First-Order Fiber-Interferometric Experiments for Crucial Test of Light-Speed Constancy*

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The Michelson-Morley experiment for examining light-speed constancy in paths moving linearly is second-order in speed, so it has never been conducted with paths moving relative to Earth. The Sagnac experiment is a first-order experiment, but it does not address motion that is linear, since its path motion is caused by rotation. The design of an interferometric experiment that is not only sensitive to linear motion, but also first-order in speed, needs two features: **1)** optical paths in uniform translational motion, and **2)** paths for light return without cancellation of possible effects. Two arrangements with these features are here presented: a conveyor-like arrangement, and a shearing parallelogram arrangement. Both can be implemented with fiber-optic technology. If the entire optical loop is fiber, the light-speed constancy in a moving path of the fiber is examined; if the fiber loop is broken to leave a gap of vacuum (or air), the light-speed constancy in a moving path of vacuum (or air) is examined. According to the same analysis as that for a fiber-optic gyro, translational motion in these arrangements will lead to an increase of optical path length and an increase of the travel time difference, a result falsifying the principle of the light-speed constancy.

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Introduction

The Sagnac effect [1] shows that in a rotating closed optical path, two counter-propagating light beams take different time intervals to travel the path. For example, when the path rotates counterclockwise, the beam propagating counterclockwise will take a longer time interval than the beam propagating clockwise, and *vise versa*. The time difference between them is given generally by $\Delta t = 4S\Omega / c^2$ (Fig. 1a; the path is a quadrilateral, S is the area of the quadrilateral, and Ω is the angular velocity of the rotation) or for a circle $\Delta t = 2vl / c^2$ (Fig. 1b; the path is a circle, the area of the circle is πR^2, v is the speed ΩR of the circular motion, and l is the circumference $2\pi R$ of the circle). The Sagnac effect is a first-order effect; that is, the time difference Δt is proportional to $(v / c)^1$. The Sagnac effect is an experimental fact with sound foundation and numerous applications, including highly precise fiber-optic gyros (FOG's) [2]. However, the experimental fact becomes controversial when one attempts to reconcile it with the principle of light-speed constancy in Special Relativity Theory (SRT). Some argue that the Sagnac effect is incompatible with light-speed constancy, because, for an observer moving with the closed path, two counter-propagating light beams would travel through paths with the same length, and since their travel times differ, their speeds must differ. Others, however, point out that in the Sagnac effect, the motion that causes the light speed difference is uniform circular, not uniform translational, as required for application of SRT. Therefore, the Sagnac effect remains an unsolved fundamental problem in physics [3]. So the Sagnac experiment cannot be considered a crucial experiment to test the principle of the light-speed constancy.

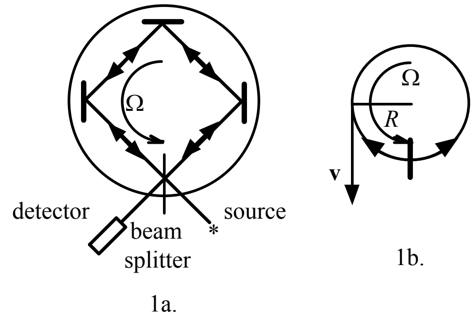


Figure 1. The Sagnac experiment.

In order to have a crucial test for light-speed constancy, the path in uniform circular motion must be changed to a path in uniform translational motion. Interferometric experiments with paths in translational motion have existed for a long time, and among them, the Michelson-Morley experiment is the most important. However, the Michelson-Morley experiment is second-order; *i.e.*, the time difference Δt possible in the experiment is proportional to $(v / c)^2$, where v is the translational speed of the apparatus. Because of that, the existence or absence of the time difference can only be determined when the translational speed v is very high. For example, an airplane, with its speed of about 300 m/s, would not be fast enough to tell whether or not light speed is constant in a path moving relative to Earth. A real test needs a Michelson-Morley type experiment in system moving fast relative to Earth; *e.g.*, a space shuttle [4]. So far, no one has conducted such an experiment. Therefore, the assertion that light speed is still c in a system moving translationally relative to Earth has not yet been verified.

Obviously, if we could have an interferometric experiment that would be not only a crucial for linear motion as the Michelson-Morley experiment is, but also first-order like the Sagnac experiment is, we could more easily conduct the experiment to check whether or not light speed is constant when the path is in translational motion relative to Earth. A crucial first-order experiment using atomic clocks has been proposed [5], but a crucial first-order interferometric experiment would be much superior because an interferometer can easily detect a time difference shorter than the period of a light wave of several femtoseconds.

Experiment Design Requirements

To design a first-order crucial experiment, we should analyze why the Sagnac experiment is first-order while the Michelson-Morley experiment is second-order. The Sagnac experiment is first-order because in its arrangement, when the closed path rotates, one of the two beams *always* propagates in the same direction as the rotation (Fig. 2a), while the other beam *always* propagates in the direction opposite to the rotation. The result is that the effect of the travel-time difference between two beams along the path is always augmented, and never cancelled, and the final effect is proportional to $(v/c)^1$. In the Michelson-Morley experiment, the closed path moves purely translationally. It is impossible for a beam to propagate in the same direction as translational motion over the whole path: if in one part of the path, a light beam propagates in the same direction as the motion, then in another part of the path, the beam must propagate in the opposite direction (Fig. 2b). The effects along these two parts tend to cancel each other, and lead to the final residual effect being proportional to $(v/c)^2$.

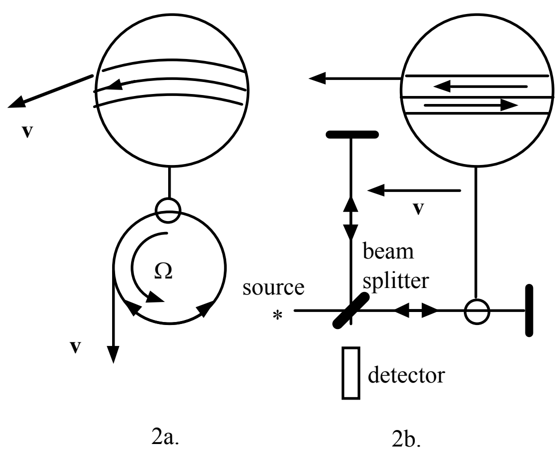


Figure 2. The Sagnac experiment is first-order and the Michelson-Morley experiment is second-order.

These facts show that designing a crucial first-order interferometric experiment involves two features: **1)** optical paths in uniform translational motion, and **2)** paths for light return without cancellation of possible effects. These features are possible to achieve, so long as not all paths in the arrangement are required to be translational. We have designed two viable arrangements. In the first arrangement, the circular path in a Sagnac experiment is divided into two half-circle paths, and two paths in translational motion are added. This results in a conveyor-like path (Fig. 3a). In this arrangement, a light beam is also divided by a beam splitter into two beams, one of which propagates in the same direction as the motion of the path, while the other propagates against the motion of the path. In the second arrangement, the path is a shearing parallelogram with top and bottom counter-moving paths, or with a top moving path and a bottom stationary path (Fig. 3b). In this arrangement, a light beam in the top moving path can return in the bottom path without weakening the possible effect. These two arrangements can be implemented with fiber technology, and they have translationally moving paths, which are the means of conducting a crucial first-order experiment to test the principle of the light-speed constancy.

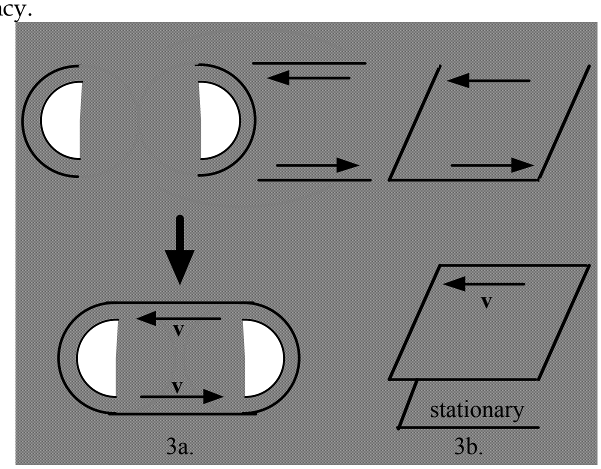


Figure 3. Two arrangements for the first-order experiment: a) conveyor-like arrangement and b) shearing parallelogram.

Experiments with Fiber-Optic Conveyors

The conveyor experiment is to be conducted by winding an optical fiber to a small conveyor instead of a cylindrical coil, and thus transforming a FOG into a fiber-optic conveyor (FOC) (Fig. 4). In a FOG, the Sagnac effect of one turn, $\Delta t = 4S\Omega/c^2 = 2vl/c^2$, is further strengthened when two counter-propagating light beams travel one turn after another through a long fiber loop wound around the coil multiple times. The total time difference for a FOG is given by $\Delta t = 4S\Omega N/c^2 = 2vlN/c^2$ where N is the number of fiber turns around the loop. In short, the Sagnac effect scales with path length.

It is expected that in a FOC also, the effect scales with path length. To avoid some possible biases in conducting the crucial experiment with a FOC, we can use two FOC's with the same conveying speed v, the same half-circle radius, but different path lengths in translational motion: one with a length of l_1 and the other with an extra length of l_0 (Fig. 5). The total travel time for a beam going through a whole path consisting of several segments is the summation of the travel-time intervals through each segment, Δl, $t(l) = \sum_{\Delta l} t(\Delta l)$. The travel-time difference between two beams through the whole path is the summation of all the travel-time differences between two beams in each segment, $\Delta t(l) = \sum_{\Delta l} \Delta t(\Delta l)$. Then the two travel-time differences, Δt_1 and Δt_2, of the two fiber-optic conveyors can be compared. The difference between the paths in the two conveyors is just the added paths with a length of l_0 in the second conveyor. Thus, if the experiment shows that $\Delta t_2 = \Delta t_1$, it proves that the added two uniformly moving paths with the length l_0 do not contribute towards the travel-time difference, and therefore, the two counter-propagating light beams have the same speed in these paths. If the experiment shows that $\Delta t_2 \neq \Delta t_1$, it means that in the added uniformly moving paths, the two counter-propagating light beams have different speeds.

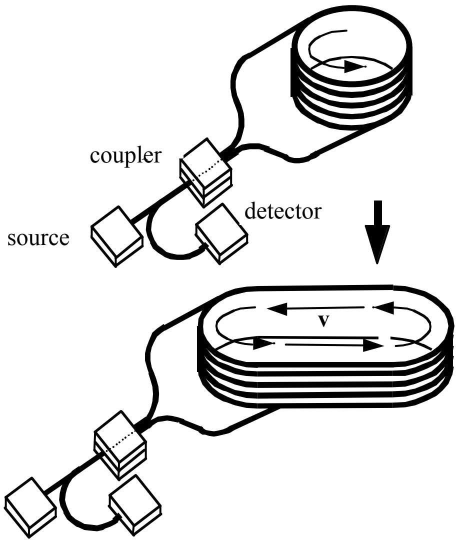


Figure 4. Transforming a fiber-optic gyro into a fiber-optic conveyor.

Analysis of Light Propagation in a FOG

We need to analyze what the expected change of the travel-time difference in a FOC would be when the two moving paths are added. To approach this problem, let us first examine how it is treated for the FOG. In [6], the propagation of light beams in a FOG is analyzed based on the Fizeau experiment [7] for light speeds in a moving medium. According to this experiment, for a stationary observer and counterclockwise rotation of a medium with refractive index n (Fig. 6a), the light speeds in the medium for counterclockwise and clockwise propagations are $c_{ccw} = c/n + (1 - 1/n^2)v$ and $c_{cw} = c/n - (1 - 1/n^2)v$. For this stationary observer, a fiber segment Δl is moving with speed v and if the time interval for a counterclockwise light beam traveling through Δl is t_{ccw}, then the fiber segment Δl will move counterclockwise a distance of vt_{ccw} in this time interval. Therefore, the counterclockwise beam will travel a total distance of $\Delta l + vt_{ccw}$. Then we have $c_{ccw}t_{ccw} = \Delta l + vt_{ccw}$. Thus $t_{ccw} = \Delta l / (c_{ccw} - v) = \Delta l / (c/n - v/n^2)$. Similarly, if the time interval for a clockwise light beam traveling through Δl is t_{cw}, the fiber segment Δl will move counterclockwise a distance of vt_{cw} in this time interval. Therefore, the clockwise beam will travel a distance of $\Delta l - vt_{cw}$. Then, we have $c_{cw}t_{cw} = \Delta l - vt_{cw}$. Therefore $t_{cw} = \Delta l / (c_{cw} + v) = \Delta l / (c/n + v/n^2)$. Finally, we obtain

$$\begin{aligned}\Delta t(\Delta l) &= t_{ccw} - t_{cw} \\ &= \Delta l / (c/n - v/n^2) - \Delta l / (c/n + v/n^2) \approx 2v\Delta l / c^2\end{aligned}$$

This result shows that the difference in travel times for a turn is $\Delta t = 2vl/c^2$, and the total travel-time difference for a loop with N turns is $\Delta t = 2vlN/c^2$. This result also shows that a fiber arc having definite length Δl and definite speed v will contribute $\Delta t(\Delta l) = 2v\Delta l / c^2$ to the total travel-time difference of the FOG, no matter how big the radius R of the arc is.

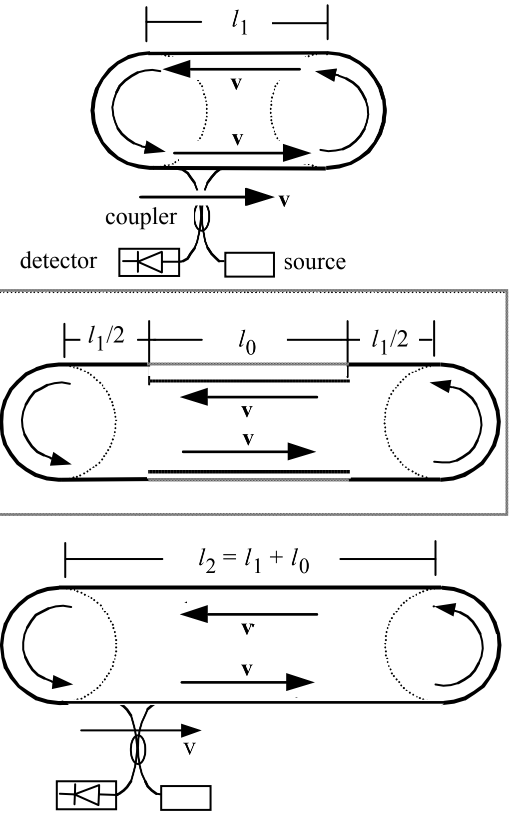


Figure 5. Comparing two traveling time differences, Δt_1 and Δt_2, of two fiber-optic conveyors with different conveying lengths.

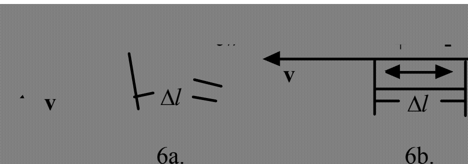


Figure 6. Light propagation in a fiber-optic gyro and in a fiber-optic conveyor.

Light Propagation in a FOC

Now let us analyze the propagation of a light beam in a FOC. For the parts of the path in translational motion, we utilize the same analysis as for a FOG. In fact, that analysis is more suitable to this case than to a FOG, because in the Fizeau experiment the medium was moving translationally, and the added paths in a FOC are also moving translationally.

According to the Fizeau experiment, in a small segment of fiber Δl of the added paths, the light speeds in a moving medium are given for a stationary observer by $c_+ = c/n + (1 - 1/n^2)v$ and $c_- = c/n - (1 - 1/n^2)v$, where + denotes a light beam traveling in the same direction as the motion of the path and – denotes a light beam traveling opposite to the motion of the path. For this stationary observer, fiber segment Δl is moving with speed v, and if the time interval for a light beam traveling in the same direction as the motion of the path through Δl is t_+, then the fiber segment Δl will move a distance of vt_+ in this time interval (Fig. 6b). Therefore, this beam will travel a total distance of $\Delta l + vt_+$. Then, we have $c_+ t_+ = \Delta l + vt_+$. Thus $t_+ = \Delta l / (c_+ - v) = \Delta l / (c/n - v/n^2)$. Similarly, for a light beam traveling opposite the motion of the path, we have $t_- = \Delta l / (c_- + v) = \Delta l / (c/n + v/n^2)$. Finally, we obtain

$$\Delta t(\Delta l) = t_+ - t_-$$
$$= \Delta l / (c/n - v/n^2) - \Delta l / (c/n + v/n^2) \approx 2v\Delta l / c^2$$

Since this segment Δl is the same as any other segment of added paths, it is expected that the added uniformly moving paths will contribute a travel-time difference of $\Delta t(2l_0) = 2v(2l_0)/c^2 = 4vl_0/c^2$ to the total travel-time difference; that is, $\Delta t_2 - \Delta t_1 = 4vl_0/c^2$ (or $4vl_0N/c^2$ if there are N turns). This means that if their lengths are the same, a path in uniform translational motion will contribute the same time difference to the total travel-time difference as a path in uniform circular motion. This means that light speed is not constant, not only when the path is in uniform circular motion, but also when the path is in uniform translation motion, a result falsifying the light-speed constancy in moving paths of fiber.

Effects Caused by Earth Rotation

Since a FOG responses to the rotation of Earth, we should examine how a FOC responses to the rotation of Earth. We should, especially, examine the effect of the rotation of Earth to the added two paths in translational motion in the FOC experiment. The rotation of Earth will cause an additional translational motion with a speed of V_E and an additional rotational motion with an angular velocity of Ω_E to the added two paths. Since the two paths have the same additional translational motion, their effects will weaken each other and there will not be a net first-order effect (Fig. 7a). However, the additional rotational motion is different. It causes the two paths moving in opposite directions and there will be a net first-order effect (Fig. 7b). Let us examine a fiber segment Δl. Its velocity caused by the rotation of Earth is $v_r = R\Omega_E / \cos\theta$, and the horizontal component of the velocity in the direction of the path is $v'_r = v_r \cos\theta = R\Omega_E$. According to the analysis mentioned above, the horizontal component $R\Omega_E$ will contribute an additional time difference $\Delta t_E(\Delta l) = 2R\Omega_E \Delta l / c^2$, and apparently, the vertical component will not cause any effect. Because $R\Omega_E$ is constant, we can conclude that because of the rotation of Earth, the two added paths with a length of l_0 and N turns will contribute an additional time difference of $\Delta t_E(N2l_0) = 2R\Omega_E(2l_0)N/c^2 = 4R\Omega_E l_0 N/c^2$.

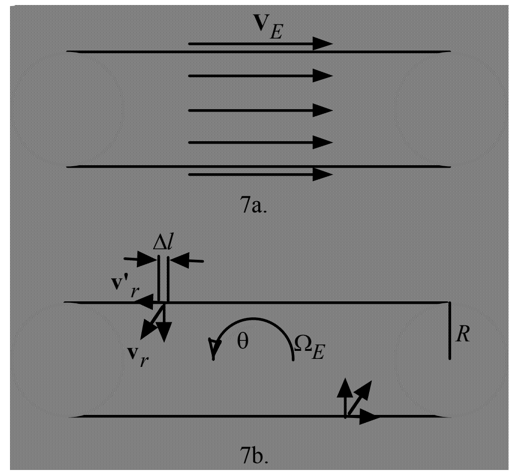


Figure 7. The effects caused by the rotation of Earth.

Examining Light-speed Constancy in Vacuum (or Air) with FOC's

It should be noted that the travel-time difference on the FOC is not related to the refractive index n. This means that if the experiment were conducted in vacuum ($n = 1$), the same result would be expected. Furthermore, the experiment can be conducted with fibers having different refractive indices. If the results, $\Delta t_2 = \Delta t_1$ or $\Delta t_2 \neq \Delta t_1$, are the same for all the fibers, then they should be the same for vacuum also.

Moreover, like the arrangement in a Sagnac-interferometer-based Fresnel drag fluid flowmeter [8], a fiber loop wound to the conveyor can be broken to leave a gap of vacuum (air), and the light can be taken out of the fiber, guided through the gap, and refocused on the fiber tips, so we can check the time difference in the gap of vacuum (air). Since it is difficult to have gaps for many turns, we will use only one turn of the fiber. We can build a new conveyor with only one turn of the fiber or we also can utilize a FOG and leave un-used fiber still wound to the cylindrical coil. When the conveyor moves, the coil will move translationally. However the translational motion of the coil will not cause any time difference because the translational motion will have the same effect on both counter-propagating light beams. That is why a FOG only detects the rotational motion, and not the translational motion.

To conduct the crucial experiment, we can compare two conveyors that have the same construction except for different lengths of the gaps: one with a length l_1 and the other with length l_2, $l_2 = l_1 + l_a$ (Fig. 8). (Because the required conveying speed v is very low, the gap will not move to the arc part of the path). In fact, two FOC's have the same length of fiber in circular motion, $2\pi R$, and the same length of fiber in translational motion. Therefore, comparing the total time differences of the two

FOC's, we can find the time difference in the moving gap with a length of l_a:

$$\Delta t[l_a(vacuum)] = \Delta t_2 - \Delta t_1$$

Checking whether this time difference satisfies $\Delta t[l_a(vacuum)] = 0$ or $\Delta t[l_a(vacuum)] \neq 0$ will show whether or not light speed is constant in vacuum (air). As a matter of fact, if the travel-time difference appearing on the FOC is really not related to the refractive index, then a time difference $\Delta t[l_a(vacuum)] = 2vl_a / c^2$ would be expected in the experiment. Since two counter-propagating light beams pass the same gap, small variations of the length of the gap during conveying will not affect this first-order time difference.

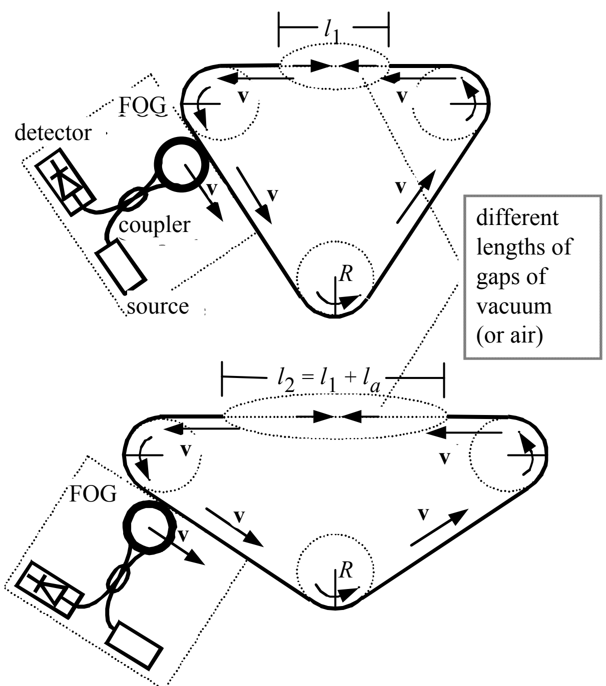


Figure 8. Examining light-speed constancy in vacuum (or in air) with two fiber-optic conveyors.

Examining Light-Speed Constancy in Vacuum (or Air) with Fiber Shearing Parallelograms

Rather than using a FOC, we can more easily conduct an experiment using the fiber shearing parallelogram arrangement with a gap of vacuum (air) shown in Fig. 9. There, the top straight line path, BE, is moving uniformly with speed v and the bottom straight line path, CD, is stationary. Path BE has a gap of vacuum (air), AF, and paths BC and ED need extra fiber because the lengths of BC and ED are not constant when moving. Because CD is stationary, the possible time difference appearing in BE will not be weakened in CD, so this arrangement is also an arrangment for conducting the first-order experiment examining light speed in vacuum (air). We can also compare two parallelograms differing only in the lengths of gaps of vacuum (air), l_1 and l_2 $(= l_1 + l_a)$, and the lengths of stationary paths. Since $\Delta t_{AB} = \Delta t_{A'B'}$, $\Delta t_{BC} = \Delta t_{B'C'}$, $\Delta t_{DE} = \Delta t_{D'E'}$, $\Delta t_{EF} = \Delta t_{E'F'}$, and especially, $\Delta t_{CD} = \Delta t_{C'D'} = 0$, we have

$$\Delta t[l_a(vacuum)] = \Delta t_{F'A'} - \Delta t_{FA} = \Delta t_2 - \Delta t_1$$

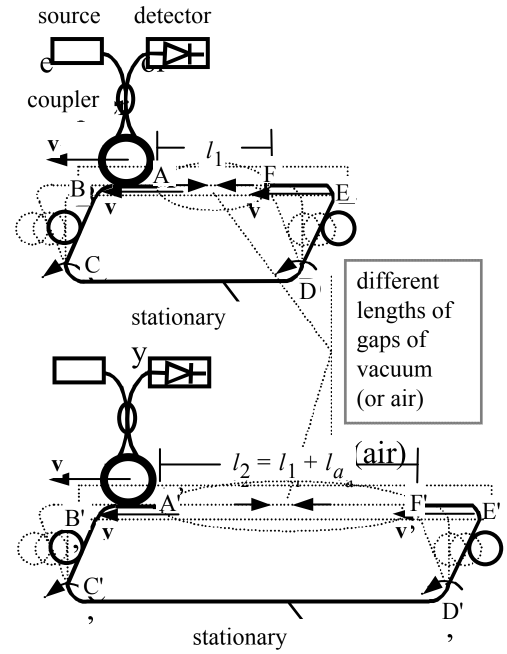


Figure 9. Examining the light-speed constancy in vacuum (or in air) with two fiber shearing parallelograms.

Since the motion of the gap of vacuum (air) is the same as the motion of the gap in a FOC, the same time difference as mentioned in FOC's can be expected here too. Thus, a conclusion can be made whether or not the principle of the light-speed constancy is correct in paths uniformly moving relative to Earth. This is a first-order fiber interferometric experiment, and the Lorentz contraction, a second-order effect, is not a factor in the experiment.

Highly Precise Experiments

Since the operation of a FOG is based on a first-order effect and in a FOG two counter-propagating beams share the same closed path, the FOG is a highly precise measuring instrument. Since the 1970s, a lot of fiber technologies have been utilized in the FOG, *e.g.*, broadband light source, single-mode polarization maintaining optical fiber, bias modulation ensuring operation of the FOG in the regime most sensitive to input rate, and other technologies to reduces the noises, making the FOG very sensitive to rotation. Many FOG's have a sensitivity for the phase shift $\Delta\phi$ of 10^{-7} rad, where phase shift $\Delta\phi = 2\pi\Delta tc / \lambda_0$ and λ_0 is the free space wavelength of light.

In a FOC or a shearing parallelogram, two counter-propagating beams also share the same closed path, and all the technologies utilized in the FOC and the shearing parallelogram could be the same as those used in the FOG. It is expected that a FOC and a shearing parallelogram are very sensitive to motion. Even if the sensitivity of a FOC and a shearing parallelogram is 2 orders of magnitude less than that of a FOG, a sensitivity of the phase shift of 10^{-5} rad can be expected. For a FOC experiment with the two FOC's without the gap, if $2l_0N = 180$ m, λ_0 = 0.8 μm, and the conveying speed v = 1 mm/s, then we could expect the possible difference of two phase shifts

$$\Delta\phi_2 - \Delta\phi_1 = 2\pi(\Delta t_2 - \Delta t_1)c/\lambda_0 = 8\pi v l_0 N / c\lambda_0 = 10^{-2}\text{rad}$$

(This difference is much bigger than the phase shift caused by the Earth rotation because $R\Omega_E$, the speed caused by the rotation of Earth, is much slower than 1 mm/s.)

For the experiments with two FOC's or two parallelograms having vacuum (air) gaps, if l_a =1.8 m, λ_0 = 0.8 μm, and the moving speed v = 1 mm/s, then we will have the possible phase shift in the gaps with length l_a

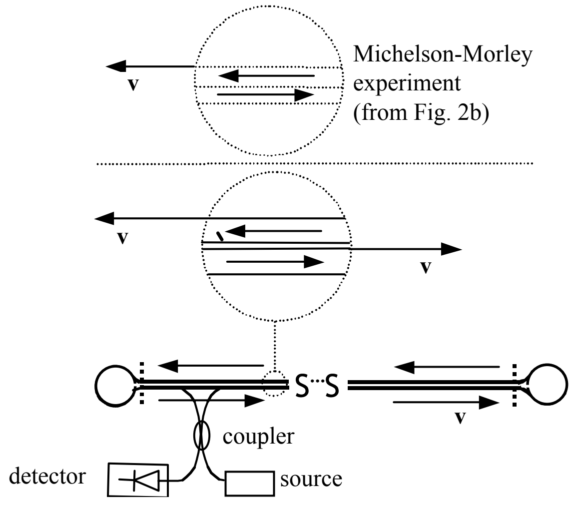
$$\Delta\phi[l_a(\text{vacuum})] = 2\pi\Delta t[l_a(\text{vacuum})]c/\lambda_0 = 4\pi v l_a / c\lambda_0 = 10^{-4}\text{rad}$$

Thus, even with a fairly slow speed of 1 mm/s, the expected sensitivities of the arrangements are good enough to decide whether or not light speed is constant in moving paths of vacuum (air) and of the fiber. These experiments definitely are highly precise experiments to examine the principle of the light-speed constancy.

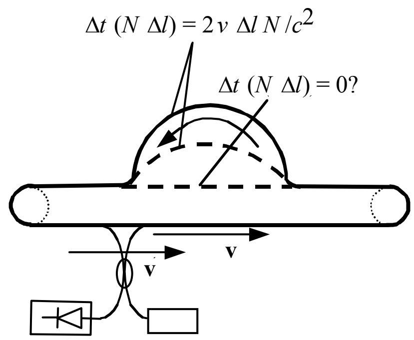
Some Interesting Arrangements of FOC's

Let us examine some interesting arrangements of the FOC. A conveyor consists of rotational motions and translational motions and can have a lot of arrangements. In the first arrangement (Fig. 10a), two paths in translational motion are much longer than the paths in circular motion and the distance between these two translational paths is very small. Omitting the short paths in circular motion, a light beam 'reflects' back and forth along uniformly moving paths in the loop, like a light beam in the Michelson-Morley experiment. However, a big difference between this arrangement and the Michelson interferometer is that two counter-moving paths, one for light beam going and one for light beam returning, are provided in this arrangement, instead of only one in the Michelson interferometer. Once again this clearly shows why a FOC experiment is a first-order experiment and the Michelson-Morley experiment is a second-order experiment. With the second arrangement (Fig. 10b), we could examine if it is true that a finite travel-time difference contribution, $\Delta t(N\Delta l) = 2v\Delta l N / c^2$, appears in the arc in circular motion regardless the radius of the arc, and if the contribution would suddenly disappear or jump to zero as required by the light-speed constancy when the arc in circular motion becomes a straight line in translational motion.

Another interesting arrangement is a 'figure 8' suggested by Whitney [9]. There, the effective enclosed area of the light path is zero. Therefore, any time difference appearing in the arrangement is not related to the classic Sagnac effect, which is proportional to the enclosed area of the light path, and the arrangement does not respond to Earth rotation.



10a.



10b.

Figure 10. Two interesting arrangements of the fiber-optic conveyor.

Conclusion

Fiber-interferometric experiments, especially experiments involving a vacuum (or air) gap, are crucial first-order experiments to examine the principle of light-speed constancy. Lorentz contraction, a second-order effect, is not a factor in these experiments. All the technologies utilized in the experiments could be the same as those used in the FOG; therefore, it is expected that these experiments will be highly precise, and a moving-paths speed of only 1 mm/s is required for examining light-speed constancy. According to the same analysis as that for a FOG, an increase of length of path in translational motion in the arrangement will lead to an increase of the travel-time difference, a result falsifying the principle of the light-speed constancy.

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Post Script

Because GED has a backlog, the manuscript above is published after the FOC experiment was conducted and reported [1]. There was a travel-time difference $\Delta t = 2v\Delta l / c^2$ between two counter-propagating light beams in a fiber segment of length Δl moving with the source and detector at a speed v, whether the segment moved uniformly or circularly. This result is very natural to those who are familiar with the Sagnac effect and have an open mind regarding the principle of the light-speed constancy. If the Sagnac effect always has a finite value while the radius of the circular motion becomes bigger and bigger, then how can it disappear in uniform motion? In fact, if the experiment yielded a zero travel-time difference in a uniformly moving fiber, then my colleagues and I would have found an unprecedented 'macro quantum jump' (Fig. 10b above).

The original Sagnac experiment was conducted in air. Recently, we conducted the FOC experiment with an air light-guide [2], and there was just the same non-zero travel-time difference found in the last experiment. This non-zero travel-time difference between two counter-propagating light beams in a uniformly moving vacuum (or air) light-guide would indicate that the speed of light in vacuum is not independent of the motion of the observer.

I consulted with Ron Hatch, because GPS offers a near vacuum Sagnac situation, and hence another good way to examine the light-speed constancy. One hundred years ago, people had to imagine a train 200,000 km long for thought experiments involving the speed of light, now a geo-stationary positioning satellite has an altitude of 35,860 km and it takes a radio signal 0.12 seconds to reach the ground. This 0.12 seconds is long enough for us to examine whether or not "(photons') speed is exactly the same for any person who cares to measure it, no matter how fast that person is moving relative to the light beam." (-U.S. News and World Report, Secrets of Genius, 2003) We care to measure it. However, we have a problem: we're not sure if relativistic physicists would agree on a way for measuring it. What do they mean by saying that the light-speed is the same for any moving observer? Measuring speed is based on measuring the distance and the elapsed time. When we say the speed of a bullet is not the same for all moving observers, everybody knows the definition of the distance and the elapsed time for the bullet. However, when it comes to measuring the speed of light, would relativistic physicists tell us the definition of the distance and the time elapsed by a light beam for any moving observer? Unfortunately, they would not.

In [3], we proposed a crucial experiment to examine both the principle of the light-speed constancy and the principle of relativity. Here we would give a reasonable definition of the light-speed constancy: there is a light source at one place and two stationary observers A and B at another place and they synchronize their clocks. Now a light beam emits from the source at t_0, and after t_0, B starts to accelerate towards the source and reaches a constant speed. In this case, two observers not only have the same light submission time but also the same distance from the source when the light beam leaves the source. Then A and B both receive the light beam and they can compare their reception times. If their reception times are the same, then the speeds of light are the same because the distances are the same and the elapsed times are the same. If the reception times are different, then the speeds of light are different. This definition is very conservative and avoids the problem for the relativity of simultaneity, because at t_0 both observers are stationary. We really cannot think of any other definition that could be more satisfactory to relativistic physicists.

It is interesting to note that this definition can be tested by a GPS experiment. Locate two GPS receivers, A and B, underneath a geostationary positioning satellite, at the same place and at the same altitude on the ground. When a signal is emitted at t_0, the two receivers are stationary. After t_0, the receiver B accelerates upwards at a constant rate, moves 0.7 m and reaches 20 m/s (a speed of a slow car) in 0.07 seconds, then moves 1 m uniformly in 0.05 seconds. About 0.12 seconds after t_0, both observers receive the signal and they compare the reception times with each other.

To be honest, every person who is familiar with the GPS could immediately tell that the receiver B would receive the signal earlier than receiver A would, and the lead is about 6 ns (1.7m/c). Therefore, our relativistic physicist friends would probably not accept this as a good definition of the light-speed constancy. Here, we challenge the relativistic physicists: please don't try to make the light-speed constancy un-definable. If you care to define that the speed of light is the same for any moving observer, we will design a GPS experiment to show it is not the truth. Give us a clear definition, and we will disprove it.

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[3] R. Wang & R. Hatch, "Conducting a Crucial Experiment of the Constancy of the Speed of Light Using GPS – Comments on Ashby's 'Relativity and the Global Positioning System'", Proc. ION 58th Annual Meeting, 495-505, June 2002, Albuquerque, NM.

Ruyong Wang

Comments:

…Ruyong Wang and his colleagues [have] performed a beautiful experiment, which shows that the Sagnac effect occurs with linear motion as well as circular. This confirms Herbert Ives 1938 suggested experiment to show the same. Actually, the GPS navigation had already confirmed this—but, as I have letters to show, the relativists were sticking their head in the sand regarding this GPS evidence.

…The (one-way) Sagnac effect caused by motion of the GPS receiver relative to the center of the Earth during the signal transit time from the GPS satellite to the receiver has to be accounted for to get the correct position solution. Interestingly, the relativists acknowledge that both **1)** motion caused by the rotation of the Earth, and **2)** additional motion of the receiver, had to be accounted for—but only labeled the former as the Sagnac effect—I do not know what they used to justify the adjustment for the latter, but it is spelled out in the latest ICD (Interface Control Document) that it be accounted for. The magnitude of the effect from Earth rotation ranges from about plus 30 meters to minus 30 meters in the computed range from the satellites to a receiver located on Earth's equator. Ron Hatch

As someone else who has looked into GPS in-depth and analyzed it for relativistic information, I would like to add my concurrence and support for Ron Hatches comments

If we could all get together on the basic experimental facts, even if not the best physics to interpret them, the dissidents could have a significant impact on the physics community. At present, our impact is barely perceptible because we are not all going in the same direction. Tom Van Flandern

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Richard Hazelett's Work

The Einstein Myth and the Ives Papers [1] is a *Festscrift* to Herbert Ives, a prolific American scientist and engineer who until his death remained un-persuaded of Einstein theory. Dean Turner and Richard Hazelett compiled the tome in 1979, and included many of the important papers that challenge relativity theory.

When one writes a paper that refers, say, to the Michelson-Gale experiment or to the Sagnac experiment, one normally gives the reference. The reader has the option of looking up those papers; however, the journals are not widely available. Consequently, the reader must be strongly motivated to seek out the original work. (That readers do not usually seek out the original work can be easily gauged by the widely-known Haefele-Keating experiment. It is almost axiomatic that your neighborhood physicist hasn't read it and does *not* know that the westbound clocks sped up compared to the laboratory clocks.)

Therein lies the value of the Hazelett/Turner book. They gathered not only Ives's very cogent papers, but also an excellent collection of papers by Sherwin, Dingle, Sagnac (translated to English), Lovejoy, Michelson, Richtmyer, and others. There are frequent annotations by both Turner and Hazelett. The reader can then read the original work and decide for himself.

I was only very casually acquainted with Dick Hazelett, and know him mainly through the book. I would suggest that the very best way to pay tribute to the man is to read his work.

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Updating Faraday (continued from p. 22)

Despite well known Panofsky and Feynman' s statements [4], [12, 13], relativity works at all in electrodynamic phenomena. The **absolutely relativistic** behavior of unipolar engines puts the end point to recent naive attempts concerning the hypothetical extraction of free energy of space through homopolar machines, as easily can be verified by visiting the Internet.

Moreover, Jehle' s model of the electron [3, 10] must be thoroughly reconsidered on the light of the recent discovery.

Referring to the quoted experiments, Fritz Rohrlich said [14]: *"Your experiments should remove the last shadow of doubt even in the most skeptical minds, that the electromagnetic phenomena are of a relativistic nature."*

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