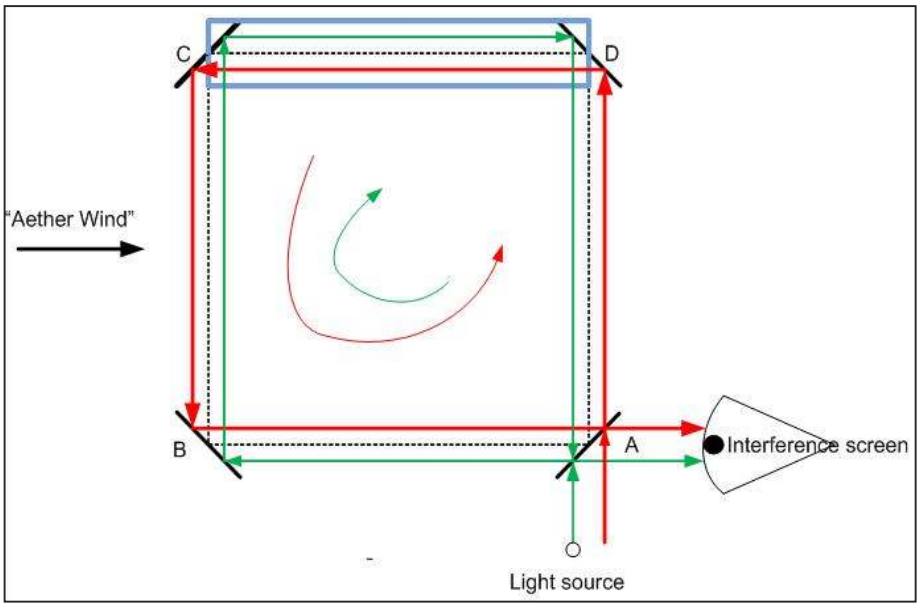

Fig. 1. Instrument motion with shielded arm moving parallel to the "aether wind" the light source as well as the screen where interference occurs between the two light beams is located in point "A". Also, a half-silvered mirror is used as a light splitter

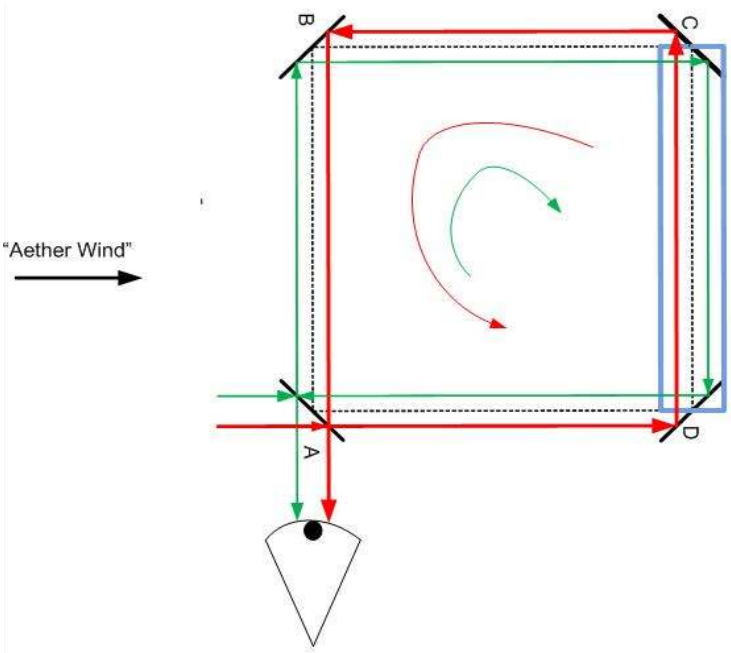

Fig. 2. Setup motion with shielded arm moving perpendicular to the "aether wind"

But, the total fringe shift observed during three consecutive days of observation was null, making Hammar to conclude:

"On September 1, 1934, the apparatus was set up on the top of a high hill about two miles south of Moscow, and many observations were made in all azimuths during the daylight hours of September 1, 2 and 3. No shift of the interference fringes was observed, although conditions were very favorable, and a shift of 1/10 fringe would easily have been seen. ***I conclude that Professor Miller's explanation of the difference between his results and those of the other investigators is not correct****."*

$\Delta\lambda = 0$ means that $w = v$, contrary to Miller's assumption that the shield affects the light speed such that the light speed is different in the interferometer arms. We arrived to a contradiction and the only resolution is that Miller's assumption is invalid. From this point there is one next logical step in concluding that the "aether wind" does not affect the light speed at all, there is no "aether wind", there is no "entrainment".

3. HAMMAR'S GENIUS

Arriving at this final point in analyzing Hammar's only foray in the testing of special relativity a natural question arises: why didn't Hammar simply re-enact the Michelson-Morley/Dayton Miller experiments while encasing one arm of the interferometer? The answer comes from examining expression (1). By using the two counter-propagating light beams we do not need to know the expressions for t_{DA}, t_{AD} nor do we need to know the expressions for t_{BC}, t_{CB}, all we need to know is that they satisfy the equalities (2). The "aether wind" might affect the light speed in the transverse direction in complicated ways, Hammar's setup, by virtue of using counter-propagating light beams frees us from trying to guess what these ways might be. It also proves, once again, that the "aether wind speed" is not measurable [5-21]. This brilliance is lost even on H.P. Robertson [4], in his paper he assumes that the aether wind affects the transverse light propagation according to the Pythagorean way normally associated with the explanation of the Michelson-Morley experiment.

4. CONCLUSIONS

In the present note we have resurrected Hammar's paper from 1935 complete with the figures and the calculations necessary to effectively teach this very important part of the experimental foundations of special relativity. The note is important because it provided the

final step to fully falsify the theory of "entrained aether".

COMPETING INTERESTS

Author has declared that no competing interests exist.

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